Business Cycle Accounting of the BRIC Economies*

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Abstract

We apply the Business Cycle Accounting methodology developed by Chari, Kehoe and McGrattan (2007) to study the economic resurgence of Brazil, Russia, India and China (BRIC) over the last decade. We document that while efficiency wedges do contribute in a large part to growth, especially in Brazil and Russia, there is an increasing importance of investment wedges especially in the late 2000s, noted in China and India. The results are typically related to the stages of development with Brazil and Russia coming off a crisis to grow in the 2000s, while India and China were already on a stable growth path. Our conclusions are robust to alternative measurements of wedges as well as model extensions allowing investment adjusment costs. Relating wedge patterns to institutional and financial reforms, we find that financial market developments and effective governance in BRICs in the last decade are consistent with improvements in investment and efficiency wedges that led to growth.

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At its simplest, a growth economy should be regarded as one that is likely to experience rising productivity, which, together with favorable demographics, points to economic growth that outpaces the global average......So we opted for the following: any economy outside the so-called developed world that accounts for at least 1% of current global GDP should be defined as a growth economy. ————Jim O' Neill (M.D. & Head of Global Economic Research at Goldman Sachs)

1 Introduction

Over the last decade, the average growth rate of the quartet, Brazil, Russia, India and China (known by the acronym BRIC coined by O'Neill in 2001) has outpaced the global average. Cumulative share of the BRIC nations in the world gross domestic product (GDP) has grown from about 16% in 2000 to 26% in 2011 earning China and India the second and third spots in world GDP rankings (the top spot still belongs to the United States), with Russia and Brazil taking the sixth and the seventh spots (**Table 1**). The trade volume of the group currently takes up 15% of the world trade and jointly, this group of countries is home to about 40% of the world population.

<Table 1 about here>

The broad facts of BRIC growth are generally well known. In **Table 2**[1], we compare the growth rates in aggregate and per capita GDP in the BRIC nations with that of the United States and the OECD since 1960*s*. A few interesting facts emerge. While Brazil and India started the 1960*s* closer to their US and OECD counterparts, China faltered[2]. During the 1970*s*, while China played catch-up and Brazil continued its economic growth, Indian growth started to decline. The tables turned in the 1980*s* with Brazilian growth slowing as India made a come-back. China continued on its path of economic growth. 1990*s* were a period of turbulence with Brazil unable to recover from the 1980*s* lost decade and the newly formed Russian Federation (1991) facing recession with the Russian financial crisis in 1998. India too began the 1990*s* with financial trouble with the the possibility of defaulting on its loans and with practically depleted foreign exchange reserves, while China faced political unrest and economic uncertainty due to the Asian financial crisis. However, growth numbers from the 1990*s* suggest that while Brazil and Russia stagnated, the economic performance of India and China remained relatively stable in the face of

[1] Tables 1 and 2 are from the IMF and Angus Maddison's online data resources

[2] Per capita GDP growth rate in Brazil was low as compared to the aggregate GDP growth due to high population growth.

economic and political troubles. Finally, during the last decade of 2000s, all BRIC nations made a remarkable come-back, with China leading the pack with double-digit economic growth.

<Table 2 about here>

The purpose of this paper is to analyze the fluctuations in output growth of the BRIC economies during 1990 to 2009 using a Business Cycle Accounting (BCA) "wedge" methodology formulated by Cole and Ohanian (2004) and Chari, Kehoe and McGrattan (henceforth CKM, 2007) amongst others.

The BCA methodology allows us to quantitatively account for the role played by changes in productivity and factor market distortions in generating output fluctuations by applying a two-pronged approach. BCA uses a real business cycle framework to model various frictions as "wedges" that keep the economy from achieving a first best outcome. These wedges show up as distortions in the first order conditions. Efficiency wedges appear as time-varying productivity. Labor and investment wedges appear as "taxes" on labor and capital income, where "taxes" represent broadly the distortions affecting the labor and investment decisions. Government consumption wedge appears as government expenditure (in a closed economy setup, net exports are also added to government expenditure). In step one, the first order conditions of the model along with data on output, consumption, investment and labor are used to estimate the wedges. In step two, the estimated wedges from step 1 are fed back into the model individually and in different combinations to ascertain their marginal contributions in generating the observed economic outcome. These wedges are the "channels" through which external forces like institutional or policy changes affect the economy.

Comparing the remarkable performance of the BRICs in the last decade with that of the earlier decade of the 1990s, we identify two distinct mechanisms at work: *i*) in Brazil and Russia, that emerged from a crisis in the 1990s to experience sharp growth in the 2000s, distortions in the investment and labor market (particularly in Brazil) are responsible for the *relative* stagnation during the 1990s while improvement in production efficiency is the single most important factor in accounting for the rapid growth in the 2000s; *ii*) in contrast, in India and China which were on a relatively stable growth path since the 1990s, while changes in production efficiency account for a large part of the output fluctuations over the two decades, decline in the investment market distortions become increasingly important in the 2000s, particularly accounting for growth in the latter half. In none of the economies do labor wedges play any role in accounting for growth in the 2000s. Government consumption wedges partially aids China[3] but is ineffective in the other three nations.

[3]The role of government consumption wedges turn out to be model specific. While it plays a minimal role in our benchmark, its contribution increases in the alternative models considered.

However, as we discuss in later sections, this does not mean that government policies are unimportant. What our BCA results tell us is that whatever policy or institutional changes (the "primary drivers") were responsible for the rapid growth of the 2000s worked primarily by increasing production efficiency or by reducing investment market frictions. This finding is particularly interesting as existing BCA literature finds little impact of investment frictions on output during sharp recession periods, attributing most business cycle fluctuations to changes in productivity. For our set of countries examined here, we find that investment wedges are important in accounting for the decade long slowdown in Brazil and Russia in the 1990s and the growth in India and China in the 2000s through gradual capital accumulation.

Our findings are robust to two checks we conduct. Firstly, our benchmark model (in the tradition of BCA literature) assumes that efficiency wedges are transitory fluctuations of productivity about its "trend" to which the economy eventually returns. For our first robustness check, we consider efficiency wedges as shocks to the trend of productivity in the spirit of Aguiar and Gopinath (2007)[4]. How we define efficiency wedges matters for investment wedges as well since the latter depends on the expectations about future efficiency. As expected, alternative definition of efficiency wedge affects the measurement of efficiency and investment wedges, however, we essentially find that the roles played by them are similar to those in the benchmark case. As a second robustness check, we add capital adjustment costs assuming that it is technologically costly to convert output into installed capital. As argued by Christiano and Davis (2006), the model simulations with investment wedges is sensitive to inclusion or non-inclusion of investment adjustment costs and can non-trivially affect the conclusions, however in our case, we find that our primary conclusions do not change.

Our accounting work can be related to two distinct strands of literature. Literature on BRIC nations have primarily focused on isolating the singular causes of growth, primarily focusing on India and China (Song, Storesletten and Zilibotti, 2011; Dekle and Vandenbroucke, 2011; Fujiwara, Otsu and Saito, 2011; Bosworth and Collins, 2008; Jones and Sahu, 2009). Focus of Brazil and Russia has been primarily to explain their business cycle downturns primarily in the late 1980s and 1990s (Braguinsky and Myerson, 2007; Merlevede, Schoors and Aarle, 2007; Kanczuk, 2004). What distinguishes our study from these previous strands of research is that while most of the earlier literature focuses on the primary drivers of growth, our focus is on identifying the *channels* through which these external drivers work to stimulate the economy. Secondly our study is related to the extensive literature applying BCA to study economic fluctuations (CKM, 2007; Graminho 2006; Kersting,

[4]Aguiar and Gopinath (2007) simulate a model with both transitory and trend shocks and find that emerging economies are often characterized by shocks to the trend component.

2008; Chakraborty, 2009; Kobayashi and Inaba, 2006; Cho and Doblas-Madrid 2012, Otsu 2010a; Lama 2011). While most existing literature applies BCA to understand crisis, analysis of growth is sparse, with the exception being Lu (2012)[5]. Our study adds to the existing BCA literature by studying BRIC growth through the lens of BCA.

Our accounting results so far suggest an important role of efficiency and investment wedges in the BRIC economies. In our final section, we attempt to tie the observed wedge patterns with some indices of institutional and policy changes in the BRICs. A growing literature in recent years have found microlevel evidence of influence of credit market movements on investment and economic growth both across nations as well as in emerging economies (Bekaert, Harvey and Lundblad, 2011; Alfaro, Kalemli-Ozcan and Sayek, 2009). Consistent with the earlier literature, we observe an improvement in credit worthiness as well as access to credit in all the BRIC nations that is consistent with declining investment market frictions and increasing efficiency. In addition, while not all institutional and governance indicators that we examine are consistent with observed improvements in efficiency and investment climate, improvements in political stability to some extent since mid-2000s (particularly in Russia) and government effectiveness to a large degree are consistent with observed time series patterns of efficiency and investment wedges. However, the BRICs still have a long distance to go to catch up to the developed West in other areas of governance like control of corruption or rule of law.

The remainder of the paper is organized as follows. In section 2 we describe the business cycle accounting model. In section 3 we explain the business cycle accounting procedure and present the results. In section 4 we provide sensitivity analysis results. In section 5 we discuss the underlying factors that can explain the evolution of wedges. Section 6 concludes the paper.

2 The Model

Traditional BCA methodology relies on a standard, closed economy RBC model with a representative household, firm and a government. The representative firm hires labor and capital from the household to produce output using a constant returns to scale technology, which is affected by time-varying production efficiency. The representative household decides on consumption, labor and investment each period. The

[5] Chakraborty (2010), Ljungwall and Gao (2009) and Hsu and Zhao (2009) are some additional studies to focus on growth, but mainly in India and China in isolated time periods. To the best of our knowledge, our paper is the first to conduct a BCA analysis for the Russian economy.

household faces a budget constraint where its expenditure is limited by its labor and capital income. In addition, as the ultimate owner of the firm, the consumer receives the profits. The consumer pays distortionary taxes on labor and capital income to the government. In the BCA framework, these distortionary taxes represent broader economic distortions that affect the factor markets. The government uses its tax revenue to finance government consumption. Any remaining amount is transferred back to the households as lump sum transfers. Exogenous shocks to production efficiency, government consumption and distortionary tax rates are revealed in the beginning of each period and affect economic incentives.

2.1 Firm

The representative firm borrows capital K_t and labor L_t from the household in order to produce output Y_t according to a Cobb-Douglas production function:

$$Y_t = K_t^{\theta}(A_t L_t)^{1-\theta},$$

where A_t denotes exogenous production efficiency. Labor is defined as total hours worked (product of employment and hours worked per worker). Productivity can be divided into a trend component Γ_t and a cyclical component γ_t, i.e. $A_t = \gamma_t \Gamma_t$, where we assume a constant growth rate in the trend component:

$$\frac{\Gamma_t}{\Gamma_{t-1}} = a.$$

Labor grows over time due to growth in population N_t where we assume a constant growth rate in population:

$$\frac{N_t}{N_{t-1}} = n.$$

Output and capital grows over time due to both population and productivity growth. All variables are detrended by the growth trends in order to define a stationary problem:

$$y_t = \frac{Y_t}{N_t \Gamma_t}, k_t = \frac{K_t}{N_t \Gamma_t}, l_t = \frac{L_t}{N_t}, \gamma_t = \frac{A_t}{\Gamma_t}.$$

Firms maximize profits π_t:

$$\max \pi_t = y_t - r_t k_t - w_t l_t \tag{1}$$

where r_t and w_t denote the real return on capital and the real wage respectively. The detrended production function can be rewritten as

$$y_t = k_t^{\theta}(\gamma_t l_t)^{1-\theta}. \tag{2}$$

For the benchmark model, we follow CKM (2007) and define the efficiency wedges as

$$\omega_{e,t} = \gamma_t. \tag{3}$$

2.2 The Household and Government

The representative household gains utility from consumption c_t and leisure $1 - l_t$ where we assume a log-linear utility function for our analysis:

$$u(c_t, 1 - l_t) = \Psi \ln c_t + (1 - \Psi) \ln(1 - l_t).$$

Total hours available is normalized to one[6]. The household maximizes its expected lifetime utility:

$$\max E_t \sum_t \beta^t \left[u(c_t, 1 - l_t) \right],$$

where β is the subjective discount factor. The household budget constraint is

$$(1 - \tau_{l,t})\, w_t l_t + (1 - \tau_{k,t})\, r_t k_t + \pi_t + \tau_t = c_t + x_t, \tag{4}$$

where τ_{lt} and τ_{kt} are distortionary labor and capital income taxes while τ_t is the lump-sum government transfers. Investment x_t is defined by the capital accumulation law:

$$nak_{t+1} = x_t + (1 - \delta) k_t. \tag{5}$$

The government collects distortionary taxes from the household in order to finance government consumption while the remainder is transferred to the household in a lump-sum fashion. Therefore, the government budget constraint is

$$g_t + \tau_t = \tau_{lt} w_t l_t + \tau_{kt} r_t k_t. \tag{6}$$

Combining the government budget constraint (6) and the household budget constraint (4) making use of the definition of profits (1), we obtain the resource constraint

$$y_t = c_t + x_t + g_t. \tag{7}$$

[6] We assume the maximum work week as $14 \times 7 = 98$ and normalize hours worked per worker h_t as

$$h_t = \frac{\text{average work week}}{98}$$

which is bounded between 0 and 1. Therefore, the detrended labor

$$l_t = \frac{\text{average work week}}{98} \frac{\text{total employment}}{\text{total population}}$$

is also bounded between 0 and 1.

Labor and investment wedges $\{\omega_{l,t}, \omega_{k,t}\}$ are defined as:

$$\omega_{l,t} = 1 - \tau_{lt},$$

$$\omega_{k,t} = 1 - \tau_{kt}.$$

Technically speaking, $\omega_{l,t}$ drives a wedge between the consumption-leisure marginal rate of substitution and the marginal product of labor while $\omega_{k,t}$ drives a wedge between the intertemporal marginal rate of substitution and the marginal return on investment. For convenience, we define government consumption wedges as the deviation of government purchases from its steady state level:

$$\omega_{g,t} = \frac{g_t}{g}. \tag{8}$$

2.3 Wedges

We define the efficiency, government consumption, investment and labor wedges $\omega_t = (\omega_{e,t}, \omega_{g,t}, \omega_{k,t}, \omega_{l,t})'$ such that an increase in each wedge should lead to an increase in output. Increases in efficiency wedge directly increases production and stimulates factor demand by increasing the marginal product of inputs. On the other hand, increases in labor and investment wedges stimulate output by encouraging the household to increase supply of factor inputs through an increase in the marginal income associated with them. Therefore we refer to increases in efficiency, investment and labor wedges as "improvements". High government consumption wedges should also increase output due to the increase in aggregate demand. However, we do not call an increase in government consumption as an "improvement" since this is associated with the crowding-out of household consumption and investment, which leads to household welfare deterioration. Following CKM (2007), we assume that the wedges are exogenous and follow a stochastic process. Defining a vector of log-linearized wedges, $\widetilde{\omega_t} = (\widetilde{\omega_{e,t}}, \widetilde{\omega_{g,t}}, \widetilde{\omega_{k,t}}, \widetilde{\omega_{l,t}})'$ where $\widetilde{\omega_t} = \ln \omega_t - \ln \omega$, we assume that the wedges follow a first order VAR process:

$$\begin{aligned} \widetilde{\omega_t} &= P\widetilde{\omega_{t-1}} + \varepsilon_t \\ &\varepsilon_t \sim N(0, V) \end{aligned} \tag{9}$$

where $\varepsilon_t = (\varepsilon_{e,t}, \varepsilon_{g,t}, \varepsilon_{k,t}, \varepsilon_{l,t})'$ are innovations to the wedges. Following CKM (2007) we allow spill-over of wedges through P and contemporaneous correlations of innovations in V.

2.4 Equilibrium

The competitive equilibrium is given by a price vector $\{r_t, w_t\}$ and an allocation of quantities $\{y_t, c_t, x_t, l_t, k_t, z_t, g_t, \tau_t, \omega_{e,t}, \omega_{g,t}, \omega_{k,t}, \omega_{l,t}\}$ such that: (a) the household maximizes utility given $\{r_t, w_t, \tau_t, \omega_{k,t}, \omega_{l,t}\}$; (b) the firm maximizes profits given $\{r_t, w_t, z_t\}$; (c) the government budget constraint (6) and the resource constraint (7) holds; and (d) the wedges follow the stochastic process (9). The competitive equilibrium is characterized by a set of first-order conditions given by: (a) the Euler equation (first order condition with respect to capital) equalizing present discounted value of marginal utility of future consumption to its marginal cost:

$$\frac{1}{c_t} = \frac{\beta}{na} E_t \left[\frac{1}{c_{t+1}} \left(\omega_{k,t+1} \theta \frac{y_{t+1}}{k_{t+1}} + 1 - \delta \right) \right], \tag{10}$$

(b) the first-order equation with respect to labor equating marginal rate of substitution between consumption and leisure to the marginal product of labor:

$$\frac{1-\Psi}{\Psi} \frac{c_t}{1-l_t} = \omega_{l,t}(1-\theta)\frac{y_t}{l_t}, \tag{11}$$

(c) the resource constraint (7) given (8), (d) the capital law of motion (5), and (e) the production function (2) given (3).

3 Quantitative Analysis

3.1 Parameter Values

The first step in BCA implementation is to obtain the parameters of the model through usual calibration techniques for each country. For calibration purposes, we assume that there are no distortions in the steady state so that $\omega = \{1, 1, 1, 1\}$. Capital share θ is calibrated to match the capital income share derived from data. The productivity growth trend a is computed as the average growth rate of per capita output. Population growth trend n is directly computed from adult population data[7]. We construct the total capital stock series as the sum of net fixed capital stock and household durables in order to compute the total annual depreciation rate δ. The subjective discount factor β is calibrated using the steady state capital Euler equation (10) to match steady state capital-output ratio given the productivity growth trend a, population growth n, capital share θ and the depreciation rate δ. The preference weight Ψ is calibrated using the steady state labor first order condition (11) given the capital share θ, to match the steady state consumption-output ratio and the steady state labor. The values are listed in **Table 3**.

Once we have the calibrated parameters, the next step is to estimate the stochastic process of the wedges (9) for which we employ the Bayesian techniques. Structural estimation is necessary for the business cycle accounting procedure since investment

[7] We used total population for China since we do not have adult population data.

wedges are defined in the intertemporal equilibrium condition (10) that depends on expectations about the future state of the economy which is not directly observable. The estimated parameters are the lag parameters in P, the standard deviation of the errors, and the cross-correlations between the errors in V. Since there are 4 exogenous variables, we use the time series data of output, consumption, investment and labor as observables. The Bayesian priors and the parameters of the vector and the point estimates of these parameters are listed in the appendix.

3.2 Simulation

The first step in the simulation process is to solve the model for linear decision rules for linearized endogenous variables $\widetilde{k_{t+1}}$ and $\widetilde{q_t} = (\widetilde{y_t}, \widetilde{c_t}, \widetilde{x_t}, \widetilde{l_t})'$:

$$\begin{aligned} \widetilde{k_{t+1}} &= A\widetilde{k_t} + B\widetilde{\omega_t}, \\ \widetilde{q_t} &= C\widetilde{k_t} + D\widetilde{\omega_t}. \end{aligned}$$

Note that, given observed investment, the entire series of $\widetilde{k_t}$ can be directly generated using the perpetual inventory method (assuming an initial value $\widetilde{k_0} = 0$):

$$\widetilde{k_{t+1}} = \frac{x}{nak}\widetilde{x_t} + \frac{1-\delta}{na}\widetilde{k_t},$$

Then the wedges can be computed as

$$\widetilde{\omega_t} = D^{-1}\left(\widetilde{q_t} - C\widetilde{k_t}\right).$$

Once the wedges are computed, they are used for simulation in step 2. We compute the endogenous reaction of selected variables to the changes in a chosen wedge $\widetilde{\omega_{j,t}}$ by plugging its time series into the linear decision rules of endogenous variables:

$$\begin{aligned} \widetilde{k_{t+1}^{\omega_j}} &= A\widetilde{k_t^{\omega_j}} + B\widetilde{\omega_{j,t}}, \\ \widetilde{q_t^{\omega_j}} &= C\widetilde{k_t^{\omega_j}} + D\widetilde{\omega_{j,t}}. \end{aligned}$$

By definition, plugging in all wedges into the model will exactly reproduce the observable data:

$$\widetilde{q_t^{\omega}} = C\widetilde{k_t} + D\widetilde{\omega_t} = C\widetilde{k_t} + DD^{-1}\left(\widetilde{q_t} - C\widetilde{k_t}\right) = \widetilde{q_t}.$$

Therefore, we can easily decompose the effects of each wedges on the observables due to linearity of the decision rules:

$$\widetilde{q_t^{\omega_e}} + \widetilde{q_t^{\omega_g}} + \widetilde{q_t^{\omega_k}} + \widetilde{q_t^{\omega_l}} = \widetilde{q_t^{\omega}}.$$

3.3 Results

Figure 1 presents the linearly detrended macroeconomic variables in Brazil, China, India and Russia for our sample period of $1990-2009$[8]. The detailed sources and data construction methods are listed in the data appendix. In reporting our results, we show the log deviations of the variables with respect to the steady state (where the first year of data availability is taken as the steady state).

<Figure 1 about here>

Figure 2 plots the time paths of output and computed wedges for each country. For the most part, we do not find much commonality in wedge movements in the four nations. For example, while efficiency wedges have been above the trend in Brazil and Russia throughout the entire period, it has been below trend for most of the time in India and China. In Brazil, there was a temporary slow down in the growth of efficiency during $1997-2003$. In Russia, it took off in 1998 and kept growing at an enormous rate, suggesting a positive impact of efficiency on growth. In India, while efficiency wedges temporarily improved in 2005, since then it has suddenly collapsed. In China, while efficiency wedges deteriorated during the $1995-2001$ period, it shows a gradually improvement ever since. In contrast, in India, except for a small uptick during $2003-2005$, efficiency has been below trend. It is hard to find common patterns in government consumption wedges and labor wedges as well, except for China and Brazil that saw an improvement in government consumption wedge during mid-twenties. Perhaps the common thread amongst all four nations is the evolution of investment wedges in the last decade. Investment wedges have been below the trend in Brazil and Russia and above trend in India and China throughout the entire period. However, they show improvements in all countries during the $2000s$, a common factor in an otherwise diverse experience of the BRICs. This suggests that improvements in investment market frictions potentially aided the resurgence of BRICs since the mid-$2000s$.

<Figure 2 about here>
<Table 4 about here>

In **Table 4**, we report the standard deviation of wedges with respect to output and the correlations of wedges with output for various leads and lags[9] to ascertain

[8] The variables are plotted as log deviations from their 1990 value (1992 in case of Russia).

[9] As defined in CKM (2007), a "$k-th$ lag" is the correlation between the $t-k$ th value of the variable of interest with output at period t.

various comovements. A positive correlation indicates a positive association between a given wedge and the observed economic outcome, and vice versa. Efficiency wedges, for the most part, are positively correlated with output in all countries except India, where the correlation turns negative contemporaneously and for the leads +1 and +2. Investment wedges also show a positive correlation with output in all countries. Labor wedges are positively correlated with output in Brazil and Russia, but negatively correlated in India. In China, while labor wedges become positively correlated for contemporaneous periods and leads +1, +2, the magnitude remains low. As for government consumption wedges, while they are positively correlated with output in Brazil (with the exception of the leads +1, +2), in India, and China, they are negatively correlated with output in Russia for all leads and lags. Given our wedges, we next feed them one by one in our benchmark model and simulate output. **Table 5** presents the decomposition of the impact of each wedges on output and the investment to output ratio. We define a contribution indicator of each wedge ω_j on an endogenous variable v as:

$$\begin{aligned} cont_j &= corr(\widetilde{v_t^{\omega_j}}, \widetilde{v}_t) * \frac{std(\widetilde{v_t^{\omega_j}})}{std(\widetilde{v}_t)} \\ &= \frac{cov(\widetilde{v_t^{\omega_j}}, \widetilde{v}_t)}{var(\widetilde{v}_t)}. \end{aligned}$$

Due to linearity,

$$\sum_j cont_j = 1,$$

as described in Otsu (2010*b*). Therefore, we can consider the value of the indicator as the contribution of each wedge to the fluctuation of the variable of interest.

3.3.1 Benchmark Model

First, we provide the simulation results for output in **Table 5** (plot of simulated output in Figure 3). Since the economies grew particularly rapidly since 2000, we also specifically discuss the period 2000 to 2009.

<Table 5 about here>
<Figure 3 about here>

In Brazil, efficiency, investment and labor wedges all contribute significantly explaining 29.3%, 36.8%, and 49.0% of output fluctuations respectively. Efficiency wedges are particularly significant in the 2000*s* with a contribution of 93.2%, while the contributions of investment and labor wedges, though positive, are much lower. As the figure depicts, the model with only efficiency wedges while capturing the short run output fluctuation quite well, predicts a much higher output level throughout the entire period than witnessed in the data. By 2009, the model predicts output to be 13 percentage points above the trend. The growth in output that would have materialized with efficiency wedges alone are tempered by government consumption wedge. Investment and labor wedges for their part account for the sub-par economic performance of the 1990s and marginally contribute to the recovery of the 2000s. In Russia, during the overall sample period, efficiency wedges have a contribution higher than 100% while all other wedges have negative contributions. According to the figure, this is because the model with only efficiency wedges predicts the economy to recover much faster from the recession in the 1990s and grow much faster in the 2000s than it actually did. On the other hand, investment wedges predict a decline in output throughout the entire period. Therefore, investment wedges contribute to the downturn in 1990s while efficiency wedges aid Russia in recuperating much of the output loss in the 1990s to get back on the development track.

In India, investment wedges contribute the most to the fluctuation of output with an overall contribution of 87.4% over the entire period. This is mainly because of the 2000s where the contribution of investment wedge rises to 105.4%. Interestingly, during the 1990s the contribution of efficiency wedge at 79.6% was much higher than that of the investment wedge at 26.5%. When we run the model with only efficiency wedge, it performs quite well in predicting the fluctuation in output until 2005 . However, it fails to predict the rapid growth after 2005. This is where the investment wedge comes in and investment wedges alone do a better job of accounting for the rapid acceleration of Indian growth during the 2000s well to the sample end. China presents a similar picture with efficiency wedges being the most important force in accounting for the output movement with a contribution of 72.6%. However, during the 2000s the contribution of investment wedges, 72.0%, becomes larger than that of efficiency wedges, 41.5%. According to the figure, the model with only efficiency wedges can almost perfectly reproduce the output fluctuations until 2004. However, mirroring the experience of India, it fails to account for the further rapid growth after 2004. On the other hand, investment wedges have significant impacts on output fluctuation throughout the entire 2000s till the end of the sample period, much like in India.

The unique experience of each country nevertheless show some common patterns, particularly in the last decade. While Brazilian and Russian growth was facilitated primarily by improvements in production efficiency (Brazil also benefitting to some extent from decline in investment market frictions), India and China grew primarily as a result of decline in investment market frictions, particularly in the later half of the 2000s, though, to some extent, China also benefitted from efficiency improvements as it did not experience the sudden loss of productive efficiency as India did since 2005. The contribution of labor and government consumption wedges to growth is negligible in all four nations.

4 Sensitivity Analysis

4.1 Test 1: Efficiency Wedges as Productivity Growth

In CKM (2007) efficiency wedges are defined as temporary shocks to productivity. However, shocks to productivity might be permanent rather than temporary. Recall that in **Figure 1**, detrended output had fallen during the 1990s and then rapidly surged during the 2000s in all BRICs nations. In order to illustrate these medium term cycles better, it might be more appropriate to model efficiency wedges as shocks to the trend component of productivity rather than the cyclical component as suggested by Aguiar and Gopinath (2007). In this section, we alter the definition of efficiency wedges and compare the results to those in the benchmark model.

4.1.1 Model II

The only alteration we make from the benchmark model is the definition of efficiency wedges (3). First, we consider efficiency wedges as the growth in productivity between the previous period ($t-1$) and the current period (t):

$$\omega_{e,t} = \frac{\gamma_t}{\gamma_{t-1}}.$$

We call this setting as model II. In model II, the realization of current productivity will define the growth of productivity and agents will anticipate the growth rate to gradually return to its mean according to (9) while this causes a permanent shift in the trend level. Therefore, the income effect caused by efficiency wedges should be stronger than that in the benchmark model[10].

4.1.2 Model III

An alternative way to model efficiency wedges as productivity growth is to assume that current efficiency wedges lead to a growth in productivity between the current period (t) and future period ($t+1$):

$$\omega_{e,t} = \frac{\gamma_{t+1}}{\gamma_t}.$$

[10] In Aguiar and Gopinath (2007) there are shocks not only to the trend but also to the transitory component. The trend shock reflects the deviation of the productivity growth rate from its mean while the transitory component captures the deviation of the productivity from its trend level. Therefore, model II is equivalent to the Aguiar and Gopinath (2007) model without the transitory component.

We denote this setting as model III. In this model, the agents know the one-period-ahead productivity level when they make decisions on current choice variables. Also, as in model II, the agents will consider efficiency wedges as permanent shocks to the productivity level.

4.1.3 Simulation

Model II and Model III are estimated and simulated in a similar fashion as the prototype model. One important modification is that since we are defining efficiency wedges as shocks to the growth of productivity, we have to define the productivity level as an endogenous state variable. The linear decision rules of endogenous variables are:

$$\begin{aligned} \widetilde{s_{t+1}} &= A\widetilde{s_t} + B\widetilde{\omega_t}, \\ \widetilde{q_t} &= C\widetilde{s_t} + D\widetilde{\omega_t}, \end{aligned}$$

where we define the endogenous state variables $\widetilde{s_t} = \left(\widetilde{k_t}, \widetilde{A_t}\right)$. The entire series of $\widetilde{k_t}$ and $\widetilde{A_t}$ can be directly computed from

$$\begin{aligned} \widetilde{k_{t+1}} &= \frac{x}{nak}\widetilde{x_t} + \frac{1-\delta}{na}\widetilde{k_t}, \\ \widetilde{A_t} &= \frac{\widetilde{y_t}}{1-\theta} - \frac{\theta\widetilde{k_t}}{1-\theta} - \widetilde{l_t}, \end{aligned}$$

assuming initial values $\widetilde{k_0} = 0$, $\widetilde{A_0} = 0$. Then the wedges can be computed as

$$\widetilde{\omega_t} = D^{-1}\left(\widetilde{q_t} - C\widetilde{s_t}\right).$$

Simulation is carried out in the same fashion as the benchmark model:

$$\begin{aligned} \widetilde{s_{t+1}^{\omega_j}} &= A\widetilde{s_t^{\omega_j}} + B\widetilde{\omega_{j,t}}, \\ \widetilde{q_t^{\omega_j}} &= C\widetilde{s_t^{\omega_j}} + D\widetilde{\omega_{j,t}}. \end{aligned}$$

4.1.4 Results

Since the growth shocks introduced in this section affects the expectations of the future, not only efficiency wedges but also investment wedges, that depend on expectations about future, are affected. The labor and government wedges are exactly the same as in the benchmark model. The output decomposition is plotted in **Figure 4** and **Table 6** provides the magnitudes.

<Table 6 about here>
<Figure 4 about here>

The simulation results under the alternative models turn out to be similar to those in the benchmark model for the most part. In Brazil, under both the alternative specifications, investment and labor wedges account for the stagnation in the 1990s while efficiency wedges are important in accounting for the rapid growth in the 2000s. In Russia, investment wedges cause the downturn during the 1990s while efficiency wedges salvage the economy in the 2000s. In India, efficiency wedges account for the output fluctuations up to the mid-2000s while investment wedges are important in accounting for the rapid growth in the later 2000s. In China, efficiency wedges play a very important role in accounting for output fluctuations in both decades. The contribution of investment wedges during the 2000s for model II and III, 35.8% and 20.6% respectively, are considerably lower compared to that in the benchmark model, 72.0%. Government consumption wedges have higher contribution than in the benchmark model to compensate for this. Nonetheless, investment wedges still play an important role in the rapid growth during the later 2000s. It is important to note that the quantitative impact of the efficiency wedges are quite similar across the three models. Intuitively speaking, changing the definition of efficiency wedges does not change the realizations of productivity A_t but it affects the expectations on future productivity. The result that the effects of efficiency wedges on output are robust across the three models indicates that the effects of the realization of productivity is more important than the expectations they generate.

4.2 Test 2: Benchmark Model with Investment Adjustment Costs

In the benchmark model capital stock is accumulated following the capital law of motion (5). However, as CKM (2007) argues, investment adjustment costs can reflect costs in converting output to capital in a detailed model, or financial frictions can manifest themselves as investment adjustment costs in a prototype RBC model. How does this modification affect our results? The only equation that changes is the capital accumulation equation:

$$nak_{t+1} = x_t + (1-\delta)k_t - \Phi\left(\frac{x_t}{k_t}\right)k_t$$

where

$$\Phi\left(\frac{x_t}{k_t}\right) = \frac{\phi}{2}\left(\frac{x_t}{k_t} - \lambda\right)^2.$$

The constant λ is set at $\lambda = na - (1-\delta)$ so that the adjustment cost is equal to zero in the steady state. The parameter ϕ is calibrated to match the marginal Tobin's Q

to one:

$$\frac{d\log q}{d\log(x/k)} = 1,$$

where q is the effective price of investment relative to consumption:

$$q = \frac{1}{1-\Phi'}.$$

This leads to $\phi = \frac{k}{x}$. We plot the simulations of output under each of the four wedges in **Figure 5** (we also plot the results of the benchmark model for comparison). Output decompositions are presented in **Table 7.**

<Table 7 about here>
<Figure 5 about here>

While our basic results do not change with efficiency and investment wedges playing an important role in the output recovery since 2000, some subtle differences are noted, especially regarding the role of government consumption wedge. During the period 2000 to 2009, the contribution of government consumption wedge to output fluctuations increase as compared to the benchmark model in India and China. However, it is still smaller in magnitude as compared to investment wedge. A higher contribution of government wedge also implies a lower contribution of efficiency wedge in China, as compared to the benchmark model, though still coming in second to investment wedge in terms of its contribution.

5 Discussion: Decomposition, Wedges and Policies

The accounting results of the previous section highlight the importance of efficiency and investment wedges in output fluctuations. In this section, we take a look at some policy changes and institutional reforms that are consistent with the observed movement of these wedges. Our discussion mainly focuses on the 2000s due to data availability. Analytically, it works for us since it is the 2000s when we witness a sharp turnaround in growth of the BRIC nations.

Figure 6a plots the private credit share in GDP and the net FDI inflow to GDP ratio and suggests an increase in both till 2008 when FDI declined as a result of the global downturn. Interestingly, domestic credit to the private sector did not show any such decline. Increased capital flows suggest an improvement in credit worthiness borne out by the financial market indicators (**Figure 6b**) provided by the IMD World Competitiveness Yearbook (henceforth, WCY). There is an improvement in credit rating, credit availability as well as the perception of businesses as to how encouraging the cost of capital was in the economy for all BRIC nations. These improvements are consistent with improved investment wedges that would lead to capital inflows fueled by rising credit ratings and increased the availability of capital for domestic businesses. Financial development is also consistent with observed production efficiency. On one hand, an increase in production efficiency should increase capital inflows as higher (perceived) efficiency leads to higher expected growth and lower probabilities of default, which is reflected in the rise in the country credit ratings. On the other hand, an increase in capital inflows can affect production efficiency through various channels. First, as discussed in Findlay (1978), an increase in FDI inflows could generate productivity spillovers through the import of managerial and organizational capital from foreign firms with superior efficiency. This effect could be particularly important in the banking sector as it improves the domestic resource allocation and thus the economy-wide efficiency. Next, as shown in Obstfeld (1994), greater diversification of income risk can lead to production specialization and the pursuit of riskier investment projects with high expected return. Finally, as discussed in Rajan and Zingales (2003), international financial integration will impose discipline on macroeconomic policies as transparency and good governance is essential to attract foreign capital and avoid capital flight. Financial liberalization and the resulting development in the financial market is consistent with the observed improvement in investment wedges in our model. When investment wedges are low, the expected return on investment is high relative to the intertemporal marginal rate of substitution as shown in (10). This can be caused by investment market distortions such as interest rate controls or capital controls which hampers the efficient flow of capital from the households to the firms. Financial liberalization increases the availability of capital by removing these distortions and enables firms to seize profitable investment opportunities. As a result, investment rises which brings down the expected return on investment due to diminishing marginal product of capital. Therefore, the gap between the intertemporal marginal rate of substitution and the expected return on capital should shrink.

<Figure 6a about here>

<Figure 6b about here>

Next, we track some institutional and governance indicators that provide the necessary framework for successful financial development and growth. Since our focus is to trace the development of BRIC policies *over time*, we focus on six time-series measures considered as conducive to economic development (definitions and explanations are in the appendix). **Figure 6c** plots the six indices[11] over time for each BRIC country and compare them to US standards where the measure ranges from -2.5 (weak) to $+2.5$ (strong). While it is clear that not all the indices show positive comovements with the time series of the estimated wedges, the two exceptions are government effectiveness and political stability to some extent. BRIC nations registered considerable improvement in government effectiveness particularly since early $2000s$, though still below US standards. The indices in almost all instances move from negative to positive with almost doubling of the index value between 1996 and 2009. Even in case of Russia that scores the lowest, a 30% improvement in score is witnessed during the last decade. This translates to a $10 - rank$ climb in percentile ranks for all nations, with the exception of India that just climbs two spots. In terms of political stability, which is related to non violence and absence of terrorism, we witness a decline in $1990s$ till about mid-$2000s$ when there is a turn-around. Brazil, the top scorer earns a score of -0.1 (still in negatives though an improvement from -0.35 in the 1990s). The most improvement was noticed in Russia that came out of the turbulent political transition of the $1990s$ to a more favorable domestic political climate. India is the only nation which seems to lag behind, not surprisingly due to its continued vulnerability to terrorism. Overall, we find that while some indices of improvement in institutional and political setup are consistent with our observed increases in productivity and investment wedges, not all indices reflect improvement.

<Figure 6c about here>

An interesting question would be why financial development might have impacted growth in efficiency in Brazil and Russia to a greater extent than in India and China, which particularly becomes apparent after 2004[12]. One important difference in these economies is the development stage that they were at when the reforms commenced. Brazil and Russia were coming out of a stagnation in early $2000s$ while India and China were already on the stable growth track since the $1990s$[13]. Therefore, it might be the case that in Brazil and Russia, the impact of financial development on growth is much stronger - a case of catching up - as compared to India and China which were already on a stable development track[14]. India, in particular, is an aberration where

[11] Voice & Accountability, Political Stability & Non Violence, Government Effectiveness, Regulatory Quality, Rule of Law, Control of Corruption

[12] Bollard, Klenow and Sharma (2012) also find that FDI liberalization had little effect on the TFP growth in Indian manufacturing firms during the $1993 - 2007$ period.

[13] The growth trends in Brazil, Russia, India and China shown in Table 3 are 1.0%, 1.8%, 4.1% and 7.4% respectively.

[14] Gente, Nourry and Leon-Ledesma (2012) show that financial liberalization can have positive or negative impacts on productivity growth depending on the national savings level in an endogenous growth setting with human capital accumulation.

efficiency suddenly collapsed after mid-2000s and we conjecture that the positive impact of financial development was overwhelmed by other factors that caused the efficiency collapse.

6 Conclusion

The growth of the BRIC nations - Brazil, Russia, India and China, has garnered much attention in the last decade. In this paper, we apply the Business Cycle Accounting methodology of Chari, Kehoe and McGrattan (2007) to explore the role of productivity fluctuations and changes in factor market distortions in accounting for the observed output fluctuations over the period 1990 to 2009. Our results, which are robust to methodological alternations, as well as model modifications, show that while each nations' experience was unique, Brazil and Russia benefitted mostly from improved efficiency. India and China, on the other hand, saw a growth spurt in 2000s that can be largely accounted for by improvements in investment wedges, particularly in the latter half. Financial market developments in the BRIC economies, like increased credit flow aided by improved credit rating and business confidence are particularly consistent with improvements in efficiency and investment wedges. Indices denoting political stabilization and government effectiveness also improve possibly aiding efficiency gains and decline in investment market frictions.

One remaining question is why in Brazil and Russia financial development was accompanied by an improvement in efficiency while in India and China it was not. While we document that it relates to the development stage- Brazil and Russia coming out of a crisis to play catch-up and India and China already on a stable path- we leave further analysis of this topic for future research. According to institutional and governance indicators, BRIC nations have a long way to go before they catch up with the US standards. BRIC countries have taken steps in this direction by signing an accord to boost credit for trade transactions and authorizing establishment of a multilateral bank for funding projects in the developing world in the latest BRIC summit on March 29, 2012 with hopes of further such initiatives in the 2013 annual meeting of the BRICS.

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Table 1: GDP ranking by PPP methodology (% share in world GDP)

Source: International Monetary Fund Statistics

	World Ranking									
Year	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**
2011	U.S.	China	India	Japan	Germany	Russia	Brazil	U.K.	France	Italy
	(19.11)	(14.36)	(5.67)	(5.58)	(3.92)	(3.02)	(2.93)	(2.86)	(2.81)	(2.32)
2010	U.S.	China	Japan	India	Germany	Russia	U.K.	Brazil	France	Italy
	(19.53)	(13.61)	(5.81)	(5.46)	(3.96)	(3.00)	(2.93)	(2.93)	(2.87)	(2.39)
2005	U.S.	China	Japan	Germany	India	U.K.	France	Russia	Italy	Brazil
	(22.26)	(9.46)	(6.83)	(4.40)	(4.29)	(3.41)	(3.28)	(2.99)	(2.88)	(2.80)
2000	U.S.	Japan	China	Germany	India	France	U.K.	Italy	Brazil	Russia
	(23.55)	(7.61)	(7.14)	(5.07)	(3.72)	(3.63)	(3.59)	(3.31)	(2.92)	(2.65)
1995	U.S.	Japan	China	Germany	France	U.K.	Italy	India	Brazil	Russia
	(22.89)	(8.71)	(5.67)	(5.55)	(3.81)	(3.64)	(3.61)	(3.31)	(3.17)	(2.94)
1990	U.S.	Japan	Germany	France	Italy	U.K.	China	Brazil	India	Mexico
	(24.70)	(9.91)	(6.16)	(4.39)	(4.14)	(4.09)	(3.88)	(3.33)	(3.17)	(2.61)
1985	U.S.	Japan	Germany	France	Italy	U.K.	Brazil	China	Mexico	India
	(25.19)	(9.29)	(6.22)	(4.47)	(4.25)	(4.16)	(3.61)	(3.18)	(2.85)	(2.84)
1980	U.S.	Japan	Germany	France	Italy	U.K.	Brazil	Mexico	India	Spain
	(24.64)	(8.65)	(6.74)	(4.74)	(4.48)	(4.28)	(3.92)	(2.97)	(2.53)	(2.41)

Table 2: Aggregate GDP and GDP per capita growth rates

Data Source: World Bank and Penn World Tables

Column (1) summarizes growth in Aggregate GDP while column (2) summarizes growth in GDP per capita

		1960s		**1970s**		**1980s**		**1990s**		**2000s**	
		(1)	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**
U.S.	Mean	4.66%	3.33%	3.32%	2.24%	3.04%	2.09%	3.22%	1.96%	1.85%	0.90%
	St. Dev.	(1.68%)	(1.67%)	(2.58%)	2.56%	(2.55%)	2.56%	(1.55%)	(1.57%)	(2.12%)	(2.08%)
OECD	Mean	5.74%	4.42%	3.73%	2.67%	2.94%	2.13%	2.56%	1.74%	1.75%	1.04%
	St. Dev.	(0.74%)	(0.81%)	(1.89%)	(1.91%)	(1.44%)	(1.46%)	(0.80%)	(0.84%)	(2.20%)	(2.18%)
Brazil	Mean	5.90%	2.97%	8.47%	5.92%	2.99%	0.82%	1.70%	0.12%	3.67%	2.49%
	St. Dev.	(3.68%)	(3.68%)	(3.48%)	(3.39%)	(4.76%)	(4.67%)	(2.94%)	(2.94%)	(2.43%)	(2.48%)
Russia	Mean							−4.91%	−4.81%	5.35%	5.66%
	St. Dev.							(6.14%)	(6.24%)	(4.73%)	(4.81%)
India	Mean	6.67%	4.44%	2.93%	0.55%	5.69%	3.35%	5.63%	3.62%	7.36%	5.74%
	St. Dev.	(6.14%)	(6.01%)	(4.16%)	(4.06%)	(1.88%)	(1.86%)	(2.0%)	(2.03%)	(2.35%)	(2.38%)
China	Mean	3.02%	0.89%	7.44%	5.34%	9.75%	8.75%	9.99%	8.75%	10.30%	9.64%
	St. Dev.	(14.85%)	(13.74%)	(5.62%)	(5.37%)	(3.24%)	(3.23%)	(3.24%)	(3.23%)	(1.81%)	(1.86%)

Table 3. Parameters and Steady States

Source: Authors' calculations

		Brazil	**Russia**	**India**	**China**
Parameter	*Explanation*	*Values*			
a	Average growth rate of per capita output	1.010	1.018	1.041	1.074
n	Average growth rate of population	1.017	0.999	1.019	1.007
θ	Share of capital in output	0.521	0.526	0.713	0.293
δ	Rate of depreciation	0.120	0.094	0.121	0.117
β	Subjective discount factor	0.849	0.939	0.776	1.042
Ψ	Elasticity of substitution between consumption and leisure	0.273	0.177	0.381	0.154
y/k	Steady state output to capital ratio	0.633	0.338	0.683	0.526
l	Steady state labor	0.230	0.193	0.218	0.230
c/y	Consumption as a share of output in the steady state	0.604	0.426	0.634	0.432
x/y	Investment as a share of output in the steady state	0.218	0.424	0.292	0.417
g/y	Government expenditure as a share of output in the steady state	0.179	0.150	0.074	0.151
Benchmark model with Investment Adjustment Costs					
ϕ	Sensitivity of investment to marginal Q	7.252	6.965	5.015	4.558
$\varkappa$	Steady state investment to capital ratio	0.147	0.111	0.181	0.198

Table 4: Properties of the wedges

Source: Authors' calculations

Benchmark Model

	Standard Deviation with respect to output	Cross Correlations of wedges with output at lag k=				
		−2	−1	0	1	2
BRAZIL						
Efficiency Wedges	2.43	0.24	0.41	0.33	0.09	−0.11
Government Consumption Wedges	2.99	0.72	0.37	0.14	−0.16	−0.44
Investment Wedges	1.36	0.25	0.63	0.68	0.12	−0.17
Labor Wedges	1.55	0.16	0.19	0.50	0.55	0.40
RUSSIA						
Efficiency Wedges	7.61	0.87	0.70	0.42	0.21	−0.02
Government Consumption Wedges	3.50	−0.28	−0.61	−0.80	−0.82	−0.73
Investment Wedges	9.61	−0.12	0.26	0.60	0.78	0.91
Labor Wedges	0.61	0.63	0.63	0.59	0.76	0.71
INDIA						
Efficiency Wedges	2.16	0.43	0.18	−0.06	−0.51	−0.68
Government Consumption Wedges	3.22	0.21	0.25	0.45	0.47	0.23
Investment Wedges	1.87	0.86	0.87	0.77	0.66	0.50
Labor Wedges	0.85	−0.55	−0.53	−0.37	−0.05	0.20
CHINA						
Efficiency Wedges	1.34	0.53	0.73	0.84	0.71	0.51
Government Consumption Wedges	3.55	0.54	0.54	0.48	0.30	0.01
Investment Wedges	1.64	0.24	0.34	0.31	0.22	0.03
Labor Wedges	1.48	−0.04	−0.11	0.01	0.10	0.26

Table 5: Decomposition of Output - Benchmark Model

Source: Authors' calculations

	Brazil	Russia	India	China
1990:2009				
Efficiency Wedges	0.293	1.826	0.039	0.726
Government Consumption Wedges	−0.151	−0.196	0.014	0.049
Investment Wedges	0.368	−0.570	0.874	0.218
Labor Wedges	0.490	−0.060	0.073	0.006
1990:1999				
Efficiency Wedges	−0.535	−0.746	0.796	0.991
Government Consumption Wedges	−0.047	0.037	−0.118	−0.005
Investment Wedges	0.609	1.619	0.265	−0.142
Labor Wedges	0.973	0.090	0.057	0.155
2000:2009				
Efficiency Wedges	0.932	1.559	−0.128	0.415
Government Consumption Wedges	−0.153	−0.041	0.005	0.131
Investment Wedges	0.143	−0.437	1.054	0.720
Labor Wedges	0.078	−0.082	0.068	−0.266

Table 6: Decomposition of Output -Alternative Models

Source: Authors' calculations

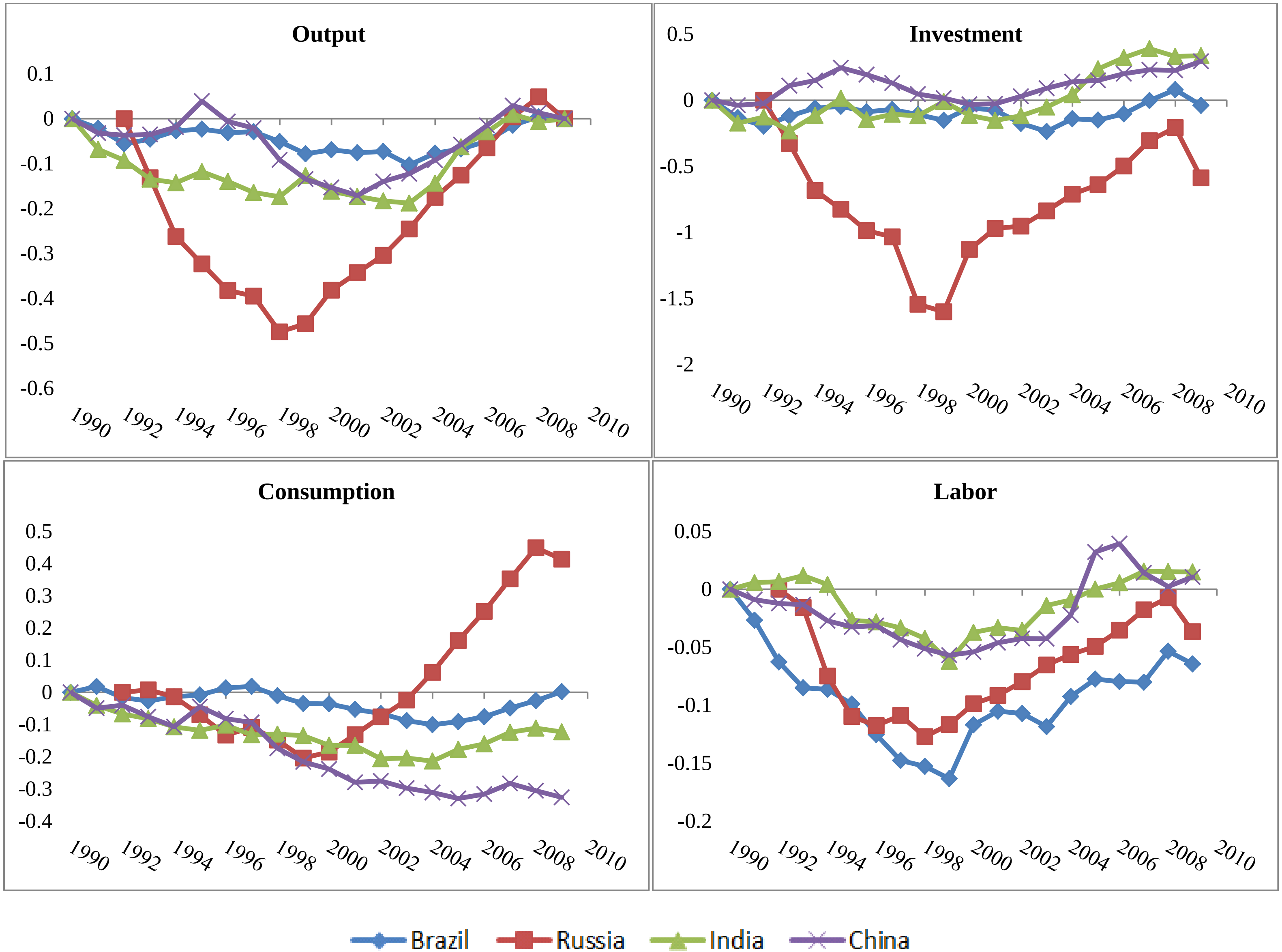
	Model II				**Model III**			
				1990:2009				
	Brazil	**Russia**	**India**	**China**	**Brazil**	**Russia**	**India**	**China**
Efficiency Wedges	0.239	1.647	0.017	0.626	0.268	1.922	0.055	0.871
Government Consumption Wedges	−0.021	−0.117	0.016	0.133	−0.102	−0.231	0.017	0.305
Investment Wedges	0.265	−0.603	0.812	0.249	0.356	−0.767	0.859	−0.187
Labor Wedges	0.516	0.072	0.155	−0.008	0.477	0.076	0.069	0.012
				1990:1999				
Efficiency Wedges	−0.54	−0.812	0.631	0.881	−0.512	−0.091	0.676	0.879
Government Consumption Wedges	0.057	0.574	−0.086	0.028	−0.008	−0.203	−0.079	0.094
Investment Wedges	0.463	1.277	0.373	0.106	0.570	1.336	0.347	−0.193
Labor Wedges	1.022	−0.038	0.081	−0.015	0.949	−0.042	0.056	0.220
				2000:2009				
Efficiency Wedges	0.854	1.297	−0.121	0.370	0.891	1.801	−0.084	0.606
Government Consumption Wedges	−0.004	0.263	0.005	0.271	−0.097	−0.177	0.005	0.556
Investment Wedges	0.073	−0.710	0.967	0.358	0.126	−0.780	1.015	0.206
Labor Wedges	0.076	0.149	0.149	0.000	0.079	0.157	0.064	−0.367

Table 7: Decomposition of Output - Benchmark Model with Investment Adjustment Costs

Source: Authors' calculations

	Brazil	Russia	India	China
1990:2009				
Efficiency Wedges	0.273	2.322	−0.166	0.636
Government Consumption Wedges	−0.052	−0.367	0.214	0.075
Investment Wedges	0.399	−0.941	0.579	0.288
Labor Wedges	0.380	−0.014	0.374	0.001
1990:1999				
Efficiency Wedges	−0.651	−0.746	0.723	0.893
Government Consumption Wedges	0.030	−0.082	−0.283	−0.013
Investment Wedges	0.749	1.807	0.396	0.067
Labor Wedges	0.871	0.020	0.165	0.052
2000:2009				
Efficiency Wedges	1.123	2.234	−0.331	0.298
Government Consumption Wedges	−0.015	−0.295	0.232	0.209
Investment Wedges	−0.002	−0.958	0.715	0.590
Labor Wedges	−0.106	0.018	0.384	−0.096

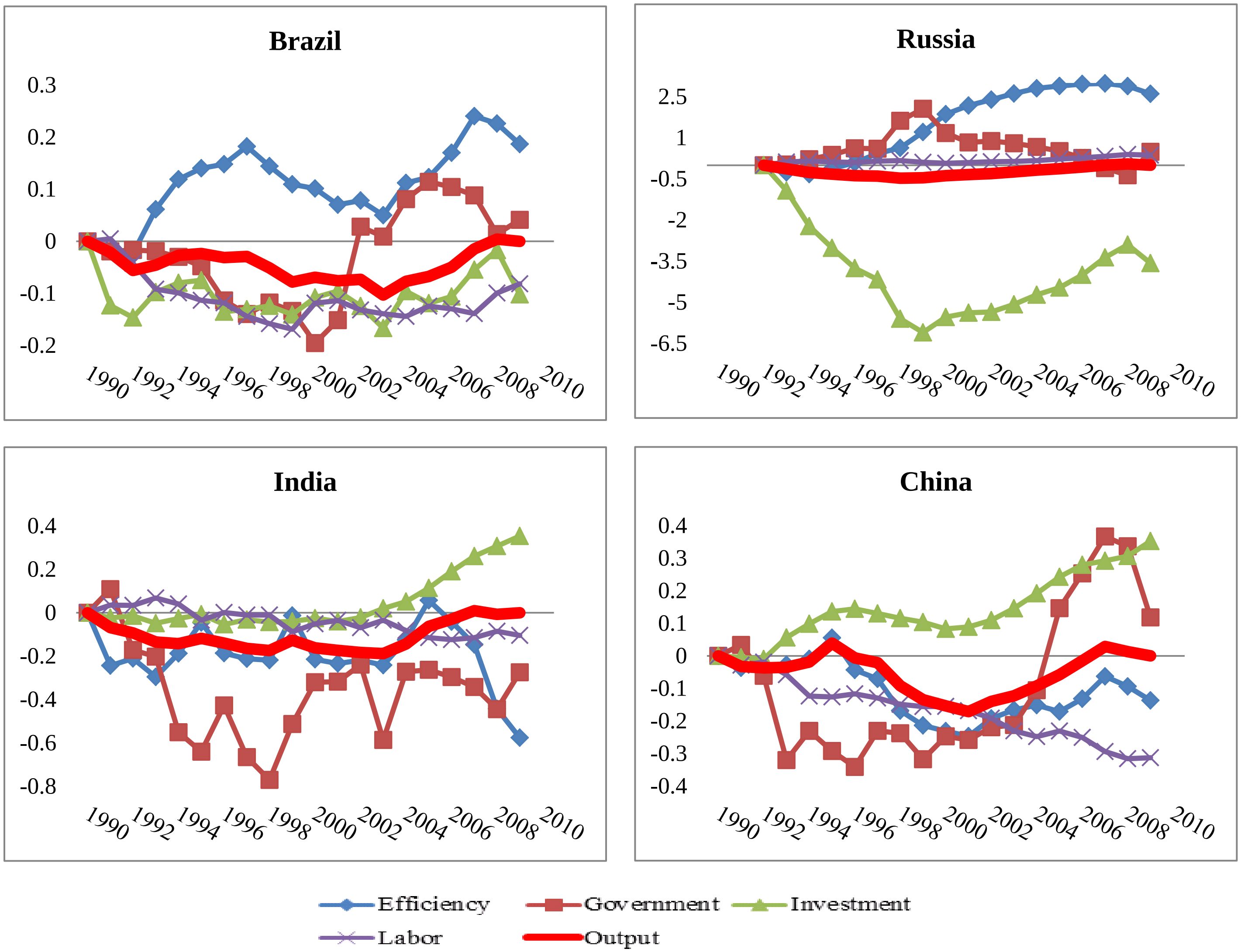
Figure 1: Real Macro Aggregates



Note: "Output (Y)" includes GDP and the imputed service flow from consumer durables. It is decomposed into "Consumption (C)" that consists of household consumption of non-durables and services (where the imputed service flow from consumer durables are included) and "Investment (X)" that includes gross domestic capital formation and household expenditures on consumer durables while the residual is defined as "Government Consumption (G)" so that Y=C+X+G "Labor (L)" represents total hours worked which consists of total employment and hours worked per workers. All variables are divided by the adult population. Output, consumption and investment are linearly detrended by the average per adult output growth rate over the 1990-2009 period setting 1990 at the trend level

Source: The data is primarily collected from the Penn World Tables edition 7.0 and its extension made by Duncan Foley

Figure 2: Estimated Wedges in the benchmark model



Note: Efficiency wedges in our benchmark model are estimated as shocks to the "level" of productivity.

Figure 3: Simulated Output in the benchmark model

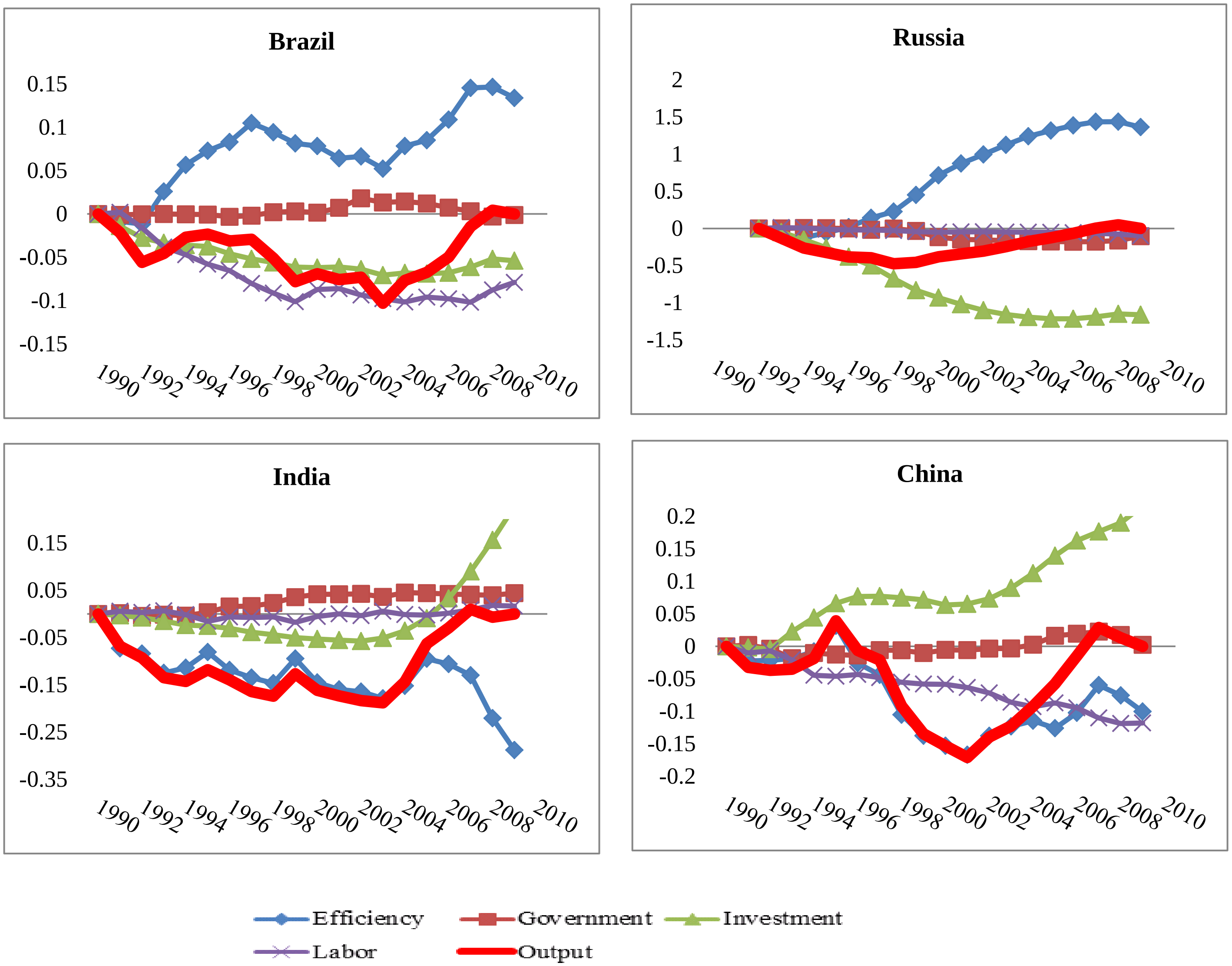
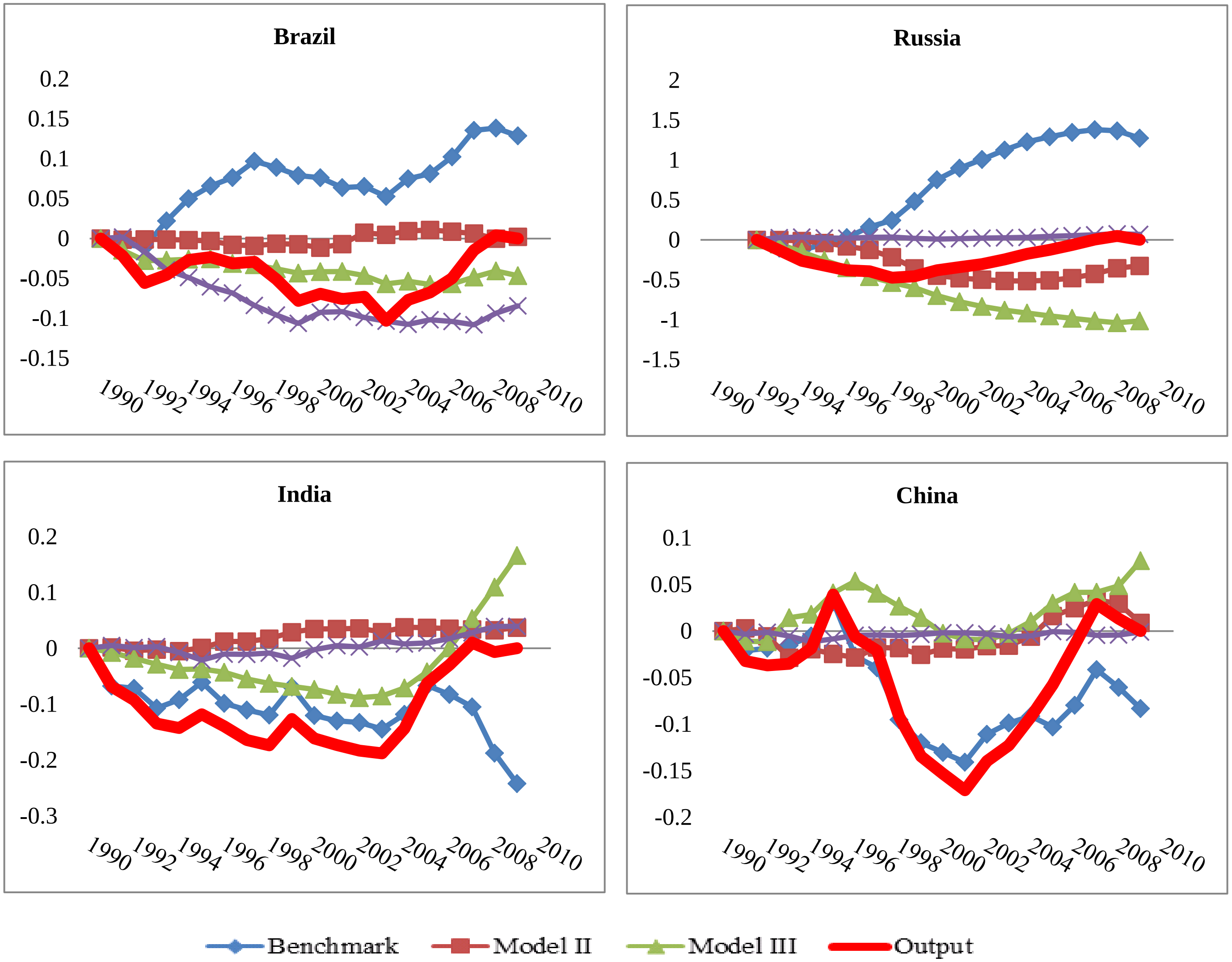
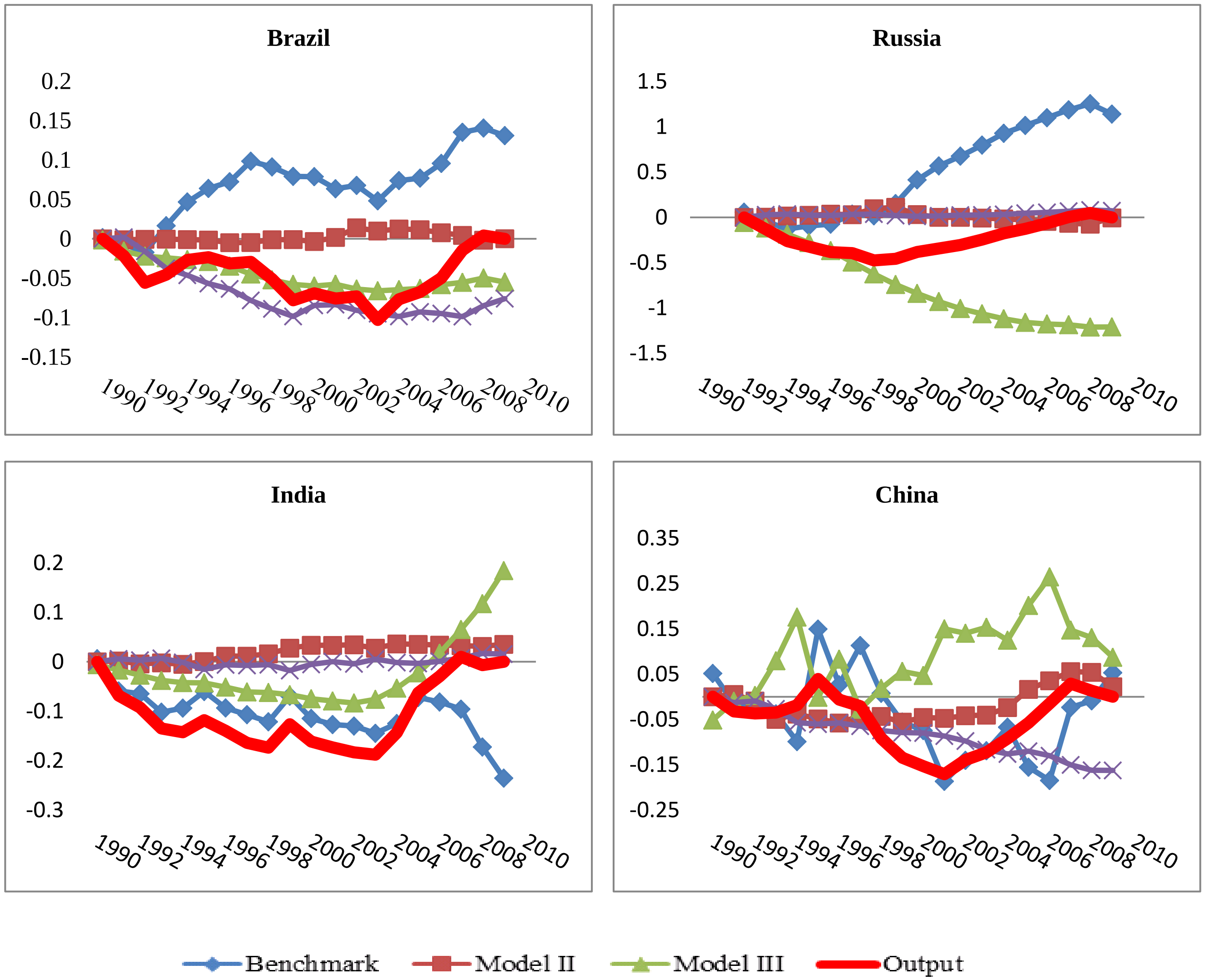


Figure 4: Simulated output under model II



Note: In model II, efficiency wedges are modeled as shocks to growth rate of realized productivity.

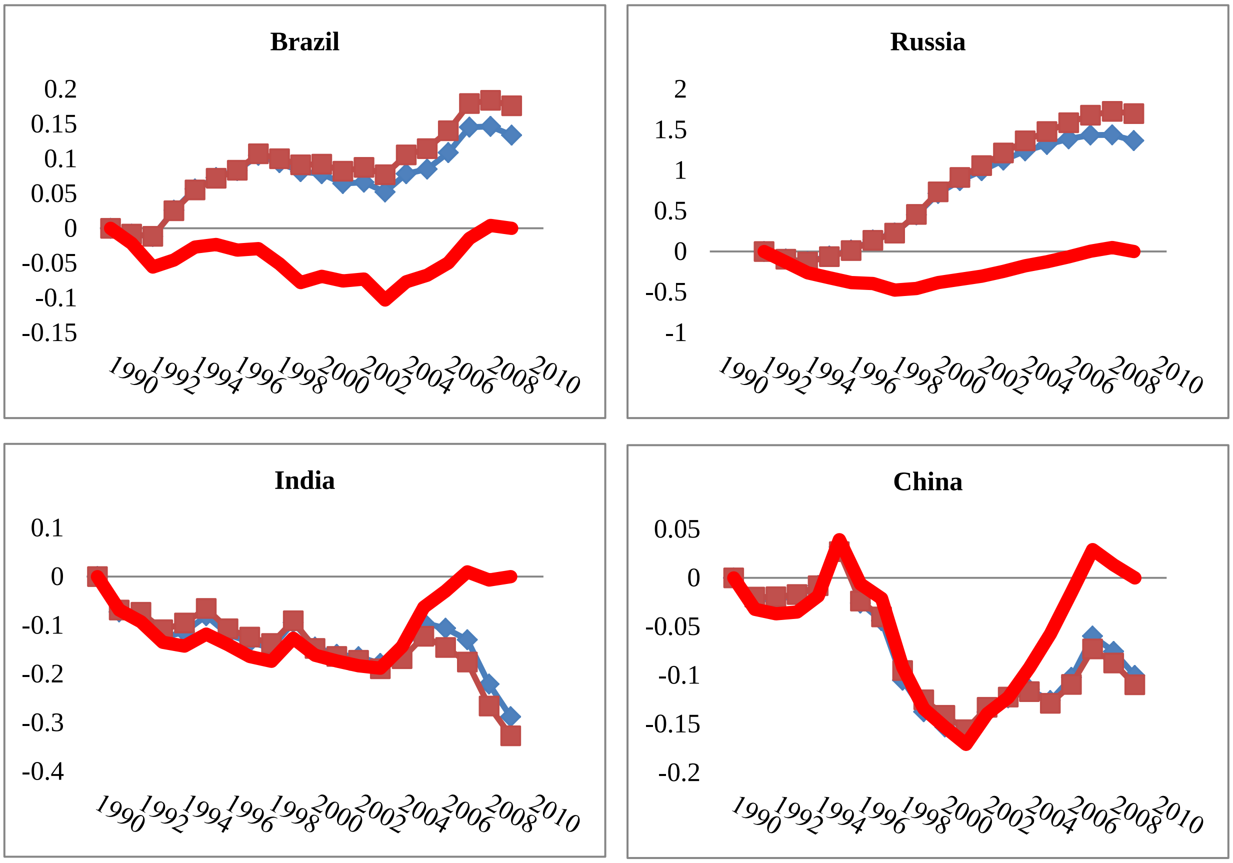
Figure 4 contd.: Simulated output under model III



Note: In model III, efficiency wedges are modeled as shocks to future productivity growth

Figure 5: Simulated output under benchmark model with investment adjustment costs

Output with efficiency wedges



Output with government consumption wedges

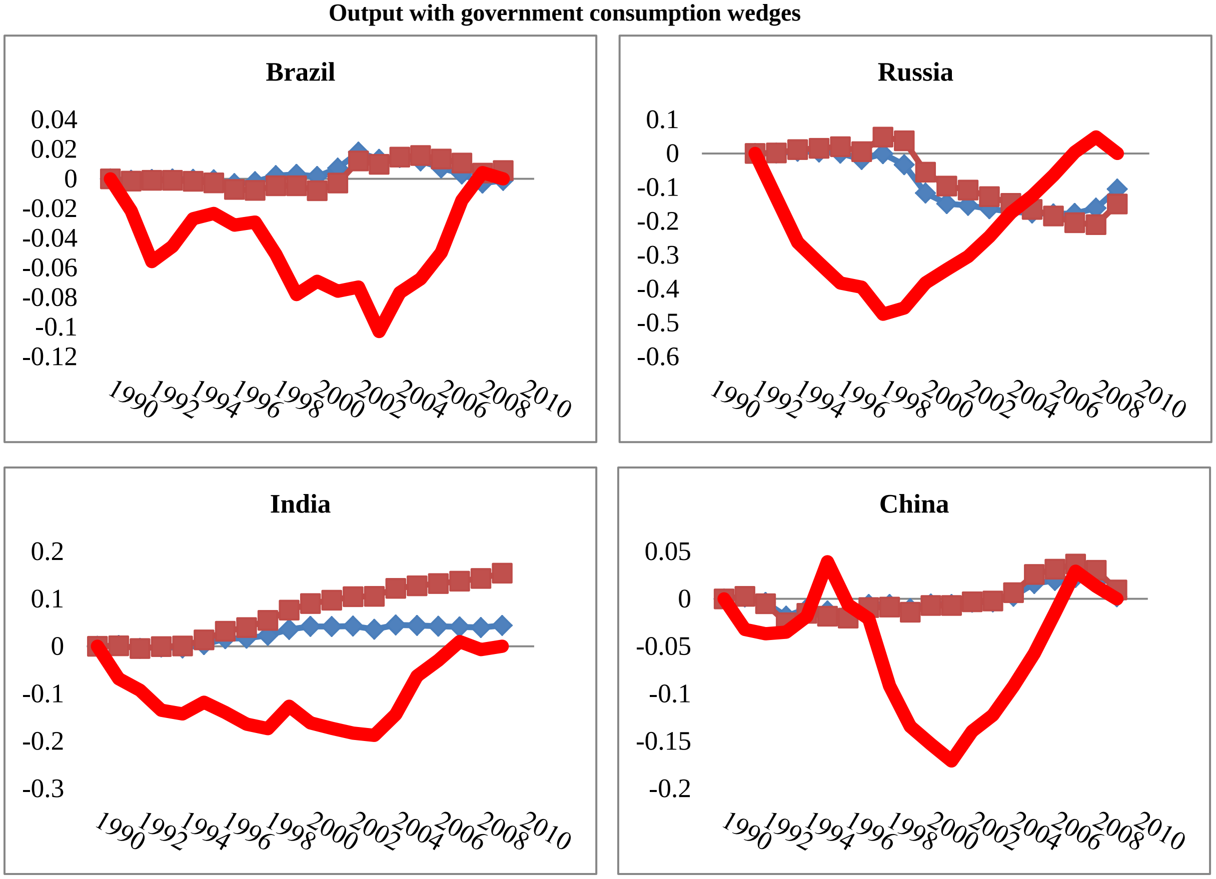
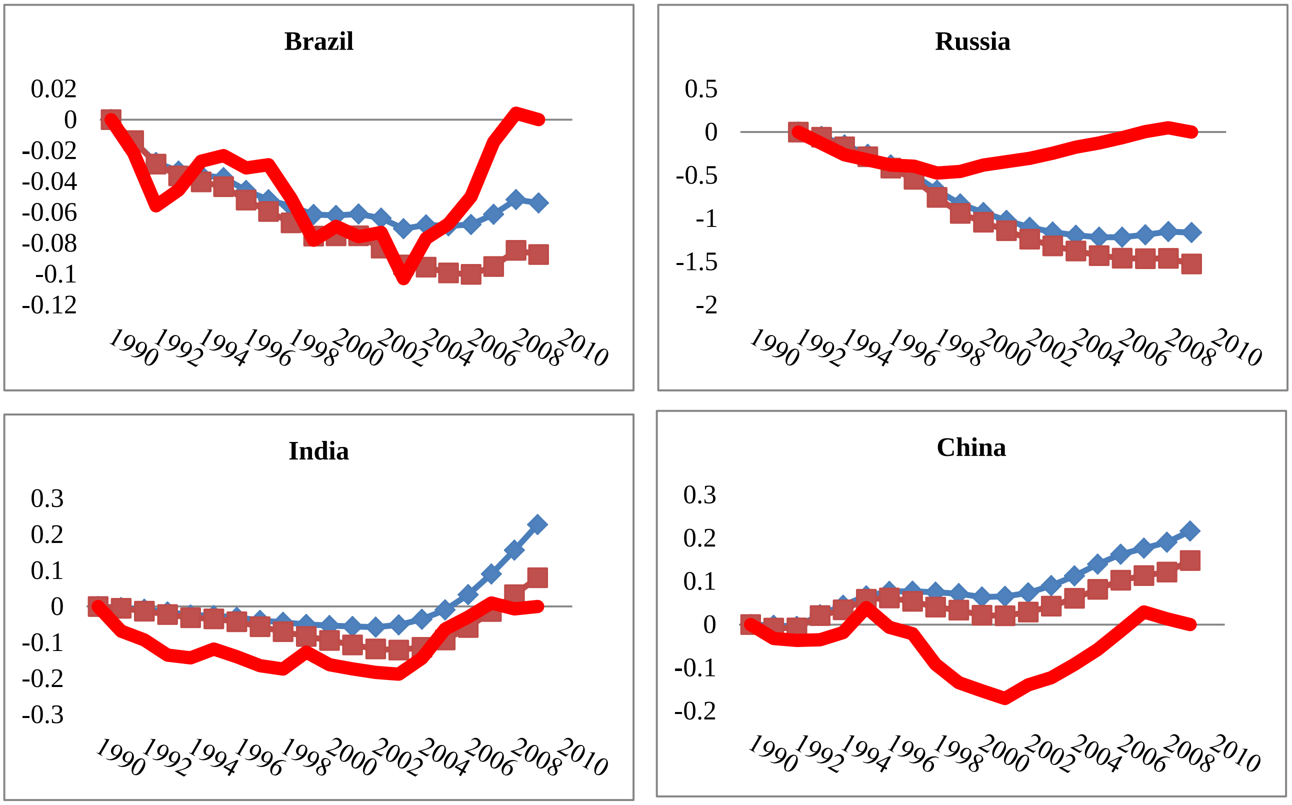
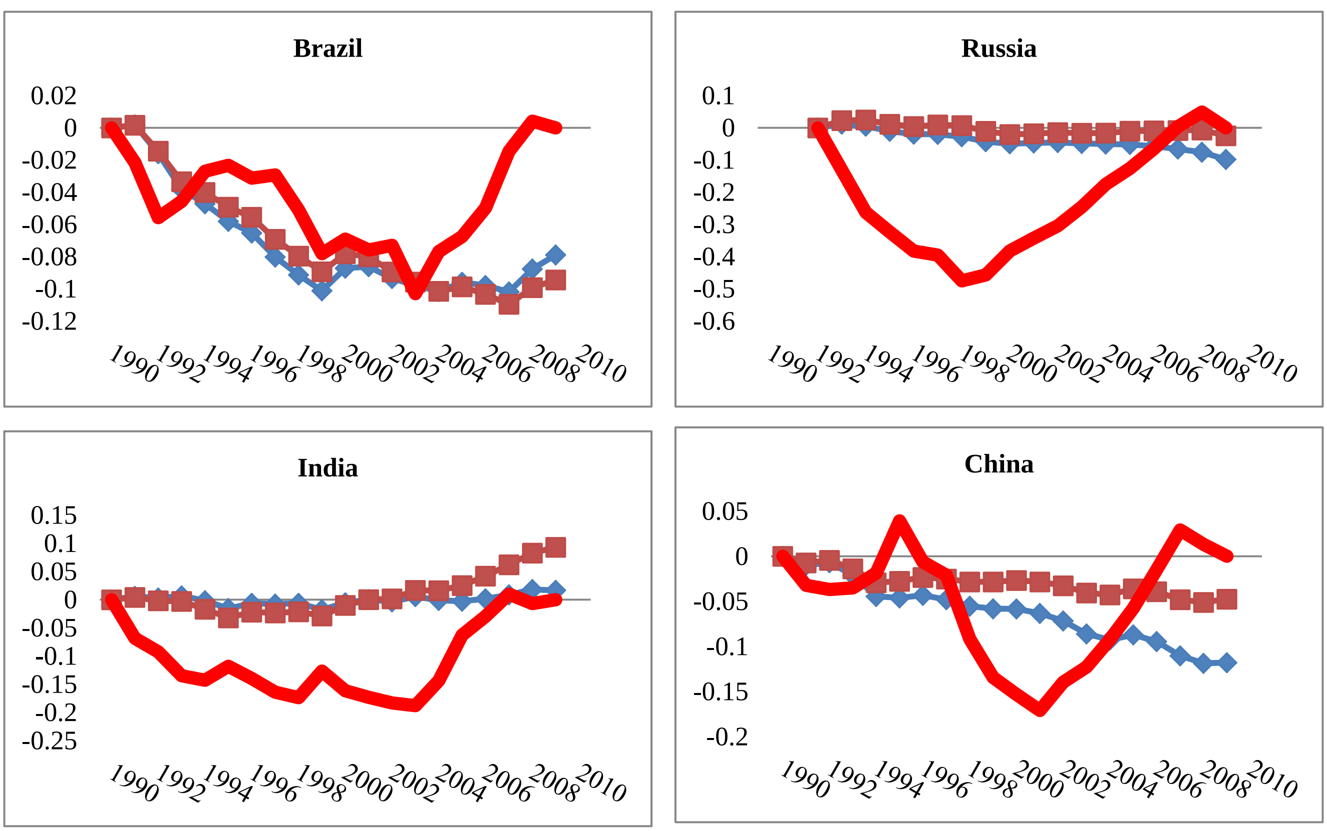


Figure 5 contd.: **Simulated output under benchmark model with investment adjustment costs**

Output with investment wedges

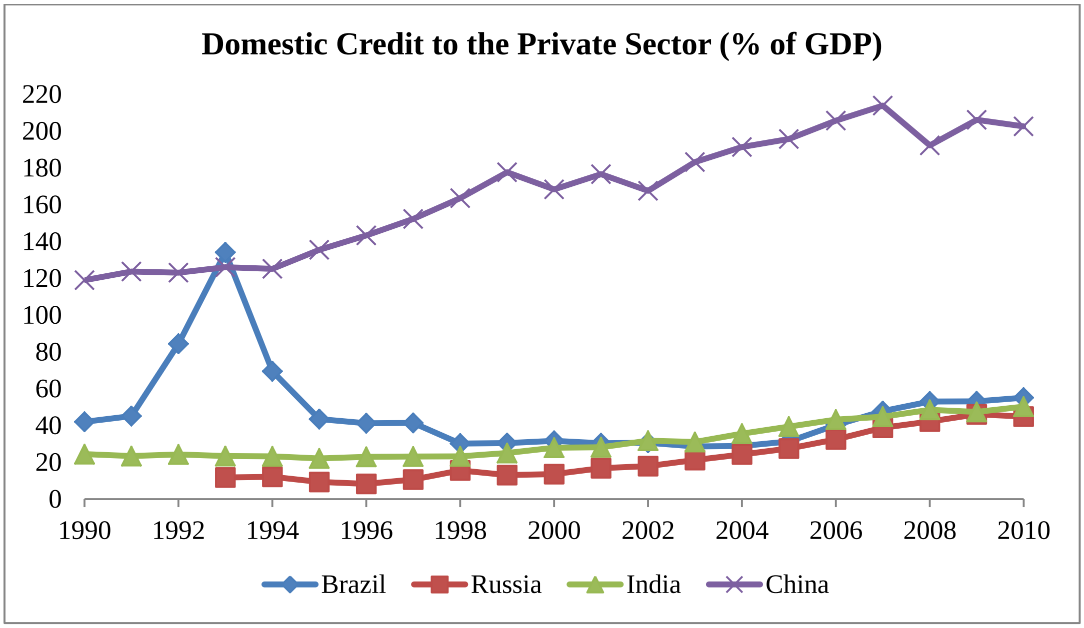


Output with labor wedges



Note: AC denotes the benchmark model with quadratic adjustment costs for investment, while the benchmark model is exactly similar to the AC model except without the quadratic adjustment costs. We feed in efficiency, government consumption, investment and labor wedges one at a time and compare the model simulations of output under the AC and benchmark model with that in the data.

Figure 6a: Flow of Domestic Credit to Private Sector and Inflows of FDI



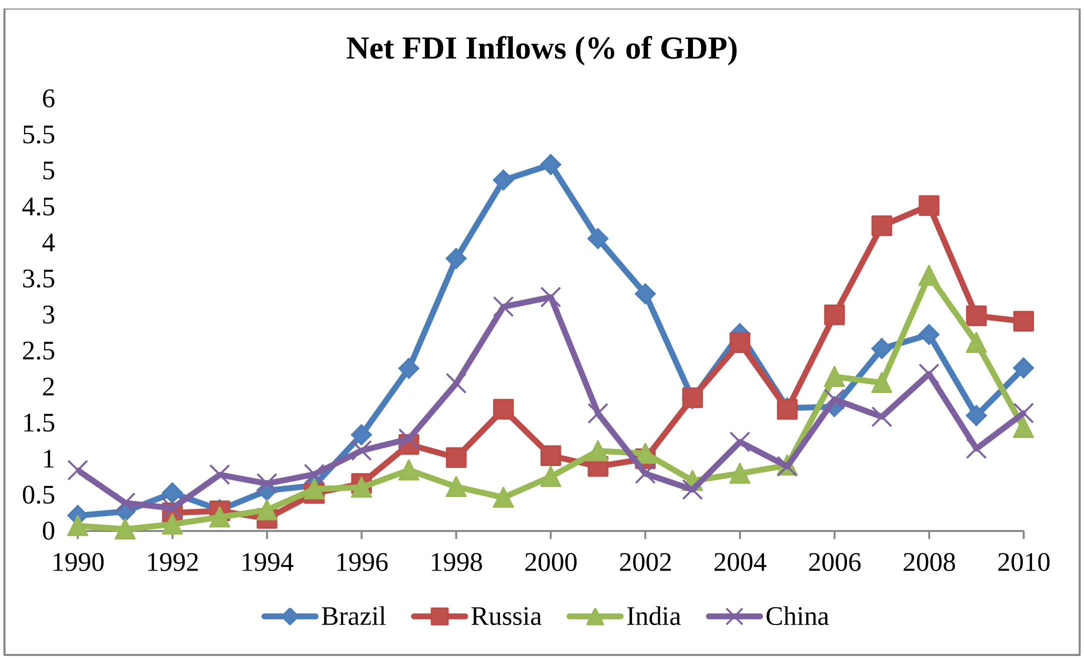
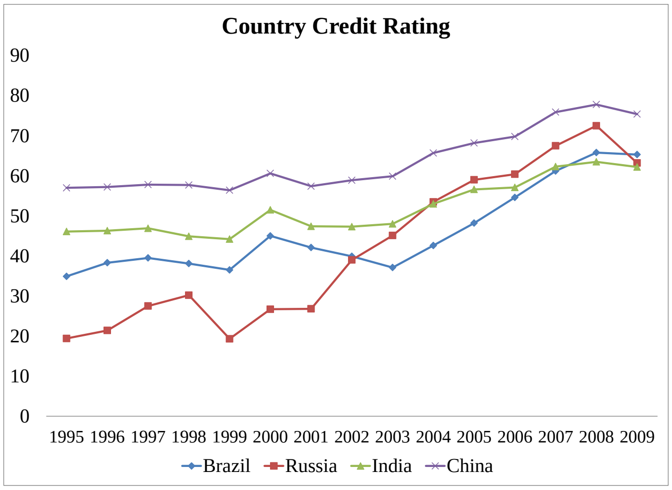
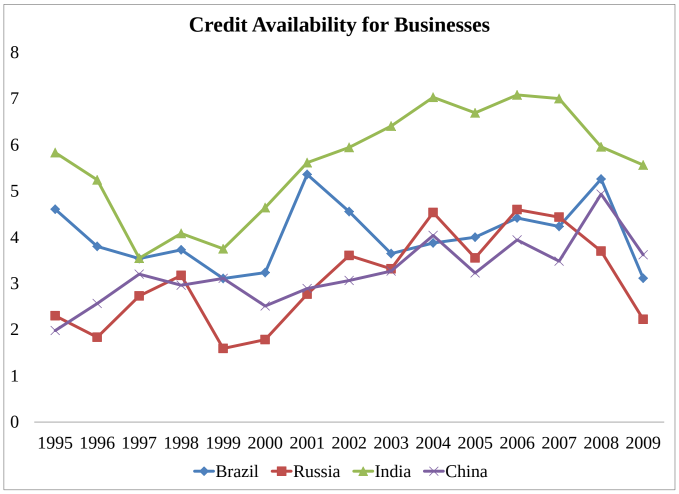


Figure 6b: Financial Market Indicators





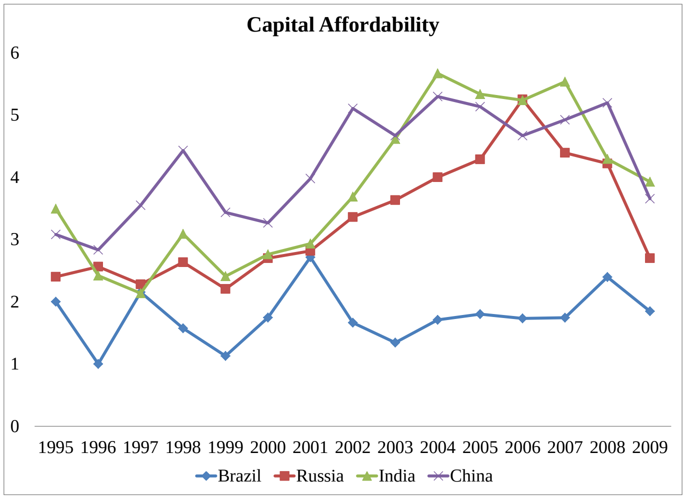
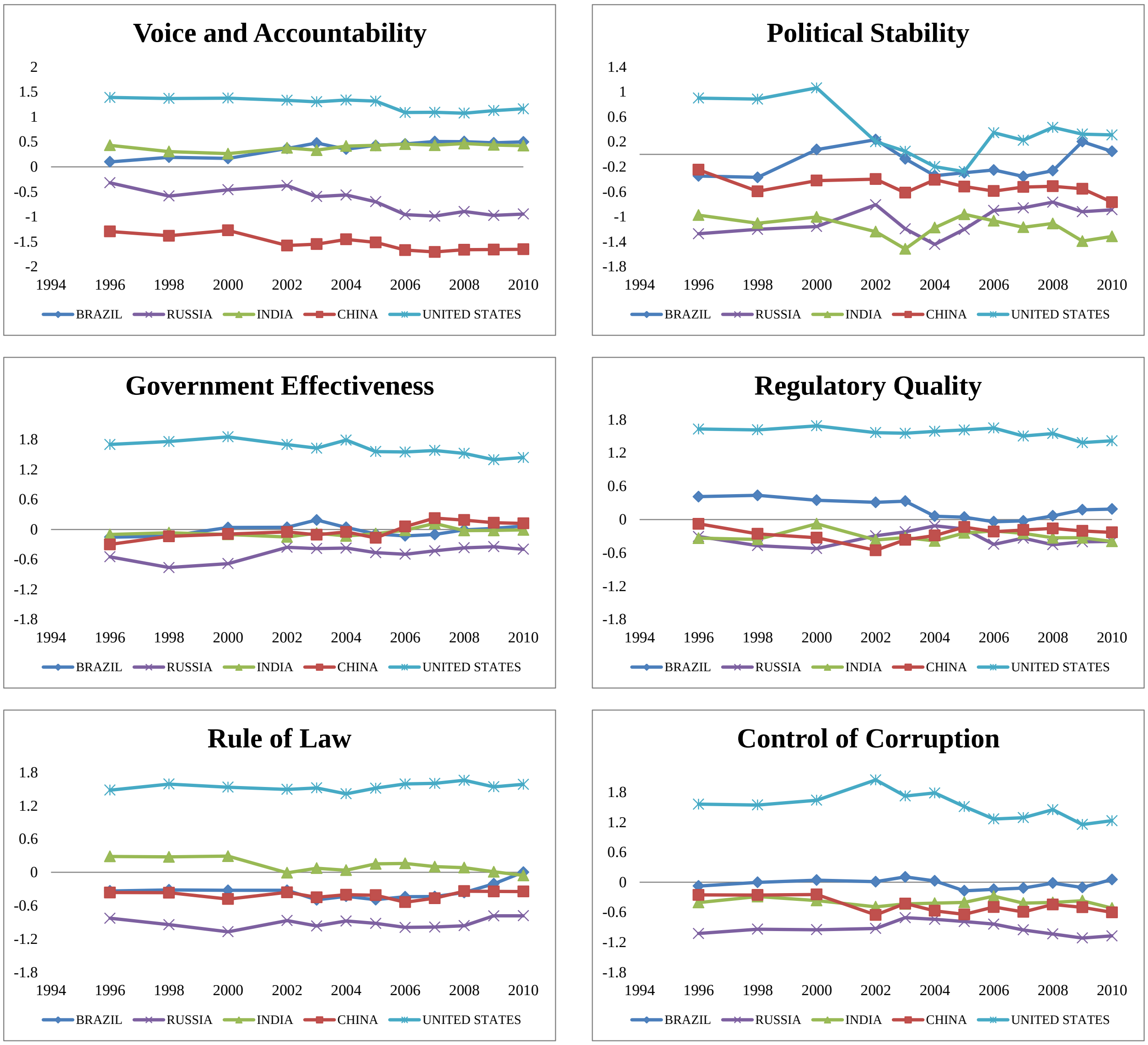


Figure 6c: Measures of Institutional and Policy Reforms



Online Appendix for "Business Cycle Accounting of the BRIC Economies"

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Keisuke Otsu† University of Kent

November 22, 2012

1 Linearization Appendix

In this section we define the log-linearized equations of our model.

We define the log linearization of each detrended variables from their steady states as

$$\widetilde{v_t} = \ln \widehat{v_t} - \ln \overline{v}$$

Then the linearized equilibrium conditions are

$$0 = \frac{\beta}{na}\theta\frac{y}{k}\widetilde{k_{t+1}} - \frac{\beta}{na}\theta\frac{y}{k}\widetilde{y_{t+1}} + \widetilde{c_{t+1}} - \widetilde{c_t} - \frac{\beta}{na}\theta\frac{y}{k}\widetilde{\omega_{k,t+1}}$$

$$0 = \widetilde{y_t} - \widetilde{c_t} - \frac{1}{1-l}\widetilde{l_t} + \widetilde{\omega_{l,t}}$$

$$0 = \widetilde{y_t} - \frac{c}{y}\widetilde{c_t} - \frac{x}{y}\widetilde{x_t} - \frac{g}{y}\widetilde{\omega_{g,t}}$$

$$0 = na\widetilde{k_{t+1}} - \frac{x}{k}\widetilde{x_t} - (1-\delta)\widetilde{k_t}$$

$$0 = \widetilde{y_t} - \theta\widetilde{k_t} - (1-\theta)\widetilde{\gamma_t} - (1-\theta)\widetilde{l_t}$$

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Finally, we consider three cases regarding the definition of $\widetilde{\omega_{e,t}}$. The first case follows Chari, Kehoe and McGrattan (2007) where efficiency wedges $\omega_{e,t}$ directly affect the level of productivity:

$$\widetilde{\omega_{e,t}} = \widetilde{\gamma}_t. \quad \text{(Model I)}$$

In the second case, we define efficiency wedges as the growth of productivity between the previous period and the current period:

$$\widetilde{\omega_{e,t}} = \widetilde{\gamma}_t - \widetilde{\gamma_{t-1}}. \quad \text{(Model II)}$$

Finally, in the third case, we define efficiency wedges as the growth of productivity between the current period and the next period:

$$\widetilde{\omega_{e,t}} = \widetilde{\gamma_{t-1}} - \widetilde{\gamma}_t. \quad \text{(Model III)}$$

2 Parameters of the Vector AR (1) Stochastic Process of the Wedges

Given the underlying vector AR(1) stochastic process for the wedges and the data on output, consumption, investment and labor in Brazil, Russia, India and China, we estimate the wedges using Bayesian techniques. The bayesian priors are listed in Table A. The parameters underlying the vector AR(1) process for the wedges in Brazil, Russia, India and China are listed in Table B for the benchmark model where productivity wedge is modeled as shocks to the level of productivity. Tables C and D list the parameters of the AR(1) process governing the shocks under models II and III where productivity wedges are modeled as shocks to the realized growth rate and future growth rate of productivity respectively.

Table A: The Bayesian Priors for structural estimation of wedges

	Prior Distribution	Prior Mean	Prior Variance
P Diagonal	Beta	0.8	0.2
P Off-Diagonal	Normal	0	0.2
V Standard Deviation	Inverse Gamma	0.05	inf
V Correlation	Uniform	0	$-1, 1$

Table B: Parameters of the Vector AR(1) Stochastic Process driving the wedges -Benchmark Model

P				V			
Brazil							
0.7930	0.1990	−0.3160	−0.1370	0.0010	0.0000	0.0000	0.0000
−0.3500	0.7940	0.3260	−0.2630	0.0000	0.0020	0.0000	0.0000
−0.0790	0.0200	0.7940	−0.0350	0.0000	0.0000	0.0010	0.0000
−0.0070	−0.0510	0.6710	0.8040	0.0000	0.0000	0.0000	0.0000
Russia							
0.9330	0.1890	0.2230	0.6110	0.0080	−0.0140	0.0000	0.0000
−0.3470	0.8690	−0.5420	−0.1030	−0.0140	0.1490	0.0000	−0.0030
0.0390	−0.0410	0.9760	−0.1290	0.0000	0.0000	0.0000	0.0000
0.0220	−0.0470	−0.1000	0.8090	0.0000	−0.0030	0.0000	0.0010
India							
0.8440	0.0110	−0.2890	0.2360	0.0090	0.0000	0.0000	−0.0020
0.2390	0.7790	0.3890	−0.0110	0.0000	0.0240	−0.0010	0.0000
−0.0050	0.0050	0.9400	−0.2730	0.0000	−0.0010	0.0000	0.0000
−0.0080	0.0610	−0.0110	0.7310	−0.0020	0.0000	0.0000	0.0010
China							
0.8250	0.0280	0.0900	0.0860	0.0020	0.0010	0.0000	0.0000
−0.0150	0.8690	0.3800	−0.0490	0.0010	0.0100	0.0000	0.0000
−0.0110	0.0050	0.7860	−0.1410	0.0000	0.0000	0.0000	0.0000
0.1070	0.0330	−0.3730	0.8220	0.0000	0.0000	0.0000	0.0000

Table C: Parameters of the Vector AR(1) Stochastic Process driving the wedges -Model II

P				V			
Brazil							
0.5490	0.0047	0.0429	−0.0217	0.0010	0.0001	0.0003	0.0000
0.0266	0.8200	−0.0707	0.0221	0.0001	0.0024	0.000	0.0000
0.1770	0.0167	0.6164	0.0723	0.0003	0.0000	0.0046	0.0000
−0.0975	0.0753	0.2248	0.8709	0.0000	0.0000	0.0000	0.0002
Russia							
0.5668	0.0464	0.054	0.1516	0.0026	−0.0024	−0.0121	−0.0008
−0.3264	0.7534	−0.0127	0.3876	−0.0024	0.8214	1.6147	−0.0113
0.0796	−0.3596	0.5894	−0.1432	−0.0121	1.6147	3.1985	−0.0235
−0.6895	0.2033	−0.0584	0.8550	−0.0008	−0.0113	−0.0235	0.0050
India							
0.5906	−0.0294	−0.0112	0.5543	0.0122	−0.0017	−0.0001	−0.0024
0.2724	0.8427	0.2137	−0.0676	−0.0017	0.0268	−0.0005	−0.0007
−0.0013	−0.0005	0.9449	−0.2645	−0.0001	−0.0005	0.0001	−0.0001
−0.1240	0.0566	−0.0563	0.7311	−0.0024	−0.0007	−0.0001	0.0008
China							
0.4931	−0.0009	0.0624	0.0832	0.0022	0.0006	−0.0071	−0.0003
0.6399	0.8373	0.2618	−0.3045	0.0006	0.0106	−0.0024	0.0008
0.7828	0.0157	0.6470	−0.5072	−0.0071	−0.0024	0.0456	0.0036
−0.2634	0.0195	0.0378	0.9684	−0.0003	0.0008	0.0036	0.0008

Table D: Parameters of the Vector AR(1) Stochastic Process driving the wedges -Model III

P				V			
Brazil							
0.6078	0.1327	−0.4426	0.0945	0.0009	0.0000	0.0002	−0.0001
0.1489	0.7636	0.3575	−0.0446	0.0000	0.0019	0.0000	−0.0002
0.2001	−0.0175	0.7729	0.0463	0.0002	0.0000	0.0006	0.0000
−0.3876	0.0148	0.5559	0.8092	−0.0001	−0.0002	0.0000	0.0002
Russia							
0.7895	0.0180	0.0654	0.2833	0.0085	0.0195	−0.0001	−0.0010
−0.1659	0.8373	−0.2054	0.2147	0.0195	0.0984	0.000	−0.0041
0.3150	−0.0646	0.9177	−0.1507	−0.0001	0.0000	0.0002	−0.0001
−0.2272	−0.0203	−0.1627	0.8610	−0.0010	−0.0041	−0.0001	0.0010
India							
0.5858	0.0152	−0.2131	0.2100	0.0150	0.000	0.0003	0.0007
−0.0100	0.8537	0.1355	−0.1041	0.0000	0.0272	−0.0009	−0.0007
0.0170	−0.0003	0.9489	−0.2441	0.0003	−0.0009	0.0001	−0.0001
−0.1805	0.0476	−0.0699	0.8130	0.0007	−0.0007	−0.0001	0.001
China							
0.7457	0.0259	−0.0299	0.0999	0.0020	0.0004	0.0084	−0.0002
1.1285	0.8002	−0.1127	−0.1722	0.0004	0.0110	−0.0022	0.0003
−0.7322	0.1422	0.8069	0.2940	0.0084	−0.0022	0.0370	−0.0011
0.3301	−0.0192	−0.1401	0.8972	−0.0002	0.0003	−0.0011	0.0004

3 Data Appendix

3.1 Data Sources

"Output (Y)" includes GDP and the imputed service flow from consumer durables. It is decomposed into "Consumption (C)" that consists of household consumption of non-durables and services (where the imputed service flow from consumer durables are included) and "Investment (X)" that includes gross domestic capital formation and household expenditures on consumer durables while the residual is defined as "Government Consumption (G)" so that $Y = C + X + G$[1]. "Labor (L)" represents total hours worked which consists of total employment and hours worked per workers. All variables are divided by the adult population[2]. Output, consumption and investment are linearly detrended by the average per adult output growth rate over the $1990 - 2009$ period setting 1990 at the trend level[3]. The data is primarily collected from the Penn World Tables edition 7.0 and its extension made by Duncan Foley[4]. Table A1 presents the original sources of the data. PWT stands for Penn World Tables edition 7.1 and the extensions made by Duncan Foley. EM stands for the Eurominotor Global Market Information Database. ILO stands for the International Labor Organization LABORSTA database. The details of data construction follows.

Table A1. Original Sources of the Data

GDP	PWT
Consumption share	PWT
Investment share	PWT
Employment	PWT
Hours worked per worker	EM
Population	PWT
Adult Share in Total Population	ILO
Household Expenditure on Durables	EM
Net fixed Capital Stock	PWT[5]
Depreciation	PWT[6]
Household Income Share of Capital	EM

[1] Therefore, G includes government purchases of goods and services as well as net exports. The inclusion of net exports in government consumption follows the tradition of a closed economy BCA model (Chari, Kehoe and McGrattan (2007)).

[2] We use total population for China due to data availability.

[3] Therefore, the output series will start at the trend level in 1990 and end at the trend level in 2009.

[4] Source: https://sites.google.com/a/newschool.edu/duncan-foley-homepage/home/EPWT

[5] For Russian capital stock and depreciation we refer to Izyumov and Vahaly (2008) because the Foley database reports capital stock data only for the 2004-2008 period.

[6] Izyumov and Vahaly (2008) assume a constant 5% annual depreciation.

Employment E is computed from the PWT data of GDP per capita ($rgdpl2$) and GDP per person counted in total employment ($rgdpl2te$) and population (POP):

$$E = \frac{rgdpl2}{rgdpl2te} \times POP.$$

Labor L, which is defined as total hours worked, is the product of hours worked per worker h and employment. The adult population is computed using the data from ILO of the adult share in total population and the population data from PWT.

In order to compute the household expenditure on durables X_d, we use the consumer expenditure data of EM and the data of PWT for consumption share of GDP (kc), GDP per capita ($rgdpch$) and population (POP):

$$X_d = \frac{\text{consumer expenditure on durables}}{\text{consumer expenditure}} \times kc \times rgdpl2 \times POP.$$

The household income share of capital θ_h is derived from EM data on household income:

$$\theta_h = 1 - \frac{\text{gross income from employment}}{\text{gross income}},$$

3.2 Imputing Service Flow from Consumer Durables

Consumption expenditure C_x in the data is defined as

$$C_x = C_{nd} + C_s + X_d,$$

where C_{nd}, C_s and X_d stand for the household expenditures on non-durables, services and durables. However, consumption in the model C is defined as

$$C = C_{nd} + C_s + C_d,$$

where C_d stands for the services flow generated from durable stocks. Investment X is defined as the sum of gross domestic capital formation X_f and X_d. Output Y is defined as the sum of GDP and C_d. Total capital stock K is the sum of net fixed capital stock K_f and the stock of consumer durables K_d.

The service flow from consumer durables C_d is imputed as

$$C_d = K_d(R_k + \delta_d).$$

where R_k is the net return on capital stock and δ_d is the depreciation rate of consumer durables assumed to be equal to 0.2. The stock of consumer durables follows a law of motion:

$$K_{d,t+1} = (1 - \delta_d)K_{d,t} + X_{d,t},$$

where the stock of consumer durables in 1990 is assumed to be equal to

$$K_{d,1990} = \frac{X_{d,1990}}{\delta_d}.$$

The net return on capital R_k is defined as

$$R_k = \theta_f \frac{GDP}{K_f} - \delta_f,$$

where θ_f is the income share of net fixed capital stock and δ_f is the depreciation rate of net fixed capital stock. The income share of net fixed capital stock is derived as

$$\theta_f = \frac{\theta_h \times NNP + \Delta}{GDP},$$

where θ_h is the household income share of capital which is directly obtained from data, Δ stands for the depreciation of net fixed capital stock and $NNP = GDP - \Delta$. The depreciation rate of net fixed capital stock is computed as

$$\delta_f = \frac{\Delta}{K_f}.$$

Finally, total capital share θ is defined as

$$\theta = \frac{\theta_f \times GDP + C_d}{Y}.$$

4 Institutional and Governance Indicators - Definitions and measurement details

World Bank collects data on a set of institutional and governance indicators from 212 nations and we have the time series since 1996. In each instance, measures range from -2.5 to $+2.5$ with standard errors reflecting variability around the point estimate. The indicators are based on 30 aggregate data sources, survey and expert assessments. The details can be found in:

Daniel Kaufmann, Aart Kraay and Massimo Mastruzzi (2010). "The Worldwide Governance Indicators : A Summary of Methodology, Data and Analytical Issues", World Bank Policy Research Working Paper No. 5430:

http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1682130

(1) Voice and Accountability - reflects perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media

(2) Political Stability and Absence of Violence/Terrorism - reflects perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including politically-motivated violence and terrorism

(3) Government Effectiveness - reflects perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies

(4) Regulatory Quality - reflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development

(5) Rule of Law - reflects perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence

(6) Control of Corruption - reflects perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests.