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Harry X. Wu
(Peking University)

Zhongwen Zhang
(Renmin University of China)

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CHINA'S INVESTMENT IN INFRASTRUCTURE: GROWTH DRIVER OR PRODUCTIVITY DRAGGER?

Harry X. Wu
Growth Lab and National School of Development, Peking University
harrywu@nsd.pku.edu.cn

Zhongwen Zhang
School of Applied Economics, Renmin University of China
zhangzhongwen@ruc.edu.cn

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ABSTRACT

Government strategic investment in infrastructure can be a powerful tool for economic growth, particularly in developing economies. While economists attempt to develop theoretical frameworks to link public infrastructure investment with economic growth (e.g., Hirschman, 1958; Hulten, 1996), they also underscore the non-linear nature of this relationship, signifying that the benefits of infrastructure may vary depending on the existing economic conditions. The effectiveness of infrastructure investment hinges on governance quality and institutional deficiencies often takes a heavy toll on the efficiency of the investment (Age'nor, 2010). However, this also means evaluating the real effect of infrastructure investment is a big challenge in empirical research.

While China's rapid development in public funded infrastructure with perhaps the world's best available technologies has been widely and highly appraised, its inefficiency problem has been questioned because of the existing institutional conditions not only encouraging central state agencies to maintain a "fast enough" pace of growth even if at a high cost, but also pressuring local governments to compete for fast growth that may lead to wasteful development of infrastructure (Qian and Roland, 1998; Li and Zhou , 2005; Xu, 2011). In the absence of systematic project-level data on China's public infrastructure investment, we opt for a growth accounting approach to address the problem. Taking stock of Wu's earlier studies (2016, 2019 and 2020), we first adopt an extended neoclassical growth accounting model *a la* Jorgenson (e.g., Jorgenson and Griliches, 1967; Jorgenson et al., 1987; Jorgenson, 2001; Jorgenson et al., 2005) that coherently integrates industry productivity accounts with the national accounts to assess the industry origin of China's growth and productivity performance focusing on the role of industries in the government's growth maintaining policy through large-scale infrastructure projects. Then, following Aoki (2012) we attempt to decompose the industry origin of the factor reallocation effects obtained from our growth accounting exercise to identify the industries that are likely impacted by government infrastructure investments.

Regarding the data used in this study, we are benefited from the newly revised and updated China Industry Productivity (CIP) database (also known as CIP/China-KLEMS) for 37 industries over the period 1992-2018 (Wu et al., 2023), re-grouped according to the impact coefficients of the industries in the initial infrastructure investment drive on all industries economy wide based on their input-output linkages. The construction of the data follows the KLEMS principles satisfying the needs of the Jorgensonian approach, which are promoted also by Dale Jorgenson in his Harvard-based World KLEMS Initiative.

Our preliminary findings show that the industries engaged in the government's initial infrastructure projects ("Infrastructure I") and the industries benefited by the spillover effect of the former ("Infrastructure II") contributed 53 percent of China's 8-percent annual growth rate, or 4.3 percentage point. More importantly, only about one fifth of the contribution is attributable to the initial group, which means that initial infrastructure investment has a strong spillover effect. This finding is in line with our expectation that infrastructure investment is a growth driver. Meanwhile, China's total factor productivity grew by only 0.55 percent per annum for the same period, which is hardly considered an efficient growth. By estimation, this is however equal to the TFP gained from industries. On top of that, a 0.75-percent annual TFP growth from labor reallocation across industries was completely offset by the TFP loss from capital reallocation across industries in which the two infrastructure groups played a dominant role (-0.74 percent points) as a productivity dragger.

Keywords: Total Factor Productivity (TFP); Resource Reallocation; Misallocation across Industries; Infrastructure Sectors

***JEL* Classification**: O47, E10, E24, C82

1. INTRODUCTION

Economists agree that infrastructure capital, such as transportation, water and energy systems and communication networks, is crucial for improving productivity and fostering economic growth. In his 1996 paper, Hulten theoretically demonstrates the positive correlation between infrastructure development and economic performance, and suggests that well-developed infrastructure reduces transaction costs, enhances efficiency, and facilitates market access, thereby promoting economic activities. While Hulten realizes the need for careful consideration of infrastructure projects and suggests policymakers to prioritize those with the most substantial expected productivity gains (Hulten and Schwab, 1997), Age'nor (2010) goes further arguing that only with high governance quality can infrastructure investments lead to substantial economic benefits, thus providing a theoretical basis for infrastructure policy emphasis on improving public sector efficiency and transparency.

When considering the widely and highly appraised China's rapid development in infrastructure, most of which are the world class of advancement, we do need go deeper to evaluate China's growth and productivity performance along with such impressive infrastructure investment yet bearing in mind Edward Gramlich's warning of oversimplification in considering the relationship between infrastructure investment and economic benefits (1994). Since infrastructure investment depends mainly on the public resources, the role of the government is crucial in general and for the case of China in particular. Due to its totalitarian political system and central planning heritage, the Chinese government's power in allocating resources is hardly be exaggerated, especially when maximizing the growth is politicized through central state agencies to maintain a "fast enough" pace of growth even if at a high cost and local governments to compete for faster growth-evaluated political performance (Qian and Roland, 1998; Li and Zhou, 2005; Xu, 2011). We therefore face an empirical challenge in weighing China's infrastructure investments against its growth and productivity performance in the absence of systematic public investment data.

We argue that as far as the government's strong ability of allocating resources concerned, a proper application of the Jorgenson-type neoclassical growth accounting model, extended to incorporate industry productivity accounts, to the newly revised and updated CIP/China KLEMS data is perhaps the best way to address the research problem from a macroeconomic perspective. Syrquin (1986) empirically manifests that resource reallocation has a significant effect on the aggregate productivity growth. Using his aggregate production possibility frontier (APPF) framework and incorporating the Domar aggregation scheme, Jorgenson (2001; Jorgenson et al., 2005) decomposes the aggregate total factor productivity (TFP) into two sources in the US economy, that is, industries and the reallocation of primary factors across industries. The reallocation effect quantifies the departure from the assumption of equal input prices for all industries and thus illustrates the concept of resource misallocation when the reallocation effect turns to negative suggesting factors to move from more productive to less productive industries because for example if less productive public investments crowd out more productive private investments.

The real challenge is how to identify industries whose growth and productivity performances are affected differently by the government's infrastructure investments, especially with the different impacts of the initial projects and their spillovers. Jorgenson's APPF-Domar framework (2001) cannot distinguish the role of individual industries in resource misallocation. Our focus is on policies that create idiosyncratic distortions to representative firms' decisions at industry level and hence cause a reallocation of resources across industries. The sector-specific frictions in the form of taxes for sectors reflect the various kinds of frictions the sector faces, which is widely used in some famous literatures on resource misallocation (e.g., Restuccia and Rogerson, 2008; Hsieh and Klenow, 2009).

We need to measure these sector-specific frictions in our framework by the differences in factor input returns between sectors and then assess the degree of misallocation for primary factors at industry level. We follow Aoki (2012)'s idea for this purpose. We opt for a counterfactual analysis to measure the effect of resource misallocation across sectors on aggregate TFP growth under the assumption that the factor inputs of the observed sector are kept to its actual values and the remaining factor inputs are reallocated efficiently across the remaining sectors of economy.

The paper is organized as follows. Section 2 provides a literature review to help raise our research problem. Section 3 proposes a gross output accounting framework to measure the effect of resource misallocation across sectors on the aggregate TFP. Section 4 describes the data and proposes data grouping and periodization to better capture the role of the government. Section 5 reports and interprets the growth accounting results, and lastly Section 6 gives some concluding remarks with caveats and future research priorities.

2. Literature Review

The important role of government infrastructure investment was well studied in the earlier development literature (Hirschman, 1958). It drew attention again when economists were concerned if the US productivity slowdown was largely attributed to insufficient infrastructure investment (Hulten, 1996). In this regard, we have benefited from seminal review papers by Gramlich (1994) and Estache and Fay (2007). More recently, China's impressive rapid infrastructure development has significantly renewed the interest in the relationship between infrastructure investment and growth.

This paper focuses on the possible impacts of infrastructure on an economy's growth and productivity performance. Common sense and some theoretical works suggests that modern economies cannot function without infrastructure and that infrastructure is a critical part of any economy's production function (Barro,1990; Age'nor,2010). However, there is no consistent evidence of the significance and magnitude of the contribution for infrastructure from empirical studies(Gramlich,1994; Morrison and Schwartz,1996; Estache and Fay, 2007). David A. Aschauer (1989, 1990), Alicia H. Munnell (1990), Ernst R. Berndt and Bengt Hansson (1992), and M. Ishaq Nadiri and Theofanis P. Mamuneas (1994) find that public capital contributes importantly to output and economic growth. In contrast, researchers such as Douglas Holtz-Eakin (1994), Charles R. Hulten and Robert M. Schwab (1984, 1991), Holz-Eakin (1994) , Holz-Eakin and Schwartz (1995) and Teresa Garcia-Mila and Therese McGuire (1992) find a negligible role for public capital.

Furthermore, Infrastructure services are mostly provided through networks, a fact that implies a nonlinear relation with output. Hurlin (2006) develops a threshold model whereby the level of available infrastructure is the threshold variable, but the number and value of the thresholds are endogenously determined. He finds strong evidence of nonlinearity and concludes that the highest marginal productivity of investments is found when a network is sufficiently developed but not completely achieved. Bougheas et al. (2000) also observed a nonlinear relationship between infrastructure and growth.

Diamond and Spence (1984) highlight the difficulties in empirically evaluating the impact of infrastructure on economic development. There are methodological challenges in empirically testing the relationship between infrastructure and economic growth at the national and regional levels, such as common trend, missing variables, reverse causality, simultaneous bias (Gramlich,1994; Fernald,1999). Later papers corrected for this by introducing country (or region) fixed effects and found much lower rates of return (Gramlich,1994). However, the fixed effect approach is affected by other slow-moving variables, which is why several authors prefer not to use it (Estache et al., 2006).

An alternative approach is to try to isolate the impact of changes in infrastructure on long-term growth, typically by using the first differences. This approach generates its own problems. Indeed, the first differences ignore the long-term relationship that exists in the data if infrastructure and growth are co-integrated (Canning and Pedroni, 2004). Several studies also devise estimation methods that make clear which way the causality runs. Calderon and Serven (2004) deal with the endogeneity of the explanatory variables using generalized method of moments (GMM) techniques. Some authors rely on simultaneous equations systems that look at the determinants of supply of (and/or demand for) infrastructure as well as its impact on output or growth (Roller and Wavusingez, 2003). Fernald (1999) uses industry level productivity growth in the United States to measure the impact of road investments.

In most developing countries, in some developed countries as well, the physical infrastructure (i.e. Railway tracks, roads, ports, water pipes, electricity transmission) is to a large extent publicly owned (Estache and Fay, 2007). Public infrastructure spending may be affected by public sector spending inefficiency. Therefore, how to identify different impacts of government infrastructure investments on industries are key issues. One issue is to better understand how decisions are made to invest in infrastructure as this is likely to affect the rate of return or the efficiency of a particular investment. Politically motivated projects are likely to exhibit low (or lower) rates of return as their objectives are to bring in the votes rather than to maximize growth (Cadot et al. 2006). Bardhan and Mookherjee (2000) offer some of the most influential theoretical findings on infrastructure, highlighting the role of local corruption on the effectiveness of public service decentralization. Andonov et al. (2021) discusses the underperformance of public institutional investors in infrastructure investing is driven by their focus on ESG and regulatory goals, governance issues, conservative investment strategies, and the constraints imposed by their public nature.

The other issue is to testify the extent to which public investment, especially in infrastructure, complements or crowds out private investment. Some works show that public capital in infrastructure may have a strong impact on private capital formation, through lowering production and adjustment cost, raising marginal productivity (Turnovsky, 1996; Cohen and Paul, 2004). On the contrary, public investment in infrastructure displaces or crowds out private investment if the public sector finances the increase in public investment through an increase in distortionary taxes or borrowing on domestic financial markets (Agénor et al., 2005). Since the role of the government is crucial in infrastructure investment for the case of China in particular, municipalities were allowed to set up "local government financing vehicles" (LGFV) to construct infrastructure projects. This paper extend these topics by discussing the contributions of infrastructure-specific sectors to China’s GDP growth, aggregate TFP growth, and factor reallocation effect.

Some earlier works address the China problems by investigating institutional deficiencies. Using a standard model of monopolistic competition with heterogeneous firms and manufacturing plant-level data from China, India and the US, Hsieh and Klenow (2009) estimated that manufacturing TFP gains of 30%–50% in China and 40%–60% in India when capital and labor were hypothetically reallocated to equalize marginal products to the extent observed in the United States. Large-scale stimulus programs, such as the four trillion-yuan stimulus, have exacerbated these issues. Studies by Bai et al. (2016) and Morrison & Schwartz (1996) highlight the role of local government debt and land finance in driving inefficient infrastructure investments. This misallocation has been driven by local governments' pursuit of economic growth, often resulting in overemphasis on infrastructure at the expense of other sectors. Consequently, this has led to significant economic distortions and inefficiencies (Aschauer, 1989; Diamond & Spence, 1984; Hirschman, 1958).

3. MODEL

3.1 A N-industry gross output model

There are N industries in the economy. Firms in each sector produce goods (homogeneous within a sector but heterogeneous between sectors) by using three factor inputs: capital input K ,labor input L and intermediate input X. Firms are price-takers in both the good and factor markets, and pay linear taxes on capital and labor inputs (owing to explore the magnified effect of intermediate inputs rather than misallocation of intermediate inputs itself, thus no taxes on intermediate inputs), which vary by sectors. Thus, firms in sector i produce goods given the goods price of the sector, p_{Yi} and capital and labor costs, $(1+\tau_{Ki})p_K$ and $(1+\tau_{Li})p_L$, where p_K and p_L are the common factor prices of capital and labor across sectors, and τ_{Ki} and τ_{Li} are capital and labor taxes of the sector. The price of intermediate inputs p_{Xi} varies across sectors, since constitute of intermediate inputs is different between industries.

The firms have Cobb-Douglas production technology exhibiting constant returns to scale[1]. Therefore, a firm i's gross output production function can be written as follows:

$$Y_i = F_i(A_i, K_i, L_i, X_i) = A_i K_i^{\alpha_i} L_i^{\beta_i} X_i^{1-\alpha_i-\beta_i} \qquad (1)$$

Y_i is gross output, K_i is capital input, L_i is labor input, X_i is intermediate input

[1] Actually we don't need to use specific function form for industry production function, only constant return to scale assumption is necessary just like in APPF. Using Cobb-Douglas production form is convenient for readers to understand the process.

and $A_i$is TFP[2]. We assume that the capital and labor output elasticity $\alpha_i$and $\beta_i$can vary by sector.

In this setting, the firm's problem is written as：

$$\max_{K_i,L_i,X_i}\{p_{Yi}Y_i - (1+\tau_{Ki})p_K K_i - (1+\tau_{Li})p_L L_i - p_{Xi}X_i\} \qquad (2)$$

The FOCs are as follows:：

$$\frac{\alpha_i p_{Yi} Y_i}{K_i} = (1+\tau_{Ki})p_K \qquad (3)$$

$$\frac{\beta_i p_{Yi} Y_i}{L_i} = (1+\tau_{Li})\, p_L \qquad (4)$$

$$\frac{(1-\alpha_i-\beta_i)p_{Yi}Y_i}{X_i} = p_{Xi} \qquad (5)$$

3.2 Aggregator function

When we consider the performance of the aggregate economy, it is reasonable to estimate the value added of the whole economy (GDP). We assume the aggregate value added V(the price scaled to unit) can be expressed by an aggregate function of industrial value added V_i ：

$$\mathrm{V} = F(V_1, \cdots, V_N) \qquad (6)$$

Where $F(\cdot)$ is assumed to constant returns to scale(CRS) ， and We also assume that the following condition is satisfied:：

$$\frac{\partial \mathrm{V}}{\partial V_i} = p_{Vi} \qquad (7)$$

Where p_{Vi} is the price of the value-added of industry i. Under this condition, the following equation holds:

$$\mathrm{V} = \sum_{i=1}^{N} p_{Vi} V_i \qquad (8)$$

It is necessary to define the industry value-added function, which gives the quantity of value-added as a function of only capital input, labor input and TFP as:

$$V_i = g_i(A_i, K_i, L_i) \qquad (9)$$

Industrial value-added and gross output relationship can be re-written as：

[2] These inputs used in industry production function are aggregate input indexes, which is attained by Tornqvist index of different types of lower-level inputs. The detailed process of constructing inputs is expressed in section 4.

$$Y_i = f_i(V_i, X_i) = f_i(g_i(A_i, K_i, L_i)\ , X_i) \qquad (10)$$

Under the assumption of constant returns to scale and competitive markets, the value of output is equal to the value of all inputs:

$$p_{Yi}Y_i = (1 + \tau_{Ki})p_K K_i + (1 + \tau_{Li})p_L L_i + p_{Xi}\, X_i \qquad (11)$$

Value-added consist of capital and labor inputs, and the nominal value is simply:

$$p_{Vi}V_i = p_{Yi}Y_i - p_{Xi}\, X_i = (1 + \tau_{Ki})p_K K_i + (1 + \tau_{Li})p_L L_i \qquad (12)$$

According to Jorgenson et al .（2005）， the quantity of value-added $V_i$is defined implicitly from a Tornqvist expression for gross output：

$$\ln\left(\frac{Y_i^{t+1}}{Y_i^t}\right) = \bar{v}_{Vi} \ln\left(\frac{V_i^{t+1}}{V_i^t}\right) + \bar{v}_{Xi} \ln\left(\frac{X_i^{t+1}}{X_i^t}\right) \qquad (13)$$

Where $\bar{v}_{Vi}$ and $\bar{v}_{Xi}$ are the two-period average share of value-added and intermediate input in gross output：

$$v_{Vi} = \frac{(1+\tau_{Ki})p_K K_i + (1+\tau_{Li})p_L L_i}{p_{Yi}Y_i}\ , \qquad \bar{v}_{Vi} = 1/2(v_{Vi}^{t+1} + v_{Vi}^t)$$

$$v_{Xi} = \frac{p_{Xi}\, X_i}{p_{Yi}Y_i}\ , \qquad \bar{v}_{Xi} = 1/2(v_{Xi}^{t+1} + v_{Xi}^t)$$

The price of value-added p_{Vi} is defined implicitly to make the identity （12） hold.

3.3 Resource constraint

Finally, we assume that aggregate capital and labor supply are exogenous. Thus, the following resource constraints apply[3]：

$$\sum_{i=1}^{N} K_i = K \qquad (14)$$

$$\sum_{i=1}^{N} L_i = L \qquad (15)$$

3.4 Distortion coefficients

According to (3), (4), (14) and (15), we derive the expressions forK_i and L_i

[3] We actually established equations for each type of capital inputs(structure and equipment) and labor inputs (low skilled labor, middle skilled labor, high skilled labor) in order to satisfy strictly the homogenous input requirement as APPF, we use this simplification to express conciseness.

$$K_i = \frac{\dfrac{(1+\tau_{Ki})p_K K_i}{(1+\tau_{Ki})p_K}}{\sum_j \dfrac{(1+\tau_{Kj})p_K K_j}{(1+\tau_{Kj})p_K}} K$$

$$= \frac{\dfrac{\alpha_i p_{Yi} Y_i}{(1+\tau_{Ki})p_K}}{\sum_j \dfrac{\alpha_j p_{Yi} Y_j}{(1+\tau_{Kj})p_K}} K$$

$$= \frac{\dfrac{\tilde{\sigma}_i \alpha_i}{1+\tau_{Ki}}}{\sum_j \dfrac{\tilde{\sigma}_j \alpha_j}{1+\tau_{Kj}}} K \qquad (16)$$

$$L_i = \frac{\dfrac{\tilde{\sigma}_i \beta_i}{1+\tau_{Li}}}{\sum_j \dfrac{\tilde{\sigma}_i \beta_i}{1+\tau_{Lj}}} L \quad (17)$$

Where $\tilde{\sigma}_i$ is the ratio of industrial gross output to aggregate value-added $\frac{p_{Yi} Y_i}{V}$, which is the usual interpretation of the Domar-weight（Domar,1961）.A distinctive feature of Domar-weight is that they typically sum to more than one.

In order to further analysis， we define two types of distortion coefficients.

Definition 1: Absolute distortion coefficients of capital and labor input for industry i, $\lambda_{Ki} = \frac{1}{1+\tau_{Ki}}$,$\lambda_{Lj} = \frac{1}{1+\tau_{Li}}$, where τ_{Ki} and τ_{Li} are capital and labor taxes of the sector.

Definition 2: Relative distortion coefficients of capital and labor input for industry i, $\tilde{\lambda}_{Ki} = \frac{\lambda_{Ki}}{\sum_j \left(\frac{\tilde{\sigma}_j \alpha_j}{\tilde{\alpha}}\right) \lambda_{Kj}}$, $\tilde{\lambda}_{Li} = \frac{\lambda_{Li}}{\sum_j \left(\frac{\tilde{\sigma}_j \beta_j}{\tilde{\beta}}\right) \lambda_{Kj}}$, where $\tilde{\alpha} = \sum_i \tilde{\sigma}_i \alpha_i$, $\tilde{\beta} = \sum_i \tilde{\sigma}_i \beta_i$ are separately expressed as Domar-weighted average of production elasticity for capital and labor.

Absolute distortion coefficients reflect the distortion degree of factors' cost contrast to the no distortion state and depict the absolute cost of factors. For example, if capital input for industry i faces no distortion, thus $\tau_{Ki} = 0$, then $\lambda_{Ki} = 1$; if the price of capital input is higher than that of no distortion, thus $\tau_{Ki} > 0$,then $0 < \lambda_{Ki} < 1$; if the price of capital input is lower than that of no distortion, thus

$\tau_{Ki} < 0$, then $\lambda_{Ki} > 1$.

Relative distortion coefficients reflect the distortion degree of factors' cost contrast to the average distortion degree of factors' cost for the whole economy, which is the signal deciding the resource allocation. For example, if ,λ_{Ki} is smaller than the weighted average of λ_{Kj} (i.e., sector i's capital is taxed more), then$\tilde{\lambda}_{Ki}$ becomes less than unity and less capital is allocated to sector i than to the level with no frictions.

In the empirical section, we do not measure absolute distortion coefficients , but measure relative distortion coefficients, which capture the distribution of frictions.

Combining definition 2, (16) and (17)，thus ：

$$K_i = \frac{\tilde{\sigma}_i \alpha_i}{\tilde{\alpha}} \tilde{\lambda}_{Ki} K \quad (18)$$

$$L_i = \frac{\tilde{\sigma}_i \beta_i}{\tilde{\beta}} \tilde{\lambda}_{Li} L \quad (19)$$

So the relative distortion coefficients are measured using the following equations：

$$\tilde{\lambda}_{Ki} = \left(\frac{\tilde{\sigma}_i \alpha_i}{\tilde{\alpha}}\right)^{-1} \frac{K_i}{K} \;, \qquad \tilde{\lambda}_{Li} = \left(\frac{\tilde{\sigma}_i \beta_i}{\tilde{\beta}}\right)^{-1} \frac{L_i}{L} \qquad (20)$$

For capital, $\frac{K_i}{K}$ is the real capital ratio of industry i accounts for the whole economy, while $\frac{\tilde{\sigma}_i \alpha_i}{\tilde{\alpha}}$ measures the theoretical capital ratio of industry i should be allocated if the resources are allocated efficiently. So the rate of the two ratios$\tilde{\lambda}_{Ki}$ can be measured as the degree of resource misallocation for capital inputs in industry i. If the rate bigger than one, it means industry i overused capital inputs; otherwise, it means industry i underused capital inputs. As defined in above, $\tilde{\lambda}_{Ki}$ is the relative distortion coefficient of capital input for industry i. If $\tilde{\lambda}_{Ki} > 1$, which means the relative cost of capital input in this industry is low, this industry has the incentive to overuse the capital input; If $\tilde{\lambda}_{Ki} < 1$, which means the relative cost of capital input in this industry is high, this industry has the incentive to underuse the capital input. Through the equation (20), the linkage between distortion of the factor's price and factors misallocation has been constructed.

3.5 *Decomposition of aggregate TFP*

To analyze the effect of resource misallocation on aggregate TFP, we compare the aggregator function between two adjacent periods.

By applying the mean value theorem and using (7) and (8), thus

$$\ln\frac{V_{\mathrm{t+1}}}{V_{\mathrm{t}}}=\sum_i\frac{\partial lnV}{\partial lnV_i}\ln\left(\frac{V_i^{t+1}}{V_i^t}\right)\approx\sum_i\bar{\omega}_i\ln\left(\frac{V_i^{t+1}}{V_i^t}\right) \quad (21)$$

where $\bar{\omega}_i$ is the average share of industry value-added in aggregate value-added：

$$\omega_i=\frac{p_{Vi}V_i}{V}\ , \qquad \bar{\omega}_i=1/2(\omega_i^{t+1}+\omega_i^t)$$

According to Jorgenson et al.,(2005), the TFP growth rate of industry i can be decomposed as ：

$$\ln\left(\frac{A_i^{t+1}}{A_i^t}\right)=\ln\left(\frac{Y_i^{t+1}}{Y_i^t}\right)-\bar{v}_{Xi}\ln\left(\frac{X_i^{t+1}}{X_i^t}\right)-\bar{v}_{Ki}\ln\left(\frac{K_i^{t+1}}{K_i^t}\right)-\bar{v}_{Li}\ln\left(\frac{L_i^{t+1}}{L_i^t}\right) \quad (22)$$

Considering the relationship between value-added and gross output, according to (13),thus

$$\ln\left(\frac{V_i^{t+1}}{V_i^t}\right)=\frac{\bar{v}_{Ki}}{\bar{v}_{Vi}}\ln\left(\frac{K_i^{t+1}}{K_i^t}\right)+\frac{\bar{v}_{Li}}{\bar{v}_{Vi}}\ln\left(\frac{L_i^{t+1}}{L_i^t}\right)+\frac{1}{\bar{v}_{Vi}}\ln\left(\frac{A_i^{t+1}}{A_i^t}\right) \quad (23)$$

Plunging (18), (19) and (23) into (21), we attain

$$\begin{aligned}\sum_i\bar{\omega}_i\ln\left(\frac{V_i^{t+1}}{V_i^t}\right)&=\sum_i\bar{\omega}_i\left\{\frac{\bar{v}_{Ki}}{\bar{v}_{Vi}}\ln\left(\frac{K_i^{t+1}}{K_i^t}\right)+\frac{\bar{v}_{Li}}{\bar{v}_{Vi}}\ln\left(\frac{L_i^{t+1}}{L_i^t}\right)+\frac{1}{\bar{v}_{Vi}}\ln\left(\frac{A_i^{t+1}}{A_i^t}\right)\right\}\\&=\sum_i\frac{\bar{\omega}_i}{\bar{v}_{Vi}}\left\{\ln\left(\frac{A_i^{t+1}}{A_i^t}\right)+\bar{\alpha}_i\ln\left(\frac{K_i^{t+1}}{K_i^t}\right)+\bar{\beta}_i\ln\left(\frac{L_i^{t+1}}{L_i^t}\right)\right\}\\&\approx\sum_i\frac{\bar{\omega}_i}{\bar{v}_{Vi}}\left\{\ln\left(\frac{A_i^{t+1}}{A_i^t}\right)+\bar{\alpha}_i\ln\left(\frac{\tilde{\lambda}_{Ki}^{t+1}}{\tilde{\lambda}_{Ki}^t}\right)+\bar{\beta}_i\ln\left(\frac{\tilde{\lambda}_{Li}^{t+1}}{\tilde{\lambda}_{Li}^t}\right)\right\}\\&\quad+\sum_i\frac{\bar{\omega}_i}{\bar{v}_{Vi}}\bar{\alpha}_i\ln\left(\frac{K^{t+1}}{K^t}\right)+\sum_i\frac{\bar{\omega}_i}{\bar{v}_{Vi}}\bar{\beta}_i\ln\left(\frac{L^{t+1}}{L^t}\right) \qquad (24)\end{aligned}$$

Where $\bar{v}_{Ki}$ and $\bar{v}_{Li}$ are average share of capital and labor input in nominal gross output of industry：

$$v_{Ki}=\frac{(1+\tau_{Ki})p_KK_i}{p_{Yi}Y_i}=\alpha_i\ , \qquad \bar{v}_{Ki}=1/2(v_{Ki}^{t+1}+v_{Ki}^t)=\bar{\alpha}_i$$

$$v_{Li} = \frac{(1+\tau_{Li})p_L L_i}{p_{Yi} Y_i} = \beta_i \quad , \qquad \bar{v}_{Li} = 1/2(v_{Li}^{t+1} + v_{Li}^t) = \bar{\beta}_i$$

According to Jorgenson et al.,(2005), we define ATFP as the growth rate of aggregate TFP, thus

$$\text{ATFP} = \sum_i \bar{\omega}_i \ln\left(\frac{V_i^{t+1}}{V_i^t}\right) - \sum_i \frac{\bar{\omega}_i}{\bar{v}_{Vi}} \bar{\alpha}_i \ln\left(\frac{K^{t+1}}{K^t}\right) - \sum_i \frac{\bar{\omega}_i}{\bar{v}_{Vi}} \bar{\beta}_i \ln\left(\frac{L^{t+1}}{L^t}\right)$$

Rewriting (24), thus

$$\text{ATFP} \approx \sum_i \frac{\bar{\omega}_i}{\bar{v}_{Vi}} \ln\left(\frac{A_i^{t+1}}{A_i^t}\right) + \sum_i \frac{\bar{\omega}_i}{\bar{v}_{Vi}} \left\{\bar{\alpha}_i \ln\left(\frac{\tilde{\lambda}_{Ki}^{t+1}}{\tilde{\lambda}_{Ki}^t}\right) + \bar{\beta}_i \ln\left(\frac{\tilde{\lambda}_{Li}^{t+1}}{\tilde{\lambda}_{Li}^t}\right)\right\} \quad (25)$$

We refer to the first term of the RHS in (25) as sectoral TFP term (STFP). STFP is a weighted average of the growth rate of sectoral TFPs with Domar-weight. The distinctive feature of Domar-weight is that they sum to more than one, which reflects that an improvement in industry TFP can have two effects: a direct effect on industry output, and an indirect effect via intermediate flows (Jorgenson et al., 2005). In other words, the intermediate inputs can magnify the effect of industry TFP growth to the aggregate TFP growth, the multiplier is positive proportional with $\frac{p_{Xi} X_i}{p_{Vi} V_i}$. The second term of the RHS in (25) consists of frictions. I refer to it as reallocation efficiency term (RE). RE measures the effect of change of distortions on resource allocation on aggregate TFP growth. If $\text{RE} > 0$, it illustrates that the resource allocation becomes better; if $\text{RE} < 0$, it illustrates that the resource allocation becomes worse. The intermediate inputs have no effect on the RE term, since the intermediate input part will cancel out from RE term after calculation. Because introduction of intermediate inputs can magnify the contribution of sectoral TFP growth and have no effect on the reallocation efficiency term, it will decrease the contribution of reallocation efficiency term to the aggregate TFP growth. In order to analyze the contribution of primary factors to reallocation efficiency, RE can be divided into two parts: RE(K) and RE(L), where $\text{RE(K)} = \sum_i \frac{\bar{\omega}_i}{\bar{v}_{Vi}} \bar{\alpha}_i \ln\left(\frac{\tilde{\lambda}_{Ki}^{t+1}}{\tilde{\lambda}_{Ki}^t}\right)$, $\text{RE(L)} = \sum_i \frac{\bar{\omega}_i}{\bar{v}_{Vi}} \bar{\beta}_i \ln\left(\frac{\tilde{\lambda}_{Li}^{t+1}}{\tilde{\lambda}_{Li}^t}\right)$.

3.6 Contribution of each sector to RE

In order to identify the contribution of sector i RE_i, we adopt the method in Aoki (2012). We fix factor inputs of a particular sector (we refer to it as sector i) to its actual observed values and then reallocated efficiently the remaining factor inputs across the remaining sectors of the economy. Then, the only source of distortion would be in sector i. For simplicity, we also assume that sectoral domar-weight and output elasticity are fixed.

We refer to the RE calculated under this assumption asRE_i.

First, according to (18),$\tilde{\lambda}_{Ki}$ is the same as the actual one. Second, since factor prices are the same across the remaining sectors, $\tilde{\lambda}_{Km} = \tilde{\lambda}_{Kn} = \tilde{\lambda}_{K-i}$ for the remaining sectors (m and n are sectors that are not sector i and we summarize these sectors by $-i$).

In the empirical section, $\tilde{\lambda}_{K-i}$ used in AE_{Ki} is measured in the following way. By rearranging,

$$K_{-i} = K - K_i = \sum_{m \neq i} K_m = \sum_{m \neq i} \frac{\tilde{\sigma}_m \alpha_m}{\tilde{\alpha}} \tilde{\lambda}_{K-i} K \qquad (28)$$

We obtain

$$\tilde{\lambda}_{K-i} = \left(\frac{\tilde{\sigma}_{-i} \alpha_{-i}}{\tilde{\alpha}} \right)^{-1} \frac{K_{-i}}{K} \qquad (29)$$

Where $\tilde{\sigma}_{-i} = \frac{\sum_i p_{Y_i} Y_i}{V} - \tilde{\sigma}_i$ and$\alpha_{-i} = \sum_{m \neq i} \frac{\tilde{\sigma}_m}{\tilde{\sigma}_{-i}} \alpha_m$ (i.e., α_{-i} is a weighted average ofα_m（$m \neq i$）).

Thus we get the contribution of industry i $\mathrm{RE}_{Ki}$when there is only distortion of capital input in this industry.

$$\mathrm{RE}_{Ki} = \frac{\bar{\omega}_i}{\bar{v}_{Vi}} \bar{\alpha}_i \ln \left(\frac{\tilde{\lambda}_{Ki}^{t+1}}{\tilde{\lambda}_{Ki}^{t}} \right) + \sum_{m \neq i} \frac{\bar{\omega}_m}{\bar{v}_{Vm}} \bar{\alpha}_m \ln \left(\frac{\tilde{\lambda}_{K-i}^{t+1}}{\tilde{\lambda}_{K-i}^{t}} \right) \qquad (30)$$

In the same way, we get the contribution of industry i $\mathrm{RE}_{Li}$when there is only distortion of labor input in this industry.

$$\mathrm{RE}_{Li} = \frac{\bar{\omega}_i}{\bar{v}_{Vi}} \bar{\beta}_i \ln \left(\frac{\tilde{\lambda}_{Li}^{t+1}}{\tilde{\lambda}_{Li}^{t}} \right) + \sum_{m \neq i} \frac{\bar{\omega}_m}{\bar{v}_{Vm}} \bar{\beta}_m \ln \left(\frac{\tilde{\lambda}_{L-i}^{t+1}}{\tilde{\lambda}_{L-i}^{t}} \right) \qquad (31)$$

where

$$\tilde{\lambda}_{L-i} = \left(\frac{\tilde{\sigma}_{-i} \beta_{-i}}{\tilde{\beta}} \right)^{-1} \frac{L_{-i}}{L} \qquad (32)$$

$$\beta_{-i} = \sum_{m \neq i} \frac{\tilde{\sigma}_m}{\frac{p_{Y_i} Y_i}{V} - \tilde{\sigma}_i} \beta_m \qquad\qquad L_{-i} = L - L_i$$

4. Data Issues

This study has uniquely benefited from a newly constructed economy-wide, industry-level data set in the on-going CIP Project. It is beyond the scope of this study to go through a long history of separate database studies.[4] We refer the interested reader for details to three working papers (Wu 2015; Wu and Ito 2015; Wu, Yue and Zhang 2015) as well as earlier versions of this work if one wants to trace the development of the data construction ideas (e.g. Wu 2008 and 2012; Wu and Xu 2002; Wu and Yue 2003, 2010 and 2012).

In the CIP Project the principles of industry data construction adhere to the underlying theory as expressed in detail in accounting of U.S. economic growth in Jorgenson et al. (2005). For the classification of industries, we in principle adopt the 2002 version of the Chinese Standard Industrial Classification (CSIC/2002) and reclassify the economy into 37 industries (see Appendix Table A1). Each sector of the economy is described by a production function, which uses primary factors and intermediate inputs to produce gross output. This output is used for final demand and intermediate demand, and GDP is the aggregate of final demand. Nominal GDP is also the sum of sectoral value added, which implies that the industry-level data are linked to and made consistent with the national production and income accounts of China.

4.1 Output and intermediate input

We must have the IOTs in time series to get time series data of output and intermediate input. Unfortunately, there are only five full-scale IOTs, so we have to reconstruct the IOTs in time series based on the five benchmarks (Wu and Ito, 2015). Based on the constructed IOTs in time series, on one hand, we can get the output for sectors directly, on the other hand, we have to use the Tornqvist aggregate to get the intermediate input for sectors.

$$\ln\left(\frac{X_i^{t+1}}{X_i^t}\right) = \sum_j v_{ij}^X \ln\left(\frac{X_{ij}^{t+1}}{X_{ij}^t}\right) \tag{39}$$

Where X_i is the intermediate input for industry i, $X_{ij}$is the intermediate input of type j for industry i, v_{ij}^X is the average share of X_{ij} in nominal intermediate input for industry i, $v_{ij}^X = {}^1/_2\left(v_{ij\,(t+1)}^X + v_{ijt}^X\right)$, $v_{ijt}^X = \frac{p_{jt}^X x_{ij}^t}{\sum_j p_{jt}^X x_{ij}^t}$.

4.2 Capital input

[4] The CIP project is based on Wu's China Growth and Productivity Database project, self-initiated in 1995 and heavily involved in Angus Maddison's work on China's aggregate economic performance from 1912 and manufacturing, mining and utility industries from 1949 (see Maddison 1998 and 2007; Maddison and Wu 2008). The CIP project began in 2010 aiming to extend Wu's earlier work to all non-industrial sectors under the KLEMS framework.

The method involves distinguishing between the stock of capital and the flow of services derived from them and is described in detail in Jorgenson et al. (2005, chapter 5). Wu（2015a）introduced the detailed process of constructing the capital service series in China.

The stock of capital of type k in sector i $A_{k,i,t}$ is accumulated from the flow of investment using the perpetual inventory method. Owing to the new investment can't be used efficiently into production, the capital input $K_{k,i,t}$ is different from the capital stock $A_{k,i,t}$. The difference between capital stock and capital service can be expressed as

$$K_{k,i,t} = Q_{K,k,i}\frac{1}{2}\left(A_{k,i,t} + A_{k,i,t-1}\right) = Q_{K,k,i}.Z_{k,i,t} \quad (34)$$

Where $Z_{k,i,t}$ is two-period average capital stock, $Q_{K,k,i}$ is the proportionality factor.

Jorgenson (1963) raised the rental price of capital service(without considering tax) as：

$$P_{K,k,i,t} = \left(i_{i,t} - \pi_{k,i,t}\right)P_{I,k,i,t-1} + \delta_k P_{I,k,i,t} \qquad (35)$$

where $P_{I,k,i,t}$ is acquisition price of capital, $i_{i,t}$ is the nominal interest, δ_k is the rate of economic depreciation, $\pi_{k,i,t}$ is the asset-specific capital gains.

With the capital input flow $K_{k,i,t}$ and capital input price $P_{K,k,i,t}$ for each asset, industry and time period. To generate estimates for total capital service flows within an industry, we use a Tornqvist quantity index to aggregate over assets as below

$$\Delta\ln K_{i,t} = \sum_k \bar{v}_{k,i,t}\,\Delta\ln Z_{k,i,t} \quad (36), \qquad v_{k,i} = \frac{P_{K,k,i}K_{k,i}}{\sum_k P_{K,k,i}K_{k,i}} (37)$$

Where $\Delta\ln K_{i,t} = \ln\left(\frac{K_{i,t}}{K_{i,t-1}}\right)$, $v_{k,i}$ is the share of *kth* capital input used in industry *i* in the value of capital input for this industry.

4.3 Labor input

The key of constructing the labor input is to convert heterogeneous hours worked into homogenous volume of labor input by the method described in detail in Jorgenson et al. (2005, chapter 6). Wu et al. （2015a）introduced the detailed process of constructing the labor input series in China.

According to Jorgenson et al. (2005), the relationship between the labor input and hours worked can be expressed as $L_{lit} = Q_l H_{lit}$ (38) , where L_{lit} is labor input of type l for industry i, H_{lit} is worked hours of type l for industry i, Q_l is the proportionality factor.

The labor input for sector can be attained by Tornqvist aggregate of different type of labor inputs for the sector.

$$\Delta\ln L_{it} = \sum_l \bar{v}_{lit}\,\Delta\ln L_{lit} = \sum_l \bar{v}_{li}\Delta\ln H_{lit} \quad (39), \quad v_{li} = \frac{P_{L,li}L_{li}}{\sum_l P_{L,li}L_{li}} \quad (40)$$

Where v_{li} is the share of labor input of type l for industry i in the value of labor input for industry *I*, $P_{L,li}$ is the price of labor input of type l for industry i.

5. EMPIRICAL ANALYSIS

In this section, applying the CIP data for the period 1992-2018 to the framework developed in Section 3, we estimate and discuss the contributions of infrastructure-specific sectors to China's GDP growth, aggregate TFP growth, and factor reallocation effect on the TFP growth.

5.1 Periodization and grouping

To explore the dynamic pattern of growth and productivity against policy regime shifts, we divide the whole period into four sub-periods base on reforms and market shocks that caused significant changes in policy regimes, namely the period 1992-2001 following Deng Xiaoping's call for bolder reforms to get rid of China's political dilemma since 1989, the period 2002-2007 or the so-called "golden period" following China's participation in WTO in 2001, the period 2008-2012 beginning with the global financial crisis (GFC) that encouraged the government to introduce an unprecedented large-scale infrastructure projects to maintain growth, and finally the period 2013-2018 that saw the running out of the power of the stimuli and the emergence of the problems nurtured by persistent structural distortions of the economy (Wu, 2019).

To better identify and distinguish the industries that are engaged in the initial infrastructure projects from those that are impacted by the spillover effect of the initiatives and those with good reasoning to stand alone, we regroup the CIP 37 industries (Table A1) into the following six groups, starting with two infrastructure-related groups: "Infrastructure I" including 4 industries that are directly engaged in the government infrastructure initiatives, namely utilities (CIP 25), transport, storage and post services (CIP 29), real estate services (CIP 32), and government services (CIP 34), and "Infrastructure II" including 11 industries identified by the impact coefficients of "Infrastructure I" estimated through the CIP reconstructed input-output matrices in time series (Wu and Ito, 2015), namely coal mining (CIP 2), oil mining and processing (CIP

3 and CIP 13), basic chemicals (CIP 14), basic metals (CIP 17), building materials (CIP 16), machinery (CIP 19), transport equipment (CIP 23), construction (CIP 26), commerce (CIP 27), and financial services (CIP 31).

The rest of the industries are categorized in the following four groups: “Other Manufacturing” including 15 industries (CIP 4-12, CIP 15, CIP 18, CIP 20-22, CIP 24; referring to Table A1 for the name of these industries); “Producer Services” including telecommunication services (CIP 30) and technical, scientific and business services (CIP 33); “Consumer Services” including 4 industries namely hotel and catering services (CIP 28), education (CIP 35), healthcare (CIP 36) and other services (CIP 37); and lastly the agriculture sector (CIP 1) standing alone as it is.

5.2 Decomposition of China’s GDP growth

Table 1 reports the contribution of various industries to China's GDP growth estimated by Equation 21. Throughout the study period, China maintained a high average growth rate of 8% per year, mainly driven by industries affected by infrastructure investment, namely "Infrastructure I" that directly participated in infrastructure investment programs such as investments in utilities, transportation and housing, and more importantly, "Infrastructure II" due to the strong spillover effect of "Infrastructure I", which contributed 1.0 and 3.3 percentage points (ppts) respectively, and together contributed more than half of the total growth. This pattern was maintained through all the four subperiods. The two infrastructure groups were followed by “Other Manufacturing”, most of which were labor intensive industries (see Section 5.1 for the industries included) that played an important role in China’s export, accounting for 2.1 ppts or contributing to about 30 percent of the aggregate growth. The rest of the growth was attributed to “Producer Services”, “Agriculture” and “Consumer Services”.

TABLE 1: CONTRIBUTION TO AGGREGATE GDP GROWTH BY INDUSTRY GROUP

	1992-2001	2002-2007	2008-2012	2013-2018	1992-2018
GDP growth (% p.a.)	8.37	10.56	7.39	5.32	**8.00**
Industry contribution*: (ppts)					
Agriculture	0.72	0.52	0.51	0.28	**0.54**
Infrastructure I	1.27	1.67	0.13	0.49	**0.98**
Infrastructure II	2.91	4.63	3.88	2.02	**3.27**
Other manufacturing	2.67	2.41	1.84	1.07	**2.10**
Producer services	0.42	0.68	0.89	1.03	**0.70**
Consumer services	0.40	0.65	0.15	0.43	**0.42**

Sources: Authors’ estimates using CIP data.
Notes: * “ppts” = Percentage points; the sum of the ppts of all groups equals to the aggregate GDP growth. See Section 5.1 for the details of the industry grouping.

Looking at the four sub-periods, 2002-2007 was the "golden period" after joining the WTO, when China's economic growth was the fastest, with an average annual growth rate of 10.6%. However, affected by the global financial crisis, the growth rate slowed down significantly, falling to 5.3% from 2013 to 2018, only about half of the level after joining the WTO. However, the basic pattern did not changed, and the contribution rate of "Infrastructure I and II" dropped from 60% to 47%, of which the proportion of "Infrastructure I", which is the initial driving force of infrastructure investment projects, dropped from one-quarter to about one-fifth. In other words, this means that the spillover effect became relatively enhanced.

Over the entire period investigated, “Other Manufacturing”, consisting of all labor-intensive manufacturing industries, contributed 2.1 ppts per annum to the aggregate growth, which maintained its traditional role in driving China’s exports despite fluctuations with a gradual decline. As for the two service groups, on annual average, “Producer Services” contributed 0.7 ppts to the growth, whereas “Consumer Services” contributed 0.4 ppts. Not surprisingly, despite the GFC shock “Producer Services” demonstrated a steadily increasing contribution to the growth, suggesting that the economy moved towards more service-involved, sophisticated activities. By contrast, the role of “Consumer Services” was not stable and slowed down significantly following the GFC. Finally, the rapid decline of “Agriculture” is in line with the expectation that economic development generally shifts labor and resources from farming to non-farming industries.

5.3 Decomposition of China’s aggregate TFP growth

In Table 2 we report the estimated aggregate TFP growth (ATFP) and its decomposed two components, a sectoral TFP (STFP, the Domar sum of TFP across industries) and a reallocation effect (RE) for the entire period and its four sub-periods. For the entire period, the average ATFP growth is 0.55 percent per annum, of which the period following Deng’s reform-promotion Southern-China trip appears to be the best whereas the second period after GFC is the worst. This 0.55-percent ATFP is made up by 0.55 ppts from STFP and 0 ppt from RE because the capital RE or REK (-0.75 ppts) is fully offset by the labor RE or REL (0.75 ppts), which is apparently coincidental. Nonetheless, it is worth a closer look because, while the changes in RE (=REK+REL) for capital and labor over the four sub-periods do not show any pattern, changes in REL are consistently positive and changes in REK are consistently negative, regardless of whether STFP is positive or negative.

The situation in the post-WTO “golden period” (2002-2007) calls for a closer attention because it benefited from a positive REL effect (1.47 ppts) but also suffering from a negative REK effect (-1.34 ppts), almost offsetting each other. From the perspective of the institutional background at the time, on the one hand, the WTO opened up to China's labor-intensive products, encouraging farmers to shift to non-agricultural industries with higher production efficiency; on the other hand, the policy focus of state-owned enterprise reform of "grasping large and letting go of small" encouraged the government to intervene in capital allocation, which damaged production efficiency.

TABLE 2: CONTRIBUTION TO AGGREGATE TFP GROWTH BY INDUSTRY GROUP

	1992-2001	2001-2007	2008-2012	2013-2018	1992-2018
ATFP (% p.a.)	1.95	1.87	-0.73	-1.76	0.55
STFP* (ppts)	**2.20**	**1.74**	**-1.48**	**-1.39**	**0.55**
Agriculture	0.28	0.32	0.62	0.56	**0.42**
Infrastructure I	-0.14	-0.50	-1.76	-1.32	**-0.80**
Infrastructure II	0.62	1.30	-0.78	-0.76	**0.17**
Other manufacturing	2.56	1.18	1.24	0.89	**1.61**
Producer services	-0.37	0.07	0.17	-0.11	**-0.11**
Consumer services	-0.77	-0.62	-0.98	-0.65	**-0.74**
REK (ppts)	**-0.62**	**-1.34**	**-0.24**	**-0.79**	**-0.75**
REL (ppts)	**0.37**	**1.47**	**0.99**	**0.42**	**0.75**

Sources: Authors' estimates using the CIP/China-KLEMS data.
Notes: See Table 1 for "ppts" and industry grouping. *ATFP growth is the sum of STFP (Domar- aggregated industry TFP), REK (the reallocation effect of capital on TFP) and REL (the reallocation effect of labor on TFP).

Thanks to the industry grouping based on the input-output matrix, the industry breakdown of STFP enables for the first time a reliable productivity assessment of China's infrastructure investment as a policy tool to sustain growth. Since the industries in the "Infrastructure I" group are directly involved in the government infrastructure programs, which is the initial driver, they are expected to have lower productivity than other industries due to more and stronger government interventions. This is exactly what Table 2 shows. On average over the entire period, "Infrastructure I" was indeed the least efficient (-0.80 ppts), while "Infrastructure II", which was assumed to be triggered by the former and hence subject to less government intervention, was slightly positively affected (0.17 ppts). Interestingly, the results for the sub-periods also show that a stronger infrastructure policy drive, through more interventions in "Infrastructure I", tended to bring about a larger negative productivity shock, which had a more negative impact on the performance of "Infrastructure II", as shown for the two sub-periods after the global financial crisis compared with the earlier periods.

At the same time, we are nonetheless observing a puzzling result that instead of being impacted by some "crowding out" effect the productivity performance of "Other

Manufacturing" appears to be impressively strong. This suggests that infrastructure investment programs might also have positive externalities on those who survived from the "crowding out" effect of the infrastructure programs. However, when the productivity performance of "Infrastructure I" and "Infrastructure II" deteriorates, the productivity performance of "Other Manufacturing" also declines. This finding cannot suggest whether the productivity improvement obtained by the latter can offset the productivity loss by the former, nor can it guarantee that intervention in the name of maintaining growth will not have a negative impact on the behavior of manufacturers.

Finally, our findings for the rest of the industries included in STFP give no surprise. The TFP performance of agriculture and services is consistent with general expectations, namely that productivity in the agricultural sector increases as resources move out of traditional agriculture, while as the "Baumol's cost disease" (Baumol, 2012) predicts, as productivity in the manufacturing industries increases, costs in the service sector rise, thereby hurting productivity.

5.4 Industry origin of the factor reallocation effect on TFP

Government interventions to sustain growth may affect resource reallocation therefore resource allocation is not necessarily consistent with productivity gains. To better understand the roles of industries in the productivity effect of the government infrastructure policy, we estimate industry origin of the reallocation effect (RE) for capital (REK) and labor (REL) respectively, using the method illustrated in Section 3.6 and report the results in Table 3.

From the average level of the entire period investigated, as mentioned earlier, the REK is negative (-0.75 ppts) and mainly attributed to "Infrastructure I" (-0.57 ppts), followed by "Infrastructure II" (-0.17 ppts), while the REK effect of other industries is negligible; on the other hand, the REL is positive (0.75 ppts) and mainly attributed to "Agriculture" (0.51 ppts), followed by "Infrastructure I" (0.12 ppts) and "Producer Services" (0.15 ppts). If comparing REK with REL, a worth noting observation is that while the industries of the original infrastructure driver group, i.e., "Infrastructure I," suffered productivity losses due to the increasingly inefficient use of capital, they benefited from the increases in labor reallocation in terms of the increase in labor supply and labor productivity, although the losses outweighed the gains. This suggests that when using infrastructure investment as a policy tool to maintain growth, the government's attention to employment problem might outweigh that to efficiency problem.

TABLE 3: DECOMPOSITION OF FACTOR REALLOCATION EFFECTS ON TFP GROWTH BY INDUSTRY GROUP

	1992-2001	2002-2007	2008-2012	2013-2018	1992-2018
REK (% p.a.)	**-0.62**	**-1.34**	**-0.24**	**-0.79**	**-0.75**
Industry contribution* (ppts)					
Agriculture	-0.02	0.01	-0.04	-0.09	**-0.03**
Infrastructure I	-0.72	-0.77	-0.33	-0.33	**-0.57**
Infrastructure II	-0.07	-0.43	0.10	-0.30	**-0.17**
Other manufacturing	0.10	-0.01	-0.06	-0.19	**-0.02**
Producer services	0.10	-0.08	0.10	0.12	**0.06**
Consumer services	-0.01	-0.06	0.00	-0.01	**-0.02**
REL (% p.a.)	**0.37**	**1.47**	**0.99**	**0.42**	**0.75**
Industry contribution* (ppts)					
Agriculture	0.41	0.85	0.59	0.23	**0.51**
Infrastructure I	0.04	0.20	0.18	0.11	**0.12**
Infrastructure II	-0.16	0.09	-0.12	-0.23	**-0.11**
Other manufacturing	0.01	0.14	0.03	0.01	**0.04**
Producer services	0.04	0.12	0.24	0.30	**0.15**
Consumer services	0.03	0.08	0.07	0.00	**0.04**

Sources: Authors' estimates using the CIP/China-KLEMS data.
Notes: See Table 1 and 2.

Overall, Table 3 shows a similar pattern through the four sub-periods, that is, the negative REK mainly came from "Infrastructure I" and "Infrastructure II", while the positive REL mainly came from agriculture and services. This not only confirms that the infrastructure investment policy adopted by the government to maintain growth indeed led to inefficient resource reallocation, but also promoted the transfer of labor from agriculture to non-agricultural activities. The former effect of such policies was more prominent in crisis periods, as shown by the results for the sub-periods following the global financial crisis, while the latter effect was more prominent in the fastest growing post-WTO period.

To better understand the behavior of "Infrastructure I" and "Infrastructure II", we report the role of the industries included in the two groups in their respective REKs in Table 4. Over the entire survey period, the -0.57 ppts-REK of "Infrastructure I" was mainly caused by real estate (-0.37 ppts) and public administration services (-0.19 ppts), while the -0.17 ppts-REK of "Infrastructure II" was mainly caused by financial services (-0.10 ppts) and industrial machinery (-0.04 ppts).

In addition, the examination of the two groups of industries in the sub-periods reveals some noteworthy results that may prompt a rethinking of the "growth maintenance" policy with infrastructure investment as a policy tool. For "Infrastructure I", we find that the traditional industries directly engaged in infrastructure construction such as utilities and transportation services were not the primary cause of the REK decline and even the role of the real estate industry turned positive in 2013-2018. Instead, it was the public administration service that played an increasingly negative role in REK or the misallocation of capital, raising a question if there was an increase in non-productive public spendings, such as national security and defense programs in the name of infrastructure construction.

TABLE 4: INDUSTRY BREAKDOWN OF THE REK EFFECT OF "INFRASTRUCTURE I" AND "INFRASTRUCTURE II"

	1992-2001	2002-2007	2008-2012	2013-2018	1992-2018
Infrastructure I (ppts)	**-0.72**	**-0.77**	**-0.33**	**-0.33**	**-0.57**
CIP 25. Utilities	-0.03	-0.03	0.10	0.01	**0.00**
CIP 29. Transport & Storage	-0.01	0.01	-0.01	-0.03	**-0.01**
CIP 32. Real Estate Services	-0.66	-0.52	-0.14	0.06	**-0.37**
CIP 34. Public Administration	-0.02	-0.23	-0.29	-0.37	**-0.19**
Infrastructure II (ppts)	**-0.07**	**-0.43**	**0.10**	**-0.30**	**-0.17**
CIP 02. Coal mining	0.05	0.00	0.00	-0.02	**0.01**
CIP 03. Oil & gas extraction	-0.01	0.00	-0.03	0.00	**-0.01**
CIP 13. Petroleum & coal prod.	0.00	0.00	0.00	-0.05	**-0.01**
CIP 14. Chemicals & allied prod.	-0.03	0.00	0.01	-0.05	**-0.02**
CIP 16. Stone, clay, & glass prod.	0.05	0.01	-0.01	-0.04	**0.01**
CIP 17. Primary & fabri. metals	0.01	0.07	0.00	-0.10	**0.00**
CIP 19. Industrial machinery	-0.12	0.08	0.00	-0.05	**-0.04**
CIP 23. Transport equipment	-0.02	0.03	0.00	0.00	**0.00**
CIP 26. Construction	0.06	-0.13	0.07	-0.02	**0.00**
CIP 27. Wholesale & Retails	-0.01	-0.08	-0.03	0.05	**-0.01**
CIP 31. Financial services	-0.05	-0.41	0.08	-0.01	**-0.10**

Sources: Authors' estimates using the CIP/China-KLEMS data.
Notes: See Table 3 for the aggregate REK effect of "Infrastructure I" and "Infrastructure II" and see Section 5.1 for the industries included in the two groups.

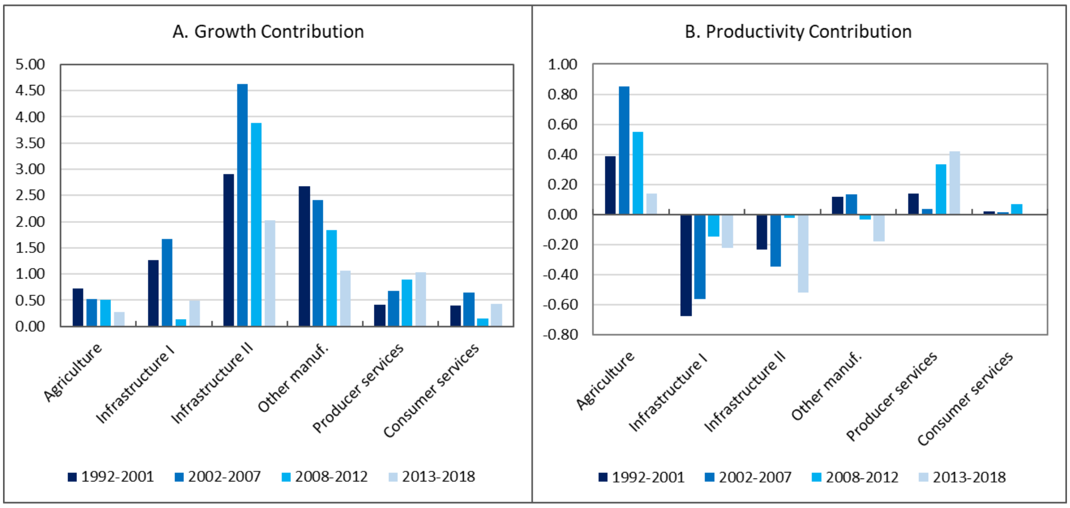
For "Infrastructure II", we find that although most of the material and machinery manufacturers that were stimulated by "Infrastructure I" were not efficient, especially in 2013-2018, it was financial services that were mainly responsible for the inefficient REK or the misallocation of capital. It appears that the involvement of the financial sector reduced rather than enhanced the efficient allocation of capital. This finding supports further reforms of China's financial system.

6. CONCLUDING REMARKS

In this study, we try to identify industries whose growth and productivity performances are affected differently by Chinese government's infrastructure investments through their direct impacts or spillover effects. It covers the reform period from 1992, the time when the CCP officially proposed its "socialist market" blueprint, to 2018 when China began running short of steam in the state-engineered "growth maintaining" policy due to an ever-rising debt.

Methodology wise, we first use a Jorgensonian type of growth accounting approach to decompose the industry origins of China's growth and productivity and to account for the factor reallocation effect on productivity across industries. We then follow Aoki's approach to identify the role of industries in such factor reallocation, yet with a revision to conform to Jorgenson's total output based APPF approach. To better understand the role of individual industries, especially those engaged in the initial infrastructure programs and those influenced by the spillover effects of the former, we innovatively use the impact coefficients through a time series of input-output matrix to regroup the economy wide 37 industries in the CIP/China KLEMS database.

FIGURE 1: GROWTH AND PRODUCTIVITY CONTRIBUTIONS: INFRASTRUCTURE-INFLUENCED INDUSTRIES VIS-À-VIS OTHERS
(All measures in percentage points*)



Sources: Tables 1-3.
Notes: *The sum of industry group contributions for each period equals to the period-specific GDP or TFP growth rate in percent per annum in Tables 1-2. See Section 5.1 for industry grouping.

We show that the industries engaged in the government's initial infrastructure projects ("Infrastructure I") and the industries benefited by the spillover effect of the former ("Infrastructure II") contributed 53 percent of China's 8-percent annual growth rate, or 4.3 percentage point. More importantly, only about one fifth of the contribution is attributable to the initial group, which means that initial infrastructure investment has a strong spillover effect. This finding is in line with our expectation that infrastructure investment is *a growth driver*. Meanwhile, China's total factor productivity grew by only 0.55 percent per annum for the same period, which is hardly considered an efficient growth. By estimation, this is however equal to the TFP gained from industries. On top of that, a 0.75-percent annual TFP growth from labor reallocation across industries was completely offset by the TFP loss from capital reallocation across industries in which the two infrastructure groups played a dominant role (-0.74 percent points) as *a productivity dragger*.

Our most important finding in a nutshell if focusing on the within industry effects, as summarized in Figure 1, answers the alternative questions raised in the title of the study, which is confirmatory to both possibilities. That is, China's infrastructure investment as a policy tool to maintain growth is a double sword in that it not only has driven growth but also reduced productivity. As a growth driver, it only worked for a period. Its impact nevertheless began to weaken when its negative influence on productivity started to bite.

We finish this preliminary draft with two major caveats. The first one is most important and crucial to our innovation in the infrastructure-specific grouping approach. The input-output approach to the grouping may need some empirical tests to further confirm the linkages. The second one is to use the full or three-digit industrial classifications rather than the two-digit system currently in the CIP data, which may help confirm the linkages based on the latter or improve the grouping. A related issue is that if we focus on the more current problem of the growth slowdown, we may consider expanding the CIP data to the three-digit system only for the recent two decades for which the most detailed industry census data are available.

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APPENDIX

TABLE A1

CIP/CHINA KLEMS INDUSTRIAL CLASSIFICATION AND RE-GROUPING

CIP Code	Grouping	Industry	
1	Agriculture	Agriculture, forestry, animal husbandry & fishery	AGR
2	Infrastructure II	Coal mining	CLM
3	Infrastructure II	Oil & gas excavation	PTM
4	Other manufacture	Metal mining	MEM
5	Other manufacture	Non-metallic minerals mining	NMM
6	Other manufacture	Food and kindred products	F&B
7	Other manufacture	Tobacco products	TBC
8	Other manufacture	Textile mill products	TEX

9	Other manufacture	Apparel and other textile products	WEA
10	Other manufacture	Leather and leather products	LEA
11	Other manufacture	Sawmill products, furniture, fixtures	W&F
12	Other manufacture	Paper products, printing & publishing	P&P
13	Infrastructure II	Petroleum and coal products	PET
14	Infrastructure II	Chemicals and allied products	CHE
15	Other manufacture	Rubber and plastics products	R&P
16	Infrastructure II	Stone, clay, and glass products	BUI
17	Infrastructure II	Primary & fabricated metals	MET
18	Other manufacture	Metal products (excluding rolling products)	MEP
19	Infrastructure II	Industrial machinery and equipment	MCH
20	Other manufacture	Electric equipment	ELE
21	Other manufacture	Electronic and telecommunication equipment	ICT
22	Other manufacture	Instruments and office equipment	INS
23	Infrastructure II	Motor vehicles & other transportation equipment	TRS
24	Other manufacture	Miscellaneous manufacturing industries	OTH
25	Infrastructure I	Power, steam, gas and tap water supply	UTL
26	Infrastructure II	Construction	CON
27	Infrastructure II	Wholesale and retail trades	SAL
28	Consumer services	Hotels and restaurants	HOT
29	Infrastructure I	Transport, storage & post services	T&S
30	Producer services	Telecommunication	P&T
31	Infrastructure II	Financial Intermediations	FIN
32	Infrastructure I	Real estate services	REA
33	Producer services	Leasing, technical, science & business services	BUS
34	Infrastructure I	Public administration and defense	ADM
35	Consumer services	Education services	EDU
36	Consumer services	Health and social security services	HEA
37	Consumer services	Other services	SER