

Bai, Chong-En; Zhang, Qiong

Working Paper

Is the People's Republic of China's current slowdown a cyclical downturn or a long-term trend? A productivity-based analysis

ADB Working Paper, No. 635

Provided in Cooperation with:

Asian Development Bank Institute (ADBI), Tokyo

Suggested Citation: Bai, Chong-En; Zhang, Qiong (2017) : Is the People's Republic of China's current slowdown a cyclical downturn or a long-term trend? A productivity-based analysis, ADB Working Paper, No. 635, Asian Development Bank Institute (ADBI), Tokyo

This Version is available at:

<https://hdl.handle.net/10419/163134>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



<https://creativecommons.org/licenses/by-nc-nd/3.0/igo/>



ADB Working Paper Series

**IS THE PEOPLE'S REPUBLIC OF
CHINA'S CURRENT SLOWDOWN
A CYCLICAL DOWNTURN OR
A LONG-TERM TREND? A
PRODUCTIVITY-BASED ANALYSIS**

Chong-En Bai and
Qiong Zhang

No. 635
January 2017

Asian Development Bank Institute

Qiong Zhang is an associate professor at the School of Public Administration and Policy, Renmin University of China. Chong-En Bai is Mansfield Freeman Chair Professor and Executive Associate Dean of the School of Economics and Management of Tsinghua University.

The views expressed in this paper are the views of the author and do not necessarily reflect the views or policies of ADBI, ADB, its Board of Directors, or the governments they represent. ADBI does not guarantee the accuracy of the data included in this paper and accepts no responsibility for any consequences of their use. Terminology used may not necessarily be consistent with ADB official terms.

Working papers are subject to formal revision and correction before they are finalized and considered published.

The Working Paper series is a continuation of the formerly named Discussion Paper series; the numbering of the papers continued without interruption or change. ADBI's working papers reflect initial ideas on a topic and are posted online for discussion. ADBI encourages readers to post their comments on the main page for each working paper (given in the citation below). Some working papers may develop into other forms of publication.

ADB recognizes "China" as the People's Republic of China.

Suggested citation:

Bai, C–E., and Q. Zhang. 2017. Is the People's Republic of China's Current Slowdown a Cyclical Downturn or a Long-term Trend? A Productivity-Based Analysis. ADBI Working Paper 635. Tokyo: Asian Development Bank Institute. Available: <https://www.adb.org/publications/prc-current-slowdown-cyclical-downturn-or-long-term-trend>

Please contact the authors for information about this paper.

Email: zhangqiong8@ruc.edu.cn, baichn@sem.tsinghua.edu.cn

Asian Development Bank Institute
Kasumigaseki Building, 8th Floor
3-2-5 Kasumigaseki, Chiyoda-ku
Tokyo 100-6008, Japan

Tel: +81-3-3593-5500

Fax: +81-3-3593-5571

URL: www.adbi.org

E-mail: info@adbi.org

© 2017 Asian Development Bank Institute

Abstract

Whether the People's Republic of China's (PRC) economic slowdown since the 2008 financial crisis is a cyclical downturn or a long-run trend has important policy implications. Based on provincial panel data, this article identifies the determinants of productivity and uses counter-factual analysis to decompose the causes of the PRC's post-crisis slowdown. It finds that economic openness has a significantly positive impact on the technical efficiency of production, whereas the income level has a significantly negative effect. Second, a significantly negative correlation is observed between the stock of inventory and productivity, while the opposite is observed between employment involvement rate and productivity. Third, government size and investment rates both have significantly negative effects on productivity. Lastly, the diminishing late-mover advantage and the growth in investment rate are both major contributors to the current decline in the PRC's productivity. Although the stimulus-induced investment surge has effectively offset the negative effects of the crisis on the PRC's growth, it is not conducive to the growth of productivity and consumption. The current economic slowdown does not seem to be a cyclical downturn. Indeed, further reforms are needed to stabilize the PRC's growth.

JEL Classification: O47, E20

Contents

1.	INTRODUCTION	1
2.	LITERATURE REVIEW	3
2.1	TFP and Estimation Methods	3
2.2	Factors Affecting Productivity Rate	4
3.	THEORETICAL FRAMEWORK AND ANALYSIS.....	4
3.1	Methodologies for TFP Estimation	5
3.2	Determinants of TFP	5
3.3	Data Source and Indicators.....	6
4.	DECOMPOSING THE RECENT DECLINE IN PRODUCTIVITY GROWTH.....	16
5.	ROLES OF THE STIMULUS-INDUCED INVESTMENT SURGE.....	19
6.	CONCLUSION.....	21
	REFERENCES	23

1. INTRODUCTION

The People's Republic of China's (PRC) economy has shown visible signs of slowdown since 2008. The annual real gross domestic product (GDP) growth rate dropped from an annual average 10.54% between 2000 and 2007, to 9.70% in 2008. Though the government stimulus triggered a pullback from 2009's record low, this rebound proved to be short-lived: the growth rate slumped again in 2011. Over the period 2011–2015, the annual growth rate for the PRC economy stood at a mere 7.84%, even below that (10.03%) between 1978 and 2007.¹

The causes of this striking slowdown and the PRC's economic outlook have been the subject of much contention. Some blame the lower growth on the financial crisis and the debt problems facing the eurozone, expecting the PRC economy to be back on its high-growth track once the residual impact of the crisis fades. Others point to the accumulated structural issues underlying the development mode of the past decade, arguing that high-speed growth is unsustainable and predicting a shift towards a "lower gear" or a "New Normal" scenario.

A good understanding of the forces behind the PRC's economic growth prior to the financial crisis is essential to this debate. Neoclassical growth theory suggests that economic growth is driven by labor (an increase in a well-educated and well-trained workforce), capital, and productivity. According to our analysis (which will be discussed in detail later), the annual productivity growth (minus growth rates of factor inputs) reached 3.55% between 1978 and 2007, much higher when compared with the rate of 1.97% over the period 2008–2014. Clearly, the PRC's productivity growth dipped in the wake of the financial crisis. The massive stimulus package and the discretionary macro-economic policies, which led to a boost in investment, had clearly played a huge role from 2008 to 2014.

Our analysis further reveals that the economic slowdown since 2008 is a result of the decrease in both labor and productivity growth rates. The cause of the former is readily explained by an aging population and more than 2 decades of widening coverage of compulsory education. A better understanding of what has led to the latter, therefore, is central to understanding the current slowdown in the PRC and the forecast of its future performance.

As such, this article first constructs provincial panel data between 1978 and 2014 based on a growth accounting model. To forecast the PRC's growth, it examines three aspects—technical efficiency, factor utilization efficiency, and allocative efficiency—to explain the regional and temporal productivity variations during this period. It then uses counter-factual analysis to reveal the causes of the PRC's productivity variations in recent years and recursively simulate the effects of a policy-promoted investment boom on growth. The article finds that, firstly, economic openness has a significantly positive impact on the technical efficiency of production, whereas income level has a significant negative effect as implied by convergence theory. Secondly, a significantly negative correlation is observed between the stock of inventory and productivity through the latter's influence on effective factor usage, while the opposite is observed between labor force involvement rate and productivity. Thirdly, through effects on the efficiency of resource allocation, government size, and investment rate both have significantly negative effects on productivity. Lastly, we conclude that the diminishing late-mover

¹ The growth rates are calculated based on real GDP data in 2005 prices (among which the GDP for 2015 is a preliminary estimate) with original data from the PRC National Bureau of Statistics (NBS) website.

advantage and the growth in investment rate are all major contributors to the decline in the PRC's productivity since the financial crisis. Moreover, although the stimulus-induced investment surge has effectively offset the negative effects of the financial crisis on the PRC's growth, it is not conducive to productivity and consumption. The current economic slowdown does not seem to be a cyclical downturn that may soon be reversed. Indeed, further reforms are needed to stabilize the PRC's growth.

The main contribution of this article is as follows. First, it offers a comprehensive estimate of the PRC's national and provincial total factor productivity (TFP) over the period of 1978–2014 based on comparable data.² More specifically, it follows the principle of “considering under-utilization of factors as efficiency loss” and differentiates between the “amount of inputs” and their “production efficiency” as much as possible when assessing the TFP. Second, it determines the impact of technical, factor utilization, and allocative efficiency on the TFP with provincial panel data, which can help to simultaneously consider provincial and year fixed effects. The former is closely related to regional, specific time-invariant characteristics over years, whereas the latter reflects the cyclical effects on all provinces during the same period. Results from the panel can then be applied to reveal long-run effects of referred determinants on TFP when short-run cyclical shocks are controlled. Third, after assessing the annual labor resource level in different provinces, the article adopts two methods to calculate the TFP: one considers human capital stock, which is a measure of the quality-adjusted labor force, as labor input; the other takes only the working-age population into account, but considers human capital as a determinant of factor utilization efficiency. Finally, it performs a counter-factual analysis to analyze the PRC's post-crisis productivity variations to predict its long-term growth rate. It answers the question of whether the PRC's economic slowdown since the 2008 financial crisis is a cyclical downturn or a long-run trend.

It is worth mentioning that there are a variety of ways to estimate TFP, each with unique advantages and disadvantages. One strand uses upstream output as downstream input to capture the productivity transferred across supply chains and considers only the actual number of factors entering the production process. This method yields very accurate results only when stringent data requirements are met—a condition that is hard to satisfy in the current PRC. Another downside of this approach is that it does not distinguish between the potential and actual input usage. In this article, we evaluate the comprehensive utilization efficiency of potential human and physical capital input throughout the entire production process. We also consider under-utilization as efficiency loss, so the transfer from potential to actual input usage, and from actual input usage to final output are all included in the calculation. To investigate the factors determining productivity, we quantitatively compare comprehensive variation across provinces over time, taking into account provincial-specific characteristics during a given period and controlling possible effects of cyclical shocks. We believe that this is the best approach under data availability constraints.

The remainder of the article includes the following sections. Part 2 briefly summarizes the research on TFP, its estimation procedures, and the factors that determine its growth. Part 3 describes the analysis framework. Part 4 explains the selection of indicators and data handling, and then applies the orthogonal decomposition method to identify effects of such indicators on productivity. Parts 5 and 6 break down the causes of the post-crisis fluctuation in productivity and recursively simulate the effects of

² The PRC's provincial administrative units consist of provinces, municipalities, and autonomous regions—all labeled as “provinces” in this article for simplicity.

policy-induced investment boom on growth using counter-factual analysis. The final part concludes.

2. LITERATURE REVIEW³

This section surveys two lines of literature: one on TFP and its estimation methods; the other on elements that impact factor utilization.

2.1 TFP and Estimation Methods

The term total factor productivity (TFP) has its origin in a 1766 article by Quesnay, which mentioned the word “productivity” for the first time, referring to the output generated per unit of input. Its conceptual framework was later established in Tinbergen’s international comparison in 1942. By linking the increase in output that cannot be explained by increase in input to TFP, Solow (1957) set up the grounds for productivity measures in his neo-classical residual growth model. Abramovitz (1956) referred to TFP as a “measure of our ignorance,” pointing to the various sources of productivity growth that cannot be explained by the factor inputs. His work spawned a series of studies aiming to expand Solow’s model, taking into account the measurement issue Abramovitz raised and relating the resulting TFP to technological progress with commonly held beliefs.⁴ However, Solow’s TFP measures remain to date the most widely used methods in the literature.

Domestic scholars started to take notice of the PRC’s TFP starting in the early 1980s, with Shi et al. (1985) one of the earliest examples. Systematic application of growth accounting theories and methods to measure technological advancement in the PRC, however, did not begin until the 1990s. Today, there are many studies on related topics. Generally speaking, most of them have focused on estimating TFP growth rates. Studies seeking to understand the change in TFP are relatively scarce.

Methodology is a central concern in obtaining TFP growth estimates. Theorists in this field are typically preoccupied with the merits of different production functions (i.e., which one more accurately describes the input–output production process) and uncovering their interlinkages. Empiricists, on the other hand, devote a large amount of effort to inferring the production process from input/output data. Several approaches are widely accepted in empirical studies, including Solow’s 1957 growth accounting method, Farrell’s 1957 deterministic production frontier, Aigner’s 1977 stochastic production frontier, Charnes’ 1978 data envelopment analysis, and Caves et al.’s 1982 Malmquist productivity index. All the available methods have pros and cons. However, the growth accounting method is perhaps the most appropriate for explaining the change in TFP (Barro and Sala-i-Martin 1995; Barro 1999).

Another issue is how to measure factor input; more specifically, how to calculate the physical capital stock and whether to take human capital into account when considering labor input. Research studying the PRC’s TFP often centers on assessing the physical capital stock; most such studies use Goldsmith’s 1951 perpetual inventory method (PIM). Yet a major point of contention exists with respect to the assumptions of the initial physical capital stock and the depreciation rate (Ren and Liu 1997). In addition, opinions are divided as to whether or not different types of capital should

³ Detailed discussion of this section can be found in Bai and Zhang (2014).

⁴ Included among these studies are Denison (1967, 1972), Jorgenson and Griliches (1967), and Christensen and Jorgenson (1969, 1970), etc.

be first assessed separately and then added to the total physical capital stock (Bai et al. 2006, 2007) or not (Zhang and Zhang 2003; Zhang et al. 2004; Perkins and Rawski 2008).

One of the thorniest issues confronting scholars studying TFP is how to introduce human capital into the growth accounting model. It is indeed widely acknowledged that human capital accounts for an impressive economic rise (Mankiw et al. 1992). However, to date, no consensus has emerged on the definition of human capital. The work of Lu et al. (2004) is one of the first PRC scholarly forays into this field. An even more complex issue concerns the impact of human capital on growth. Scholars distinguish between the roles of human capital as a factor of production, and one that affects the growth rate of TFP (Benhabib and Spiegel 1994; Wei and Zhang 2010), both through domestic innovations (Romer 1990a) and by facilitating technological adoption and catch-up (Nelson and Phelps 1966). In the former, the benefit of human capital is measured as a production process input, whereas in the latter its growth effects operate through input utilization efficiency.

2.2 Factors Affecting Productivity Rate

Empirically speaking, the estimates of TFP are sensitive to the choice of method, researchers' selection of indicators to proxy the input-output process, and possible measurement errors in the original data. Although work devoted to the systematic decomposition of TFP growth is scarce, scholars have looked at various areas in their attempt to explain the increase in TFP.

Many early studies sought to identify the source of TFP growth. For example, Arrow (1962) observed that productivity gains are achieved through learning-by-doing and spillovers. Romer (1990b), on the other hand, labeled firms' research and development (R&D) as a major source of TFP growth. Other scholars further noted that increasing economic integration has facilitated technological spillovers through foreign direct investment (MacDougall 1960) and trade (Grossman and Helpman 1991; He 2007).

The allocation of production factors is of primary interest to scholars studying the PRC's TFP. As Jones (2011) noted, income differences across countries associated with resource misallocation are one of the most important developments in the growth literature of the last decade. Scholars including Banerjee and Duflo (2005) and Restuccia and Rogerson (2008) have made attempts theoretically and empirically to prove the linkage between misallocation and the income gap between low-income countries and their industrialized peers. Many believe that reforms and policy adjustments aiming to correct resource misallocation in the PRC have the capacity to unlock the country's huge growth potential (Hsieh and Klenow 2009; Brandt et al. 2012; Luo et al. 2012).

3. THEORETICAL FRAMEWORK AND ANALYSIS

This section offers first an explanation on how national and provincial TFP rates are estimated, followed by an introduction on ways of orthogonally decomposing TFP into several factors and an assessment of their marginal effects.

3.1 Methodologies for TFP Estimation

Of the many TFP estimation methods, the growth accounting approach is well suited for exploring the factors influencing TFP. More specifically, this approach assumes a production function reflecting the relationship between the output Y , physical capital stock K , and human capital stock H , which takes the form of $Y = AK^\alpha H^{1-\alpha}$, where α is the capital income share, and A the TFP. From the above production function, we have $g_A = g_Y - \alpha g_K - (1-\alpha)g_H$, which implies that TFP growth rate (g_A) can be obtained once the growth rates of output (g_Y), physical (g_K), and human capital stock (g_H), as well as the capital income share, are known.

We can rewrite the production function as $Y = A^{\frac{1}{1-\alpha}} \left(\frac{K}{Y}\right)^{\frac{\alpha}{1-\alpha}} H$ ($\frac{K}{Y}$ is the capital output ratio), from which we get $g_A = (1-\alpha)g_Y - \alpha g_{\frac{K}{Y}} - (1-\alpha)g_H$. Thereby we can compute

TFP growth rate for given measures of output growth rate, capital–output growth rate ($g_{\frac{K}{Y}}$), human capital growth rate, and share of capital income. This article adopts the

second approach since the neoclassical growth model implies a constant capital output ratio at steady state. This approach assumes that the parallel growth in physical stock (accumulated by investment, which is part of output) to that of output is assured by TFP (otherwise one would assume that decreasing marginal product would reduce investment and accumulation of physical capital stock). In that sense, it would be better to attribute the growth in output resulting from such induced growth in physical capital to the TFP. The physical capital only augments economic growth when it grows faster than output, which means changes in capital output ratios or shifts of the growth path.

3.2 Determinants of TFP

TFP measures the portion of output not explained by the amount of inputs used in production. As such, the level of TFP (and, by extension, the efficiency of an economy's factor utilization) is determined by how intensely the inputs are utilized in production and how much output is generated per unit of input. In the latter, productivity gains can be attributed to technological progress and a range of other changes including economic, political, regulatory, and cultural developments. Regardless of the source, productivity growth is either reflected as an overall boost (technical efficiency) or an average increase via reallocation (allocative efficiency).⁵

We hence model TFP growth as a function of three groups of determinants: 1) variables that will improve technical efficiency and, in turn, boost overall productivity (hereafter Group 1 determinants); 2) variables that will boost factor utilization (Group 2 determinants); and 3) variables that will boost factor allocation (Group 3 determinants). The equation is expressed as follows:

$$tfp_{it} = \underbrace{(\phi_1 TE_{1,it} + \phi_2 TE_{2,it} + \dots)}_{\text{Group1 determinants}} + \underbrace{(\varphi_1 EU_{1,it} + \varphi_2 EU_{2,it} + \dots)}_{\text{Group2 determinants}} + \underbrace{(\gamma_1 AE_{1,it} + \gamma_2 AE_{2,it} + \dots)}_{\text{Group3 determinants}} + \Gamma X + \varepsilon_{it} \quad (1)$$

⁵ For example, factors flow from less to more productive sectors, or, in extreme cases, the least productive sectors are weeded out.

3.3 Data Source and Indicators

This section first discusses how we estimate the annual provincial TFP, and then explains our choice of indicators for the aforementioned three groups of determinants.

3.3.1 Provincial TFP

The first step in growth accounting exercises is to compute the capital income share, human capital stock, and output and physical capital stock in real terms using the most recent data. The detailed procedure works as follows.

3.3.1.1 Annual Real Gross Regional Product (GRP) by Province (At 2005 Constant Price)

Provincial Gross Regional Product (GRP) data from 1978 to 2014 (previous year=100) are compiled from the *China Compendium of Statistics over Sixty Years* for 1978–1992, and from the PRC’s National Bureau of Statistics (hereafter “NBS website” if no other specification of the data source is provided) for 1993–2014. Since the price base changes every year, these figures do not form a homogeneous time series. We therefore recalculate them in 2005 prices and then adjust for inflation to obtain the provincial time series for real GRP at a constant 2005 price.⁶

3.3.1.2 Annual Capital Income Share by Province

Growth accounting literature (e.g., Chen et al. 1988; Chow 1993; Chou & Li 2002) traditionally estimates the aggregate production function from which the share of capital income is derived. We find that this approach may not be applicable here for two reasons. First, such an approach produces a fixed share of capital income, which is empirically unlikely given that the time series we chose spans 36 years. Second, empirical investigations of aggregate production may be theoretically flawed as they treat capital as an independent variable (because the change of capital is closely associated with the rate of return, which, in turn, is largely affected by productivity). As Perkins and Rawski (2008: 6) observed, “in China and other nations that experience major economic or institutional reforms, the growth of capital is itself in part the result of acceleration in TFP growth.”

Here we compute the capital income share based on data of output structure accounted in income approach. We exclude net production tax from the capital income share calculation because the taxable amount includes income from both capital and labor inputs,⁷ expressed as follows:

$$\alpha_{it} = \frac{\text{depreciation on fixed assets}_{it} + \text{operating surplus}_{it}}{\text{compensation of employees}_{it} + \text{depreciation on fixed assets}_{it} + \text{operating surplus}_{it}}.$$

⁶ Principally speaking, so long as a single, fixed base year is chosen, price variation across provinces will have little effect on the final results. However, given the continuous adjustment made to the official data, the effect of provincial TFP determinants may not be accurately measured if we use time series expressed in prices of the previous year. As such, we pick 2005 as the fixed benchmark year, as opposed to the typical choice of 1952 or 1978, although our robustness analysis shows that choosing a different reference year (such as 1978) has no significant impact on the results.

⁷ This is a simplified assumption when detailed data on the tax burden of capital as well as labor are not available.

It is worth mentioning that the growth accounting method allows for the calculation of TFP only when the capital income share is fixed. However, it may be far-fetched to claim a constant provincial annual share of capital income (e.g., using the average of the annual capital income shares as a proxy) over a very long horizon (1978–2014) of rapid transformation. Such an assumption ignores the change in income distribution within and across provinces over time. For this reason, we only assume that the current year's capital income share is the same as that of the previous year. In other words, we use the mean of the capital income share of the t th and $(t-1)$ th year to calculate t th year's TFP growth rate for the i th province.

3.3.1.3 Annual Human Capital Stock by Province

The lack of a large-scale survey on educational attainment poses a challenge to directly measuring the provincial stock of human capital. In this article we opt to construct time-series of stocks of educational attainment for the provincial working-age population. We begin with the time-series estimates of age-specific population structure and average educational attainment years. Next we obtain the total years of education of the population in working age following UN standards (aged 15–64) by taking a weighted sum of the average years of schooling (weights are assigned to different age groups based on their size), which then is used as a proxy for human capital stock.⁸ The details of this procedure are presented below.

Step 1: Construct provincial population age structure. To date, the PRC government has conducted only six censuses and several population sampling surveys, the provincial age structure details of which are not disclosed to the public. While many demographic and sociological studies have attempted to present an accurate portrait of national population age structure, far fewer such endeavors have been made provincially. We believe that the dynamics of provincial population change over time are well described by the Markov process in which a given individual will either die (exit the economy), or move into the group one year older; at the same time, a group aged zero will be formed by newborns. In the absence of interprovincial migration,⁹ it is feasible to infer historical and future patterns of provincial population age composition based on relevant data of a given year and every year's birth rate and age-specific mortality rates. Here we use the age-specific rates of mortality estimated by assuming

$$d_{a,i,t} = d_{i,t} \frac{d_{a,i,2000}}{d_{i,2000}}$$

where $d_{i,t}$ and $d_{a,i,t}$ are the mortality rate of the whole population

and that of the population group aged a in province i in year t , respectively; $d_{i,2000}$ and $d_{a,i,2000}$ are the corresponding rates for the year 2000. The basic concept underlying the above assumption is that the possibility of death for any particular individual in a given year is affected both by their age and specific risk factors present in that year (reflected in that year's crude death rate).

⁸ An alternative case that considers working-age people as those aged 20–60 delivers very similar results, which, though not reported for space limitation, are available upon request.

⁹ This assumption can be readily accepted when estimating national population structures since the number of emigrants and immigrants is negligible when compared with the PRC's domestic population. However, it may not be feasible to apply such an assumption provincially. Nonetheless, we make such a simplified assumption for two reasons. One is that detailed annual data on age-specific migrants (or more specifically, age-specific migrants by education levels) is not publicly available. The other is that migration (reallocation of population) itself may influence factor utilization efficiency and therefore should be included as a determinant of productivity. Consequently, here we make this assumption when estimating human capital stock, while adding variables of migration as determinants of productivity later.

Step 2: Estimate provincial age-specific education attainment.¹⁰ We first measure the average years of schooling received by the working-age population (aged 15–64) based on individual data from the 2005 population census (the sample contains about 2.48 million people). Take, for example, the population group aged 35, which is denoted by $Educyear35_{it}$; for any province i at any time t , we assign the number of average years of schooling for all individuals aged 35 from 2005 survey data as the realized value of $Educyear35_{it}$ in 2005, that for all individuals aged 36 as the realized value of $Educyear35_{it}$ in 2004,¹¹ that for all individuals aged 37 as the realized value of $Educyear35_{it}$ in 2003,¹² and so forth. Similarly, we get realized values of $Educyear35_{it}$ between years 2006 and 2014 from the 2010 census data. For all other age groups between 15 and 64 of each province, we estimate their average years of schooling in a similar way.¹³

3.3.1.4 Annual Physical Capital Stock by Province

Following Bai et al. (2006, 2007), we use the PIM to measure the annual provincial physical capital stock. We first compute the annual provincial physical capital stock (at 2005 constant price) for construction and installation, and that for equipment separately and then add them up to obtain the aggregate annual provincial physical capital stock.¹⁴

¹⁰ We assume an education system where an individual starts school at 6 years old, receives 6 years of primary and 3 years of secondary education, 3 years of high school, 2 years of junior college or 4 years of undergraduate, and then 2 years of graduate education. Also, graduates from a certain educational level obtain all years of that level, while dropouts and those who have completed schooling without earning a diploma or alternative credential of that level obtain half the years (or, equivalently, assuming uniform distribution of dropouts for that education level). Since school students are not classified as economically active, they are excluded thusly: individuals aged 20 with high school education when surveyed in 2005, for example, should be students between 1991 and 2003; hence, we exclude them when calculating average education attainment for the years before 2003.

¹¹ Individuals aged 35 in 2004 form the group aged 36 in 2005 if they live for another year; in this sense, the group aged 36 in 2005 is the best representative of the group aged 35 in 2004.

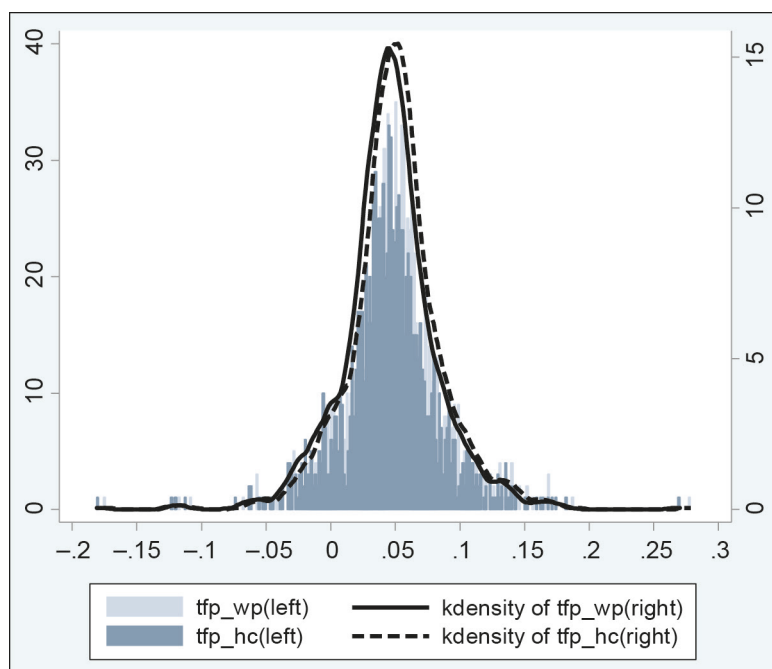
¹² Individuals aged 35 in 2003 become 37 in 2005 if they survive.

¹³ Note that here we actually assume no re-education experience for all individuals—no individual receives any further education once they start working. We believe it is an acceptable scenario for older people (e.g., aged 30 and above). Younger people (e.g., aged between 15 and 16), however, are far more likely to re-enroll some years after dropping out or pursue a higher level of education. That is, the average years of schooling of individuals aged 18 when surveyed in 2005 may be longer than that of individuals aged 15 in 2002 (though the former is the best representative of the latter). Nevertheless, we still make such assumptions for the following three reasons. First, the 15–64 age group is classified as working-age by the United Nations, and the commonly used dependency ratios are subsequently defined. This implicitly assumes that individuals over 15 do not re-enter the education system; otherwise this group will be excluded from the labor force (not willing to work). Second, the idea that individuals enter the work force at age 15 is roughly consistent with the PRC's education pattern. Most in the PRC start primary school at age 6, move on to secondary school at age 12, and then attain secondary education (compulsory) at age 15. Third, if we know the average age when people in each province start working (e.g., age 18), we can easily apply the aforementioned analysis to a different definition of working age (e.g., aged 18 to 64). In other words, we make such a simplified assumption owing to data limitations, but it can be readily modified when more data are available.

¹⁴ See Bai et al. (2006, 2007) for more details. We update Bai et al.'s estimates with the latest data from the NBS website and most recently published yearbooks. Note that instead of summing the capital stock of construction and installation and that of equipment as done by Bai et al. (2006, 2007), we alternatively estimate the physical capital stock directly with annual aggregate investment data. We prove that these two approaches are theoretically equivalent if the deflator used for aggregate investment is the weighted harmonic mean of the deflators of construction and installation investment and equipment investment. However, they may be empirically different since the price index of aggregate investment includes those that can be grouped neither into construction and installation nor equipment.

Figure 1 shows the distribution of the provincial TFP growth rates from 1978 to 2014 (frequencies are shown on the left vertical axis, with the corresponding fitted kernel density shown on the right vertical axis). Results when human capital is included (with human capital stock as an input, tfp_{hc}) and excluded (with the working age population in the 15–64 range as an input, tfp_{wp}) are both displayed in the figure.¹⁵ The growth rates of TFP (written as $\{tfp_{it}\}$, which reflects the change in overall productivity) obtained with or without a human capital variable are quite similar. As such, we start with tfp_{hc} and use tfp_{wp} (where human capital is additionally considered as a utilization efficiency determinant) as a robustness check in the following analysis.

Figure 1: The Distribution of the Average TFP Growth Rate, 1978–2014



Sources: The China Compendium of Statistics; The Demographic Data Assembly of the People’s Republic of China; Almanac of China’s Population; County Level of Population Statistics in the People’s Republic of China; National Bureau of Statistics of China (stats.gov.cn/English).

3.3.2 Factors of Changes in Productivity

As mentioned previously, the “residual” TFP measures the portion of output not explained by the amount of tangible, and therefore quantifiable, inputs used in production. As such, the growth of TFP can be attributed either to a raise in aggregate productivity (potential productivity), or an increase in input utilization rate, or more efficient allocation of factor input between different production sectors. In this article, we denote the three groups of determinants as “technical efficiency,” “utilization efficiency,” and “allocative efficiency,” respectively.

¹⁵ We compare our estimates of these two series with those obtained by other scholars such as Perkins and Rawski (2008) and find them to be very similar despite the differences in data, estimating methods, and indicators. Only some minor differences exist in terms of years of beginning (possibly due to different assumption of initial physical capital stock) and ending (possibly due to data later modified by the NBS).

Specifically, Group 1 determinants (technical efficiency) act on the utilization of capital and/or labor inputs in different sectors simultaneously. Institutional quality (e.g., rule of law), technological progress (neutral, labor-augmenting, and capital-augmenting) and openness to the world economy are some well-studied examples. Economic catch-up (or “convergence”) as reflected in income levels relative to the world frontier also falls in this category.

We introduce Group 2 determinants (utilization efficiency) for the following two reasons. First, although it is the flow of services from the capital stock and the people employed that make active contributions to the output, under-utilization of available capital and labor resource is in itself a loss of efficiency, which therefore should be captured by the estimated TFP. Hence, to fully separate the effects of the amount and the utilization efficiency of inputs, we recommend estimating TFP by considering all physical capital stock (whether used or not) and the entire working-age population (whether employed or not) as production inputs. Second, given that the demand-side factors influence the short-term utilization efficiency of inputs and the supply-side factors affect the amount of long-run available resources, it is only natural that we seek to separate the effects of the latter from the former.

Group 3 determinants (allocative efficiency) are well explored in the misallocation literature. Resource reallocation often affects factor utilization, given the productivity gap between, for example, government and households, state-owned enterprises (SOEs) and non-SOE firms, urban and rural areas, different industries, and investment goods and consumer goods sectors.¹⁶ As the “reform dividends” literature (among other researches) observed, reallocation has been a major source of economic growth since the PRC’s reforms. Therefore, even when sector-specific productivity remained constant, structural reforms could enhance overall productivity by changing the relative weight of different economic sectors. By choosing appropriate indicators such as government size, the share of state ownership, urbanization progress, and the weights of the primary and the tertiary sectors in the economy, it is possible to measure the effects of resource reallocation resulting from structural reforms.

We identified two major indicators associated with Group 1 determinants: 1) provincial income level (the catch-up indicator [CUI]), which measures the catch-up effect, defined as the natural logarithm of relative provincial lagged real GRP per capita to lagged real GDP per capita of the US (written as $L.\ln relativeGRP$);¹⁷ and 2) the degree of foreign trade dependence, which reflects the level of openness and trade orientation of a provincial economy and its capacity to capture technology spillovers, defined as the ratio of exports and imports to GRP (written as fd). Imports and exports data used to calculate this indicator are expressed in US dollars (US\$),¹⁸ and thus

¹⁶ Significant productivity differences among these sectors are well documented in the literature.

¹⁷ US provincial GRP and national GDP are both valued in 2005 prices in US dollars. We first get the annual US\$/yuan bid and ask rates based on data of the PRC’s GDP respectively valued in yuan and US\$ (both are in 2005 prices) from the UN data website. The data of provincial GRP per capita valued in yuan are then accordingly converted into those in US\$. The annual GDP per capita data in 2005 prices for the US are calculated with data of GDP (from the UN data website) divided by data of aggregate population (from the OECD website). This means we always assume the US as the productivity frontier. Some may prefer to consider another CUI to be the productivity level for each province relative to the US. For simplicity’s sake, we here follow Lucas (2009) to consider the CUI of relative income levels. The results with the alternative CUI of relative productivities, which are not presented here, though are available upon request, are similar.

¹⁸ The NBS website has published two data series of exports and imports since 1993: one is recorded according to the jurisdictions where the domestic firms are registered, while the other is classified by the commodities’ region of origin and destination. We carefully compare these two series with data from the *Compendium of Statistical Data and Materials on 50 Years of New China* and find that the former is

need to be converted into yuan (CNY). We make this conversion by first obtaining the annual US\$/yuan bid and ask rates based on national layer data (the NBS website provides annual data on total imports and exports both in US\$ and yuan).¹⁹

Group 2 determinants include variables that affect the level of output generated per unit of input through effective usage. We select two indicators. The first indicator is the provincial inventory stock, which measures the accumulation of non-productive capital, defined as the ratio of inventory stock to GRP (written as *inventory*). We adopt an approach similar to that used to calculate the physical capital stock to assess the real inventory stock in 2005 prices. Data needed are gathered from the NBS website and the *China Compendium of Statistics 1949–2008*. The second indicator is the labor involvement rate, which measures the proportion of working-age population active in production, defined as the percentage of employed persons aged 15–64 (written as *lir*). This indicator can be derived by multiplying the proportion of economically active persons (or labor force) in the working-age population (the labor participation rate [LPR]) with that of employed persons in labor force (the so-called employment rate). In our opinion, the former mainly reflects the health status and working willingness of the PRC working-age population, whereas the latter mainly indicates how active they are in the economy; their products, here termed as the labor involvement rate, therefore show comprehensively the efficiency of potential labor input to actual labor input. Data on the total number of employed persons come mainly from the *China Compendium of Statistics 1949–2008*, complemented by information from provincial statistical yearbooks, statistical bulletins of human resources and social security development, and statistical bulletins of national economic and social development.

We only introduce human capital intensity *princomp_hc* as a third indicator when tfp_{wp} is used as a dependent variable. Human capital intensity as a composition factor is defined as the weighted average of age-specific education attainments of the working-age population, which can be calculated using the Principal Component Analysis (PCA) method. Specifically, we use the principal component as a proxy for human capital intensity.

The indicators for the Group 3 determinants include government size, the weight of SOEs in the economy, investment rate, industrial structure, urbanization, and migration. Government size and the weight of SOEs in the economy are two variables that measure the influence of government intervention on TFP growth. Investment rate measures the factor utilization difference between investment goods sectors and consumer goods sectors. Industrial structure measures the productivity gap between different economic sectors. Urbanization and migration measures the effects of factor mobility.

more comparable with the compendium data and therefore choose it for combining the final series between 1978 and 2014.

¹⁹ It is worth mentioning that the way of obtaining the annual US\$/yuan bid and ask rates for converting imports and exports are slightly from the way of those for converting provincial GRP. This is because we think the former is mainly related to tradable goods, whereas the latter is used for all goods (including tradable and non-tradable ones).

Government size is defined as the ratio of local government revenue to provincial GRP (written as *govsize*).²⁰ Annual local government revenue data (in current prices) are collected from the NBS website (local government budgets and expenditures sector).²¹ Provincial GRP (in current prices) data for the period 1993–2014 come from the NBS website; those for the period 1978–1992 come from *China Compendium of Statistics 1949–2008*.

The economic weight of SOEs (written as *soe*) is defined as the ratio of investment in fixed asset to the aggregate investment in fixed asset.²² Data for the period 1978–2004 are sourced from *China Compendium of Statistics 1949–2004*; those for the period 2005–2014 come from the NBS website.

Investment rate (written as *inv_rate*) is defined as the ratio of aggregate capital formation to provincial GRP. Data for the period 1993–2014 come from the NBS website; those for the period 1978–1992 come from the *China Compendium of Statistics 1949–2008*.

Industrial structure includes the “weight of the primary sector” (written as *prim*) and the “weight of the third sector” (written as *third*). The former is defined as the share of value added of the primary sector in provincial GRP. The latter is defined as the share of value added of the third sector in provincial GRP. Data for the period 1993–2014 come from the NBS website; those for the period 1978–1992 come from the *China Compendium of Statistics 1949–2008*.

Urbanization is defined as the growth rate of the share of urban population in total population (written as *urgr*). Data of the share of urban population for the period 2000–2014 are from the NBS website; data for the period 1978–1999 are collected from *The China Compendium of Statistics 1949–2008*.

Migration includes the rate of entrance (written as *migratein*) and the rate of exit (written as *migrateout*),²³ both of which measure the effect of interregional labor mobility on TFP growth. Data for these two indicators, which could at least partially correct the bias of assuming the lack of migration among provinces previously when calculating provincial human capital stock, come from several sources: those for the period 1978–1984 are from *The Demographic Data Assembly of the People's Republic of China 1949–1984*; those for 1985–1991 are correspondingly collected from various issues of *Almanac of China's Population* for years between 1986 and 1991; those for

²⁰ Measuring government size can be a daunting task. Some recommend the use of the ratio of local government expenditure to provincial GRP as a proxy. This method is not considered here for two reasons. First, these two measures are very similar since local government income approximately equals local government expenditure for all provinces in all years. The second is that part of the central government spending, such as funding for certain agricultural irrigation projects, targets only one or several provinces, and thus should be included into the local government expenditure of the benefiting provinces. Such detailed data are not publicly available and exploration in this area, though meaningful, is beyond the scope of this article. Therefore, we choose to ignore the nuances for simplicity.

²¹ Measuring the impact of non-budgetary expenditures (which also play a significant role in boosting local economic growth) on TFP, though important, is well beyond the scope of this article, due to the lack of comparable datasets.

²² An alternative is to define the economic weight of SOEs as their proportion of industrial output out of total industrial output. Both indicators only partly represent the relative size of SOEs in the PRC economy (measuring only the size of investment, in the former case, and the industrial output, in the latter, by firms large enough to be surveyed).

²³ Note that both indicators contain inter- and intra-provincial migration. A much more reasonable way is to establish three indicators to distinguish between intra-provincial migration rate, immigration rate, and emigration rate. Unfortunately, we do not have access to the relevant data.

1992–2010 are from various issues of and *County Level of Population Statistics in the People's Republic of China* for years from 1992 to 2010.

Table 1 presents the summary statistics for all aforementioned variables.

Table 1: Summary Statistics and Unit Root Tests for Key Variables

		Obs.	Mean	Std.	Min.	Max.
TFP growth rate	tfp_hc	1,106	0.046	0.037	-0.181	0.270
	tfp_wp	1,106	0.050	0.037	-0.176	0.279
L.InrelativeGRP		1,147	-3.461	0.570	-4.686	-1.757
ftd		1,109	0.228	0.337	0.001	1.912
inventory		1,147	0.650	0.331	0.072	2.740
lir		1,144	0.746	0.093	0.373	0.981
princomp_hc		1,147	-0.033	6.212	-21.251	21.693
govsize		1,136	0.104	0.065	0.006	0.620
soe		1,137	0.581	0.227	0.114	1.000
inv_rate		1,140	0.453	0.151	0.138	1.304
prim		1,147	0.219	0.126	0.005	0.606
third		1,147	0.341	0.098	0.087	0.779
urgr		1,138	0.033	0.090	-0.652	0.903
migratein (‰)		993	17.907	7.165	1.980	61.250
migrateout (‰)		963	15.812	6.847	2.720	66.020

Sources: The China Compendium of Statistics; The Demographic Data Assembly of the People's Republic of China; Almanac of China's Population; County Level of Population Statistics in the People's Republic of China; National Bureau of Statistics of China (stats.gov.cn/English).

3.3.3 Determinants' Effects on the TFP Growth

Given that the Hausman test confirms fixed effect models are better than random effect ones, we further use them to orthogonally decompose the above potential determinants on TFP growth rate in the following analysis.

We also test the stationarity of residuals in the fixed-effect regression to ensure that the estimates are reliable and co-integration relationship exists between the TFP growth rate and the potential determinants.²⁴ On the basis of the tests suggested by Wooldridge (2003), we find that the fixed-effect regression continues to suffer from auto-correlation problems. We therefore report Newey–West standard deviations.

3.3.3.1 The tfp_{hc} Approach

The first part (columns 1–4) of Table 2 presents the results when we adopt the tfp_{hc} approach, namely estimating TFP growth rate when human capital is treated as a quality multiplier to adjust labor force.

²⁴ Commonly used LLC (Levin et al., 2002), IPS (Im et al., 2003), and Hadri (2000) tests can all be applied to unit root tests on panel data. The null hypothesis is that some panels contain unit roots for the LLC test, all panels contain unit roots for the IPS test, and all panels are stationary for Hadri test, respectively. However, the LLC and Hadri tests require strictly balanced panels, which is not satisfied here since observations for certain indicators are missing in some provinces in some years.

Table 2: Determinants of TFP Growth Rate

	<i>tfp_{hc}</i>				<i>tfp_{wp}</i>		
	1978–2014		2001–2014	1978–2014	2001–2014		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
L.InrelativeGRP	–0.075*** (0.013)	–0.075*** (0.013)	–0.066*** (0.011)	–0.065** (0.028)	–0.097*** (0.015)	–0.080*** (0.012)	–0.067** (0.028)
ftd	0.028*** (0.009)	0.028*** (0.009)	0.027*** (0.008)	0.007 (0.013)	0.026*** (0.009)	0.026*** (0.008)	0.007 (0.013)
inventory	–0.020** (0.009)	–0.020** (0.009)	–0.012 (0.008)	0.000 (0.020)	–0.023** (0.010)	–0.011 (0.008)	–0.003 (0.020)
lir	0.081*** (0.028)	0.081*** (0.027)	0.074*** (0.023)	0.063 (0.039)	0.083*** (0.028)	0.071*** (0.023)	0.053 (0.040)
princomp_hc					0.008*** (0.002)	0.005*** (0.002)	0.006 (0.004)
govsize	–0.108** (0.046)	–0.108** (0.045)	–0.113*** (0.041)	–0.083 (0.162)	–0.108** (0.046)	–0.102** (0.041)	–0.084 (0.149)
soe	0.002 (0.014)	0.002 (0.014)			–0.000 (0.014)		
inv_rate	–0.052 (0.073)	–0.052** (0.023)	–0.049*** (0.016)	–0.068*** (0.014)	–0.100 (0.072)	–0.031* (0.018)	–0.053*** (0.017)
inv_rate square	–0.000 (0.060)				0.060 (0.063)		
prim	0.009 (0.045)	0.009 (0.045)	–0.029 (0.039)	–0.393*** (0.098)	0.027 (0.046)	–0.010 (0.040)	–0.363*** (0.104)
third	–0.039 (0.041)	–0.039 (0.041)	–0.055 (0.033)	–0.109** (0.045)	–0.055 (0.044)	–0.071* (0.037)	–0.128** (0.054)
urgr	0.012 (0.011)	0.012 (0.011)	0.014 (0.010)	0.009 (0.016)	0.009 (0.010)	0.012 (0.010)	0.010 (0.017)
migratein	0.000 (0.000)	0.000 (0.000)			0.000 (0.000)		
migrateout	–0.000 (0.001)	–0.000 (0.001)			–0.000 (0.001)		
Province effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	939	939	1,095	432	939	1,095	432
IPS test	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Note: 1) The Newey–West standard deviations are in parentheses. 2) *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively. 3) For the Im-Pesaran-Shin (IPS) test, we report the P-values.

Sources: The China Compendium of Statistics; The Demographic Data Assembly of the People's Republic of China; Almanac of China's Population; County Level of Population Statistics in the People's Republic of China; National Bureau of Statistics of China (stats.gov.cn/English).

Column 1 includes all potential variables of the above three groups of determinants and shows how technical efficiency-related indicators, namely, income level (*L.InrelativeGRP*) and degree of foreign trade dependence (*ftd*) both have a statistically significant impact on TFP growth. The estimated coefficient on the former variable has the expected negative sign, as convergence to the productivity frontier naturally entails a slowdown of TFP growth in the larger economy. The coefficient on the latter variable has the expected positive sign, confirming the common belief that

learning and adaptation of advanced technology associated with, and facilitated by, a high level of openness raise productivity.

The utilization-efficiency indicators, that is, the relative size of inventory stock (*inventory*) are found to have an expected negative impact on tfp_{hc} ; whereas the labor involvement rate (*lir*) is found to have an expected, significantly positive effect on tfp_{hc} . Indeed, an increase in inventory stock implies a decrease in the amount of output entering the production process, whereas a higher labor involvement rate means more working-age people entering the work force.

Allocative-efficiency indicators such as government size (*govsize*) have a significant negative effect as expected, whereas the economic weight of SOEs (*soe*) appears to have an insignificant effect. Slightly inconsistent with the commonly held belief, the results shown in column 1 suggest that state ownership may not necessarily reduce efficiency. One possible explanation is the choice of indicator. We proxy the weight of SOEs in fixed asset investment to that in the whole economy. Moreover, the insignificance of the corresponding efficiency may be a result of two opposing effects. As Bai et al. (2000) observed, SOEs have positive spillover effects. Such positive impacts on the economy could be offset by the well-documented negative impacts associated with monopolies and resource under-utilization. The observed insignificance may also be a result of the synchronous relationship influenced by a third factor (i.e., economic prosperity): an expansion of the state-owned economy and growth in productivity would be simultaneously observed during the economic boom.

Results of the investment rate (*inv_rate*), along with its square terms to show possible non-linear effects, indicate an insignificant inverted U-shape effect on tfp_{hc} . The estimated coefficients for industrial structure (*prim* and *third*), migration (*migratein* and *migrateout*), and urbanization (*urgr*) turn out to be statistically insignificant.

The statistically insignificant estimate of the square term of investment rate (*inv_rate*) then suggests the omission of this variable in column 2. Moreover, given the missing migration data (*migratein* and *migrateout*) for certain years (mainly since 2011) and the imperfect representation for the economic weight of SOEs (*soe*), together with the insignificant impact of these three indicators (their estimated coefficients are close to zero), we recalculate the estimates when excluding these indicators. The results are shown in column 3. Clearly, the estimated coefficients in columns 2–3 are close to their counterparts in column 1, except for statistically significant estimates for the variable *inv_rate*.

For an economy undergoing dramatic transformation, the PRC may have experienced significant structural changes within the time horizon under investigation (1978–2014). In other words, a certain determinant's effect on tfp_{hc} may vary over time. An example is how "investment" could play a different role in different development stages: early on, investment (on infrastructure in particular) served to promote resource reallocation and productivity growth; however, it could prove to be detrimental in later stages when over-investment leads to a consumption imbalance. Hence in column 4 we focus on the 2001–2014 time period, which can be conveniently divided into two intervals of the same length before and after the 2008 crisis. We find similar values for the estimated coefficients. Under this approach, however, the degree of foreign trade dependence (*ftd*), relative size of inventory stock (*inventory*), labor involvement rate (*lir*), and government size (*govsize*) collectively have an insignificant impact on tfp_{hc} ; whereas

the two indicators for industrial structure (*prim* and *third*) both have significantly negative impact.²⁵

3.3.3.2 The tfp_{wp} Approach

As previously discussed, human capital can be both viewed as a factor and a utilization efficiency determinant. Results obtained using the first approach are displayed in the first part of Table 2 (columns 1–4). The following section discusses results obtained when adopting the second approach. In other words, tfp_{wp} is turned into an explained variable and human capital intensity ($princomp_hc$) is entered as the utilization-efficiency variable. Results are shown in the second part of Table 2 (columns 5–7).

Clearly, human capital intensity ($princomp_hc$) has a significant, positive impact on TFP growth (tfp_{wp}). In addition, although the effects of individual indicators on the TFP growth rates in parts 1 and 2 are similar, they are, however, more pronounced in the former. We use regressions to orthogonally decompose the effects of potential determinants on productivity because TFP as “a measure of our ignorance” to date has remained largely unexplained. Further, data limitation prevents us from directly revealing influences of these determinants. Human capital, however, can be more or less estimated, as we have done in earlier sections. We therefore adopt the tfp_{hc} approach to decompose the causes of the PRC’s post-crisis slowdown of productivity growth in the next section.

4. DECOMPOSING THE RECENT DECLINE IN PRODUCTIVITY GROWTH

Next we analyze the difference in TFP growth rate between 2001 to 2007 and 2008 to 2014, and then determine the extent to which the gap could be explained by the change in individual determinants before and after 2008 (see Table 3).

To be more specific, we first calculate the TFP growth rate (in the tfp_{hc} situation with human capital included) and the values for the three subsequent indicators—relative income level ($L.\ln relativeGDP$),²⁶ investment rate (inv_rate), and industrial structure (*prim* and *third*)—year by year from 2001 to 2014 at the national level.²⁷ Then we compare the mean values of these four indicators before and after 2008. Based on a given determinant’s average effect on TFP growth (which is obtained applying the estimated coefficient from column 4 in Table 2), we next compute percentage of change in its rate after 2008 that can be explained by the change in a given determinant. As Table 3 clearly shows, the PRC suffered a drop (0.019) in TFP growth rate after 2008, about 95.08% of which could be attributed to the four growth determinants.

²⁵ This implies lower productivity growth rates for the primary and tertiary industries. While the former is naturally expected, the latter may be partly due to its inclusion of some sectors with lower productivity such as public administration and social service institutions.

²⁶ That is, the natural logarithm of relative lagged real GDP per capita of the PRC to lagged real GDP per capita of the US. For estimation methods and data source, see previous discussion.

²⁷ We choose the 2001–2014 time horizon because it can be conveniently divided into two intervals of the same length: 2001–2007 (before 2008) and 2008–2014 (after 2008). The four indicators are chosen because their estimated coefficients are statistically significant. For estimation methods and data source, see previous discussion.

Table 3: Change in TFP Growth Rate Before and After 2008 and the Percentage Explained by Growth Determinants

	Interval Mean		Change after 2008		Percentage Explained (%)
	2001–2007	2008–2014	Change	Marginal Effect of Change on TFP	
tfp _{hc}	0.0388	0.0197	−0.0191	−	−
L.InrelativeGDP	−3.2787	−2.9693	0.3094	−0.0201	105.43
inv_rate	0.3986	0.4665	0.0678	−0.0046	24.14
prim	0.1224	0.0964	−0.0260	0.0102	−53.52
third	0.4188	0.4520	0.0332	−0.0036	19.03
Total	−	−	−	−0.0181	95.08

Notes: 1) All items presented in this table are authors' estimates (for methods of calculation, see previous discussion). 2) Percentage explainable by a given determinant is given by the following equation: explainable percentage = change in determinant after 2008 *estimated coefficient/ change in TFP growth rate after 2008 (tfp_{hc}).

Sources: The China Compendium of Statistics; The Demographic Data Assembly of the People's Republic of China; Almanac of China's Population; County Level of Population Statistics in the People's Republic of China; National Bureau of Statistics of China (stats.gov.cn/English).

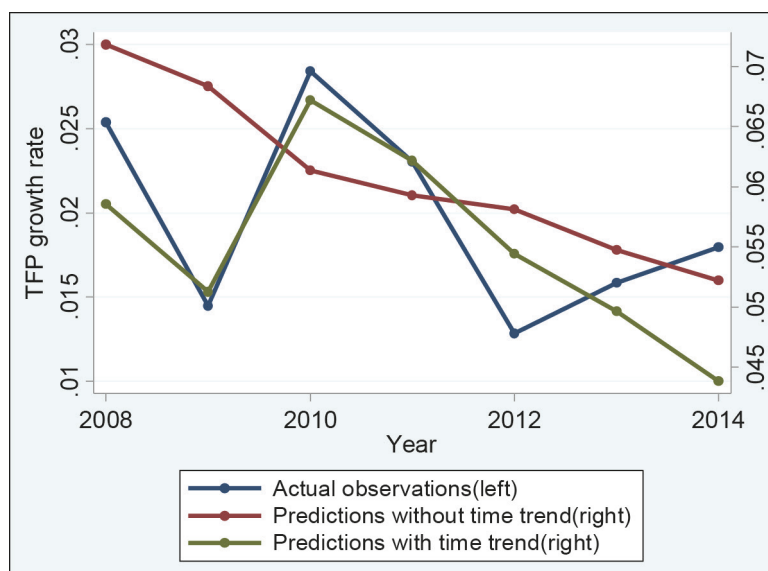
To further explore the PRC's post-crisis productivity variations, we conduct a counterfactual analysis (CFA) under a comparative static situation. In other words, to assess the growth effects attributable to a candidate determinant, we assume that only this particular determinant remains constant during the observing period and look at the "outcome" in the absence of its "intervention." The determinant's impact on TFP growth rate (i.e., its explainable percentage) is then estimated by comparing CFA predictions to actual observations. Let the candidate determinant be x , with the CFA predictions given by the equation $tfp_{no\ x,t}^{CFA} = tfp_t - \hat{\beta}_x(x_t - x_0)$ where tfp_t refers to the actual outcomes, $\hat{\beta}_x$ is the estimated marginal impact of x on productivity (which equals the estimated coefficient of x in column 4 of Table 2), and x_0 and x_t stand for the original value of x and the value of x in a given year during the observing period, respectively. The "comparative static" analysis is so called to distinguish it from the later dynamic analysis, as this approach neglects the interactive effects among these determinants over time.²⁸

Before proceeding further, it is useful to look at the combined effect of the four indicators on the TFP growth rate during 2008–2014. Figure 2 demonstrates this effect (the "without time trend" curve), calculated based on estimated coefficients from column 4 in Table 2 and values for the four indicators from 2008–2014, and its prediction when cyclical effects, namely the estimated time dummies from column 4 in Table 2, are included (the "with time trend" curve).²⁹

²⁸ For example, a change in investment rate in 2008 would cause a change in TFP in 2008; therefore, the GDP in 2008 would change. The new GDP would further predict a new TFP in 2009 since its growth rate is related to GDP in 2008 as implied by convergence theory (the GDP in 2009 would also change).

²⁹ We cannot get corresponding estimators for time dummies at the national level, but their cyclical pattern can be approximated from those at the provincial panel (though most of them are statistically insignificant in all columns of Table 2). It is worth noting that the means of the indicators in Table 2 for the national time series and the provincial panel are not exactly the same; therefore, we show the actual observations on the left axis and the "with-" and "without time trend" curves on the right vertical axis in Figure 2. This is to better show the trend of these curves without affecting the final conclusion.

Figure 2: Change in TFP Growth Rate and Its Source, 2008–2014



Sources: The China Compendium of Statistics; The Demographic Data Assembly of the People's Republic of China; Almanac of China's Population; County Level of Population Statistics in the People's Republic of China; National Bureau of Statistics of China (stats.gov.cn/English).

Figure 2 shows that the “with time trend” curve moves closely with the data between 2008 and 2014, when both the long-run trend (as predicted by the four indicators) and short-run cyclical variations (as implied by estimated time dummies) are considered. This further supports the validity of orthogonally decomposing effects of potential determinants with panel data as we have done in previous sections. The “without time trend” curve indicates that it is the long-run structural factors that are mainly responsible for the decrease in TFP growth rate during this period, rather than short-run cyclical factors. The differences between the “with-” and “without time trend” curves result from influences of policies (excluding investment stimulus) and many other factors during this period.

Table 4 presents the CFA estimates of the growth effects of four indicators from 2008 to 2014. The figures in the first part show what the CFA productivity growth rate would be over the period 2008–2014 and how would it change if we fixed a certain candidate determinant from 2008 onward at the 2007 level while allowing all the others to take their actual values. The differences between the corresponding CFA estimates and the actual observations (as shown in the last row) can be treated as the marginal effects of the particular determinant on productivity growth.

In summary, the continued fast growth of the PRC economy relative to the US since the financial crisis has slowed down the convergence process. The changes in investment rate and the weight of the tertiary industry have combined to impede the continued improvement in TFP growth. Their negative influence has far outweighed the positive impact brought by the decrease in the weight of the primary industry. Had all four indicators remained constant at the 2007 level, the growth rate of the PRC's productivity would have risen by 0.006, 0.009, 0.016, 0.018, 0.020, 0.023, and 0.026 in 2008, 2009, 2010, 2011, 2012, 2013, and 2014, respectively. Of all the three factors acting against growth in productivity, diminishing late-mover advantage as implied by higher relative income level is the primary culprit, followed by investment rate and the weight of the tertiary industry.

Table 4: CFA Predictions of TFP Determinants, 2008–2014

		2008	2009	2010	2011	2012	2013	2014
	L.InrelativeGDP	0.030	0.021	0.042	0.039	0.029	0.034	0.039
CFA	inv_rate	0.027	0.018	0.033	0.028	0.017	0.020	0.022
predictions	prim	0.025	0.013	0.026	0.020	0.010	0.012	0.013
	third	0.025	0.016	0.030	0.025	0.016	0.020	0.024
Actual observations		0.025	0.014	0.028	0.023	0.013	0.016	0.018

Notes: 1) The “actual observations” in the above table are the national TFP growth rates (tfp_{hc}) for 2008–2014. 2) “CFA predictions” are estimates calculated holding a given determinant constant at 2007 level. The difference between CFA predictions and their corresponding actual observations reflects the marginal effect of this particular determinant on the growth rate of productivity.

Sources: The China Compendium of Statistics; The Demographic Data Assembly of the People’s Republic of China; Almanac of China’s Population; County Level of Population Statistics in the People’s Republic of China; National Bureau of Statistics of China (stats.gov.cn/English).

Given that the PRC economy is set on an upward track, with relative higher growth rates than that of the US for years to come, the investment rate is likely to remain high and the tertiary industry will keep expanding in the short term. Consequently, the slowdown since 2008 will become an inevitable trend for the conceivable future. The need to find new ways to raise productivity is urgent and real. Policies to facilitate trade openness and the optimal allocation of resources, and support full employment are a good start to improve the PRC’s productivity and long-term economic growth.

5. ROLES OF THE STIMULUS-INDUCED INVESTMENT SURGE

The massive stimulus package rolled out by the government in the wake of the 2008 financial crisis has had a discernable effect: the PRC economy has been able to continue to expand at a relatively fast pace in spite of the tumbling productivity growth. Our concern is with the role the package, and, in particular, the surge in investment induced by it, played in this process. In this section, we adopt a dynamic CFA to investigate how the interaction between investment rate (inv_rate) and other determinants affect TFP growth.

Again, we maintain the investment rate on construction and installation, as well as equipment, at the 2007 level while all other determinants take actual, observed values. We then calculate TFP growth rates and physical capital stock for 2008 based on the estimated coefficients in column 4 in Table 2. The GDP for 2008 is obtained next by

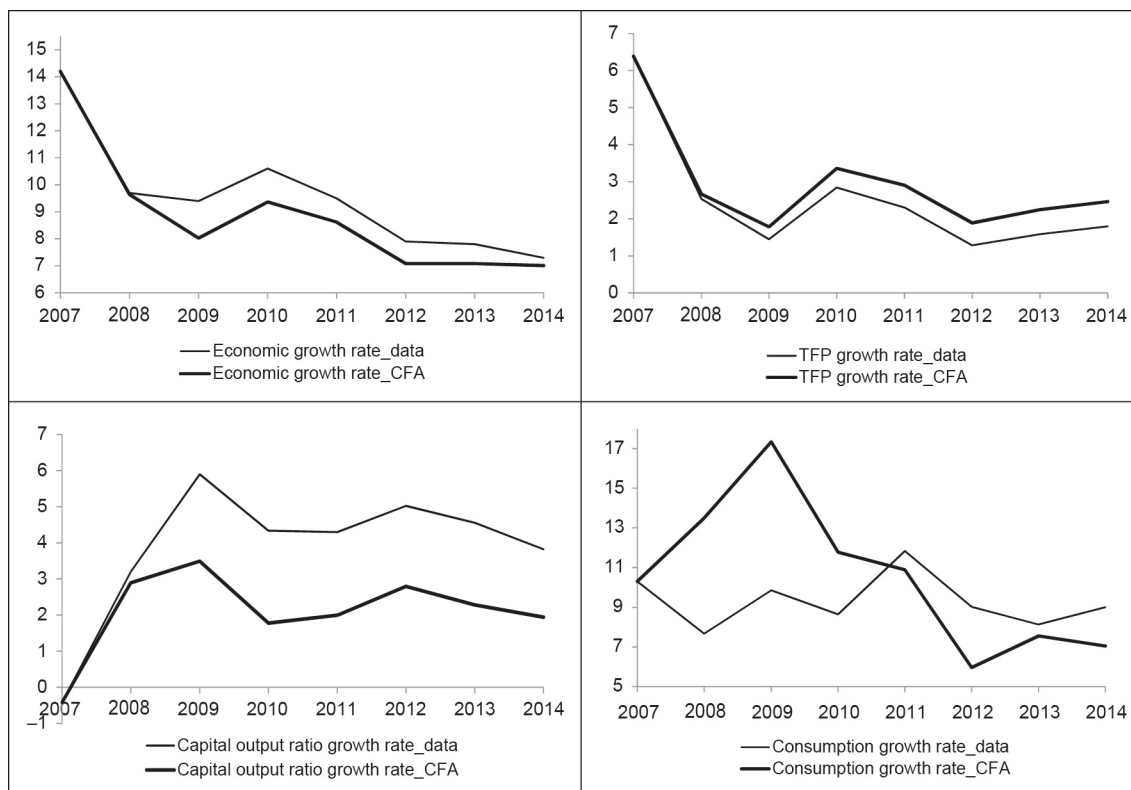
substituting relevant estimates into the equation
$$\bar{Y} = \frac{1}{1-\alpha} \bar{A} + \frac{\alpha}{1-\alpha} \left(\frac{\bar{K}}{\bar{Y}}\right)^{\alpha} \bar{H}^{\beta}$$
,³⁰ with

which we are able to assess the TFP growth rate for 2009 based on an assumed investment rate for the same year. The same procedures are then repeated to compute the physical capital stock and the GDP for 2009, etc. Combined with CFA predictions, we obtain the growth rates of the national economy, capital output ratio, as well as the TFP growth rates. Further, we hold the ratio of aggregate capital formation to GDP (i.e., investment rate) fixed at the 2007 level while allowing the share of government

³⁰ The GDP value obtained here could affect capital output ratio and, in turn, its growth rate. For this reason, instead of using the growth accounting equation, we adopt the goal-seeking method to find a GDP to solve the equation for each year.

spending in GDP, and the share of net exports in GDP, to take observed values.³¹ Based on the thusly estimated GDP data we compute consumption and, in turn, its growth rate for 2008–2014.

Figure 3: The Investment Surge Impact over the Period 2008–2014



Sources: The China Compendium of Statistics; The Demographic Data Assembly of the People’s Republic of China; Almanac of China’s Population; County Level of Population Statistics in the People’s Republic of China; National Bureau of Statistics of China (stats.gov.cn/English).

Figure 3 consists of four charts comparing the growth rates of the economy, TFP, capital output ratio, and consumption with those predicted by CFA, respectively. Several observations from Figure 3 can be made. First, the rise in the investment rate has effectively mitigated the negative impact of the financial crisis on the growth of the PRC economy; its effect is most evident for 2009 and 2010. If the PRC had been able to maintain its investment rate at the 2007 level (41.24%) over the consecutive years, its annual economic growth rate would have dropped to 9.64%, 8.03%, 9.37%, 8.62%, 7.08%, 7.09%, and 7.01%, below the actual observations by 0.06, 1.37, 1.23, 0.88, 0.82, 0.71, and 0.29 percentages, respectively.

In addition, increasing the investment rate has a negative effect on the TFP growth rate in the same duration (cutting the TFP growth rates by 0.13, 0.33, 0.52, 0.61, 0.61, 0.66, and 0.67 percentages, respectively). Its effect on the capital input is the opposite (the capital output ratio rose by 0.31, 2.41, 2.56, 2.30, 2.23, 2.27, and 1.88 percentage points, respectively). The investment rate’s impact on consumption, however, is less consistent. From 2008 to 2010, the increase in investment drove the growth rate of consumption down by 5.83, 7.48, and 3.12 percentage points, respectively, whereas

³¹ Recall that GDP as measured by the expenditure approach equals C (consumption) plus I (investment, or capital formation) plus G (government spending) plus NX (net exports). These two assumptions are consistent with the CFA on investment rate where the government size and trade dependency ratio both take their actual values for all the years from 2008 to 2014.

the former's continued rise since 2011 was emulated by the latter (the consumption growth rate increased by 0.94, 3.05, 0.58, and 1.96 percentage points, respectively).

All in all, the investment rate experienced a sharp climb and remained at a high plateau between 2008 and 2014. Although it has alleviated the negative effects of the financial crisis, it does so by harming productivity improvement and impeding consumption growth. Moreover, it failed to retard the long-term slowdown of the PRC's economy.

6. CONCLUSION

The causes of the PRC's slowdown in the aftermath of the 2008 financial crisis and its economic outlook have been the subject of much contention. The answers have particularly important policy implications. Some believe that this slowdown is merely a cyclical downturn that may be soon reversed. Others consider it the start of a long-term structural trend. We find that the economic slowdown since 2008 is a combined result of a decrease in both the labor growth rate and the productivity growth rate. The cause of the former is readily explained by an increasingly aging population and more than 2 decades of widening coverage of compulsory education. A better understanding of what has led to the latter, therefore, is central to understanding the PRC's current economic slowdown and forecasting its future performance.

Previous studies that employed a variety of methods to survey the PRC's TFP at sectoral, regional, and national levels based on available data sought to trace different sources of TFP movement, including those that link "reform dividends" to post-reform economic growth. However, model uncertainty and the challenges researchers face in selecting and handling data hamper TFP estimation consensus. Building on studies that investigate the source of potential TFP growth, we first select a series of robust indicators, construct comparable time series from historical records, and then estimate the provincial and national TFP. Next, we examine three aspects—the technical efficiency, utilization efficiency, and allocative efficiency—to explain the evolving pattern of the PRC's productivity growth based on the orthogonal decomposition method using panel data, which allows controlling for both regional and year fixed effects. Finally, we apply counter-factual analysis to decompose the national factor utilization movement from 2008 onward, and simulate the effectiveness of the stimulus-induced investment surge as a tool in mitigating the impact of the financial crisis.

The results suggest that, in terms of technical efficiency, both economic openness and relative income levels have an expected significant impact on productivity, although the former has a positive effect and the latter has a negative effect. In addition, a significantly negative correlation is observed between inventory stock and productivity through the former's influence on effective factor usage, while the opposite is observed between the labor force involvement rate and productivity. As for indicators acting on factor utilization, both government size and investment rate have significantly negative effects on productivity; weights of the primary and the tertiary industries tend to be negatively correlated with productivity growth. State ownership and population migration, however, show no statistically significant effects. Lastly, a decrease in late-mover advantage and growth in the investment rate are both major contributors to the recent decline in the PRC's productivity growth since the financial crisis. Moreover, although the stimulus-induced rise in investment has effectively mitigated the negative effects of the financial crisis on the PRC's growth, it is not conducive to the growth of productivity and consumption. Therefore, we believe that the PRC economy will continue to slow down in the conceivable future. Policies that facilitate trade openness

and optimal resource allocation, and support full employment are a good start to improving the PRC's productivity and, thus, its long-term economic growth.

This article is certainly not devoid of flaws. For example, we still rely on historical data. We choose to ignore the nuanced effect of migration when we estimate human capital stock and working-age population. Moreover, we consider a sub-optimal method of econometric regression analysis to identify determinants of productivity; the regression results we obtained are better suited to describe the correlation (instead of casualty) between TFP growth rate and the indicators we choose. In addition, our counter-factual analysis conveniently ignores the effect the interaction between determinants (except the investment rate) could have on TFP growth rate. The issues outlined above could all be interesting directions for future research.

REFERENCES

- Abramovitz, M. 1956. Resource and Output Trends in the United States since 1870. *American Economic Review Papers and Proceedings* 46: 1–23.
- Aigner, D., C. A. Lovell, and P. Schmidt. 1977. Formulation and Estimation of Stochastic Frontier Production Function Models. *Journal of Econometrics* 6(1): 21–37.
- Arrow, K. J. 1962. The Economic Implications of Learning by Doing. *The Review of Economic Studies* 29(3): 155–173.
- Bai, C. E., D. Li, Z. G. Tao, and Y. J. Wang. 2000. A Multi-Task Theory of the State Enterprise Reform, *Journal of Comparative Economics* 28(4): 716–738.
- Bai, C. E., C. T. Hsieh, and Y. Y. Qian. 2006. The Return to Capital in China. *Brookings Papers on Economic Activity*: 61–88.
- . 2007. The Return to Capital in China. *Comparative Studies* 28: 1–22. (in Chinese)
- Bai, C. E., and Q. Zhang. 2014. Revealing the Unknown with the Known: Implications for Total Factor Productivity Researches in China. *China Finance Review* 1: 135–151. (in Chinese)
- Barro, R., and X. Sala-i-Martin. 1995. *Economic growth* (2nd Edition). Cambridge, MA: MIT Press.
- Barro, R. J. 1999. Notes on Growth Accounting. *Journal of Economic Growth* 4(2): 119–137.
- Benhabib, J., and M. M. Spiegel. 1994. The Role of Human Capital in Economic Development Evidence from Aggregate Cross-country Data. *Journal of Monetary Economics* 34(2): 143–173.
- Banerjee, A. V., and E. Duflo. 2005. Growth Theory through the Lens of Development Economics. *Handbook of Economic Growth* 1: 473–552.
- Brandt, L., J. Van Biesebroeck, and Y. Zhang. 2012. Creative Accounting or Creative Destruction? Firm-level Productivity Growth in Chinese Manufacturing. *Journal of Development Economics* 97(2): 339–351.
- Caves, D. W., L. R. Christensen, and W. E. Diewert. 1982. The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity. *Econometrica* 50(6): 1393–1414.
- Charnes, A., W. W. Cooper, and E. Rhodes. 1978. Measuring the Efficiency of Decision Making Units. *European Journal of Operational Research* 2(6): 429–444.
- Chen, K., H. Wang, Y. Zheng, G. H. Jefferson, and T. G. Rawski. 1988. Productivity Change in Chinese Industry: 1953–1985. *Journal of Comparative Economics* 12(4): 570–591.
- Chen, Z., M. Lu, and Y. Jin. 2004. Regional Differences of Human Capital and Education Development in China: An Estimation of the Panel Data. *The Journal of World Economy* 12: 25–31. (in Chinese)
- Chow, G. C. 1993. Capital Formation and Economic Growth in China. *The Quarterly Journal of Economics* 108(3): 809–842.

- Chow, G. C., and K. W. Li. 2002. China's Economic Growth: 1952–2010. *Economic Development and Cultural Change* 51(1): 247–256.
- Christensen, L. R., and D. W. Jorgenson. 1969. The Measurement of US Real Capital Input, 1929–1967. *Review of Income and Wealth* 15(4): 293–320.
- . 1970. US Real Product and Real Factor Input, 1929–1967. *Review of Income and Wealth* 16(1): 19–50.
- Denison, E. F. 1967. *Why Growth Rates Differ; Postwar Experience in Nine Western Countries*. Washington, DC: Brookings Institution.
- . 1972. Classification of Sources of Growth. *Review of Income and Wealth* 18(1): 1–25.
- Farrell, M. J. 1957. The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society. Series A (General)*: 253–290.
- Goldsmith, R. W. 1951. A Perpetual Inventory of National Wealth. *Studies in Income and Wealth* 14: 5–74.
- Grossman, G. M., and E. Helpman. 1991. Trade, Knowledge Spillovers, and Growth. *European Economic Review* 35(2): 517–526.
- Hadri, K. 2000. Testing for Stationarity in Heterogeneous Panel Data. *Econometrics Journal* 3: 148–161.
- He, Y. Q. 2007. Openness and TFP Growth: An Empirical Study Based on the Inter-Provincial Panel Data in China. *China Economic Quarterly* 6(4): 1127–1142. (in Chinese)
- Hsieh, C. T., and P. J. Klenow. 2009. Misallocation and Manufacturing TFP in China and India. *The Quarterly Journal of Economics* 124(4): 1403–1448.
- Im, K. S., M. H. Pesaran, and Y. Shin. 2003. Testing for Unit Roots in Heterogeneous Panels. *Journal of Econometrics* 115(1): 53–74.
- Jones, C. I. 2011. Misallocation, Economic Growth, and Input–Output Economics. National Bureau of Economic Research Working Paper w16742. Cambridge, MA: NBER.
- Jorgenson, D. W., and Z. Griliches. 1967. The Explanation of Productivity Change. *The Review of Economic Studies* 34(3): 249–283.
- Leibenstein, H. 1966. Allocative Efficiency vs. "X-efficiency". *The American Economic Review* 56(3): 392–415.
- Levin, A., C. F. Lin, and C. S. Chu. 2002. Unit Root Tests in Panel Data: Asymptotic and Finite-sample Properties. *Journal of Econometrics* 108(1): 1–24.
- Lucas, R. 2009. Trade and the Diffusion of the Industrial Revolution. *American Economic Journal: Macroeconomics* 1(1): 1–25.
- Luo, D. M., Y. Li, and J. C. Shi. 2012. Factor Distortion, Misallocation and Productivity. *Economic Research Journal* (in Chinese) 3: 4–14.
- MacDougall, G. D. A. 1960. The Benefits and Costs of Private Investment from Abroad: A Theoretical Approach. *Bulletin of the Oxford University Institute of Economics & Statistics* 22(3): 189–211.
- Mankiw, N. G., D. Romer, and D. N. Weil. 1992. A Contribution to the Empirics of Economic Growth. *The Quarterly Journal of Economics* 107(2): 407–437.

- Nelson, R. R., and E. S. Phelps. 1966. Investment in Humans, Technological Diffusion, and Economic Growth. *The American Economic Review* 56(1/2): 69–75.
- Perkins, D. H., and T. G. Rawski,. 2008. Forecasting China's Economic Growth to 2025. In *China's Great Economic Transformation*, edited by L. Brandt and T. G. Rawski. Cambridge: Cambridge University Press.
- Quesnay, F. (1766/1973). *The Economic Table—Tableau Economique*, New York, NY: Gordon Press.
- Ren, R. E., and X. S. Liu. 1997. Some Problems with Estimating Capital Stock in China. *The Journal of Quantitative & Technical Economics* 1: 19–24. (in Chinese)
- Restuccia, D., and R. Rogerson. 2008. Policy Distortions and Aggregate Productivity with Heterogeneous Establishments. *Review of Economic Dynamics* 11(4): 707–720.
- Romer, P. M. 1990. Human Capital and Growth: Theory and Evidence. *Carnegie–Rochester Conference Series on Public Policy*. North-Holland 32: 251–286.
- . 1990. Endogenous Technological Change. *Journal of Political Economy* XCVIII: S71–S102.
- Shi, Q. Q., B. T. Qin, and J. Chen. 1985. *Technological Progress and Economic Growth*. Beijing: Science and Technology Literature Press. (in Chinese)
- Solow, R. M. 1957. Technical Change and the Aggregate Production Function. *The Review of Economics and Statistics* 39(3): 312–320.
- Tinbergen, J. 1942, Zurtheorie der Langfristigenwirtschaftsentwicklung (On the Theory of Long-term Economic Growth). *Weltwirtschaftliches Archiv*: 511–549.
- Wei X. H., and J. W. Zhang. 2010. Threshold Effect of Human Capital on TFP Growth: Evidence from China. *Chinese Journal of Population Science* 5: 48–57. (in Chinese)
- Wooldridge, J. M. 2003. *Introductory Econometrics: A Modern Approach* (2nd Edition). Cincinnati, OH: South-Western, Division of Thomson Learning.
- Zhang, J., and Y. Zhang. 2003. Recalculating the Capital of China and a Review of Li and Tang's Article. *Economic Research Journal* 7: 35–43. (in Chinese)
- Zhang, J., G. Y. Wu, and J. P. Zhang. 2004. The Estimation of China's Provincial Capital Stock: 1952–2000. *Economic Research Journal* 10: 35–44. (in Chinese)