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Accounting for the Sources of Growth in the Chinese Economy

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Accounting for the Sources of Growth in the Chinese Economy *

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ABSTRACT

Using a newly constructed China Industrial Productivity (CIP) data set, this study adopts the Jorgensonian aggregate production possibility frontier (APPF) framework incorporating Domar weights to account for the industry origin of China's aggregate growth for the period 1980-2010. We show that 7.14 percentage points of China's gross domestic product (GDP) growth of 9.16% per annum can be attributed to the increase in labor productivity and 2.02 percentage points to the number of hours worked. The labor productivity growth can be further decomposed into 5.55 percentage points of capital deepening, 0.35 percentage points of labor quality improvement, and 1.24 percentage points of total factor productivity (TFP) growth. Across industries, those less prone to government intervention, such as agriculture and "semi-finished & finished" manufacturing industries, appear to be more productive than those subject to more government intervention, typically the "energy" industry group. The Domar aggregation scheme also reveals that only two-thirds of the 1.24% annual TFP growth, or 0.84 percentage points, are directly from industries and the remaining 0.40 percentage points are from a net factor reallocation effect in which labor played a positive role of 0.56 percentage points whereas capital played a negative role of -0.16 percentage points.

Keywords: Aggregate production possibility frontier (APPF), Domar weights, Total factor productivity (TFP), Resource reallocation, Government intervention

JEL Classification: E10, E24, C82, O47

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1. INTRODUCTION

What China has achieved over the past thirty-five years is remarkable in human history, especially given its sheer size and heavy burden from the central planning period. China's unprecedented rapid growth of 9.2 percent per year[1] has not only lifted over 600 million people out of poverty, but also made the country the largest manufacturer and top exporter in the world. Nevertheless, China's strong growth has not come without high cost. China's new government under the leadership of Xi Jinping and Li Keqiang is currently facing a series of key challenges: how to clean up the dirty air, polluted water and tainted food supplies, how to stop severe corruptions that are eroding almost every organ of the government and the communist party, and how to reduce high income inequality in the society.

Underneath these problems is the China model of economy growth that has been heavily relying on government-engineered excessive physical capital investment. The nature of the problem is essentially political. When GDP growth is set up as a political performance indicator by the central government, it is inevitable for local governments to intervene resource allocation and business decision at their discretion. This is because local officials are highly motivated to participate a "growth tournament" with their peers of other localities (Li and Zhou 2005).

Whether China should slow down and shift to a healthier growth model that is reliant on the market to allocate resources has remained in the center of policy debate since the mid 1990s. The central authorities showed their objectives to abandon the extensive growth model in each of the past three "five-year plans". But, the situation has not yet been improved.[2] The debate has been revitalized following the 4-trillion-yuan central government stimulus package accompanied by 18-trillion-yuan projects financed by local governments in the wake of the global financial crisis in 2008-09 which resulted in a new wave of state enterprises-led investment. The new Xi-Li administration has appeared to be on the reform side and agreed to allow the market to play a key role in resource allocation. Indeed, in what is now known as the three-pillared "Liconomics", the new administration seems to be committed to reducing leverage ratio, restricting fiscal injections, and carrying out structural reforms. The government's new strategic move is to transform the Chinese economy from an input-driven to a more productivity-led growth model in the next decade via deeper structural reforms.

However, what has been missing in the debate is a proper productivity analysis. We have seen that the government's heavy involvement has (so far) successfully solved China's growth problem, but it remains unclear to what extent and in which sectors a strong role of government has taken its toll on the economy's efficiency improvement and productivity growth. Ultimately, productivity is the key to an efficient and sustainable growth in any economy. Therefore, this policy debate could be better facilitated and the new strategy could be more clearly addressed by an industry-level productivity analysis.

To analyze China's productivity performance in the light of the role of government, it is essential not only to adopt an appropriate methodological framework that is able to examine

[1] This growth estimate is completely based on official statistics but obtained in a more rigorous growth accounting framework adopted in this study (see growth rates reported in Table 1 and 6). It is lower than the usually cited 10 or nearly 10 percent of official annual average growth rate. However, one may also see Maddison and Wu (2008) and Wu (2013a and 2014a) for a critical scrutiny of the official growth estimates.

[2] See Wu J. (2008) for details of the debate and also see a collection of speeches in the current debate at Boyuan Foundation (a non-government think tank)'s five-year anniversary conference in Beijing (Boyuan 2013).

productivity performances of individual industries integrated and contributing the aggregate productivity performance of the economy, but also to obtain industry production accounts data that are constructed as coherent parts of the national input and output accounts. This "industry perspective" is indispensible because government interventions are often made through industry-specific policies and individual industries with different degrees of government interference may affect other industries through the input-output linkages of the economy.

The present study benefits from a newly constructed economy-wide industry-level data set of the on-going China Industrial Productivity (CIP) Database Project that follows the KLEMS principles in data construction.[3] Methodology-wise, following Jorgenson, Ho and Stiroh (2005a) this study adopts the Jorgensonian aggregate production possibility frontier (APPF) framework that incorporates Domar weights to account for contributions of individual industries to the growth of aggregate inputs and output as well as the growth of aggregate total factor productivity (TFP). This approach relaxes most of the restrictive assumptions of popularly used aggregate production function (APF) in growth accounting that all industries are homogenous, subject to the same value added function and facing the same input and output prices.

The rest of the paper will be organized as follows.[4] Section 2 discusses the role of government in the Chinese economy from an industry perspective. Section 3 introduces the APPF framework incorporating Domar weights. Section 4 briefly explains the features of the CIP data and introduces industry grouping. This is followed by Section 5 to present descriptive observations based on the grouped data. Section 6 reports and discusses empirical results. Finally, Section 7 concludes this study.

2. Considering the Role of the Government

We are interested in whether government involvement has affected the productivity performance of the Chinese economy. This is challenging because policy or institutional factor is not an inherent part of the standard theory of production function, hence difficult to measure. However, government policy is industry-specific and industries are connected through vertical input-output links. Therefore, to explore the role of government we may first consider distinguishing industries with different types of government interventions and then make conjectures about the productivity implications of the interventions.

Despite a significant decline of the state sector in size since the reform, the state monopoly in the so-called "strategic industries" has never been weakened and government interventions in resource allocation have been maintained and even strengthened in the wake of the global financial crisis in 2008. However, one important change since the reform is that government interventions are no longer all-embracive as in the central planning era which completely ignored the market. They have, however, become more industry-specific through

[3] KLEMS is used as an acronym for **K**(C)apital, **L**abor, **E**nergy, **M**aterials and **S**ervices that are used to produce any product. By the same token, the gross output of an industry equals the total costs of "KLEMS" and the gross output of an economy equals the sum of the costs of KLEMS of all industries. See O'Mahony and Timmer (2009) for an introduction of the EU-KLEMS database.

[4] We skip a usual literature review section mainly because almost all studies in the literature do not consider the aggregation across industries in methodology and hence incomparable with the methodology used in this study. We will however compare our results with those of the only similar study by Cao *et al*. (2009) at the last section.

either subsidization or administrative interference or some combination of both. Subsidies can be in direct or indirect form. Indirect subsidies aim to reduce the producer cost of inputs including energy, land, environment, labor and capital (Huang and Tao, 2010). In contrast, direct subsidies which may come with administrative interferences aim to compensate for output losses. Administrative interferences serve the state interests with strategic plans by controlling or influencing output prices or business operations from managerial personnel to the choice of technology.

We may argue that whether or to what extent the government uses administrative interference or different types of subsidization depends on the distance of an industry from the final demand especially the international market. Indirect subsidies have been mainly used by local governments to promote export-oriented manufacturers that make semi-finished and finished goods. Most of these downstream industries are labor-intensive and therefore crucial for China to timely reap its demographic dividend. However, the government tends to directly get involved in upstream industries such as energy and primary input materials industries that are considered strategically important to sustain the growth of downstream industries. Administrative measures such as managerial and price controls are used to ensure that upstream industries can provide sufficient and cheap supplies to downstream industries.

Considering the behavior of enterprises in such a policy environment and its implications for efficiency improvement and productivity growth, we may conjecture that industries that are mainly supported by input subsidies could be more efficient and productive than those that are subject to administrative interferences or direct subsidies for losses. The latter policy instruments will only be counterproductive to competitive industries. When subsidies do not come with administrative interferences in business decision, enterprises may still behave like true market competitors although their competitiveness is arbitrarily enhanced by the cheaper cost of some factors influenced by the government.[5] By contrast, upstream industries are far away from the end market. They are traditionally dominated by state-owned enterprises and do not conform to China's comparative advantage. However, their assumed "strategic importance" gives them strong bargaining power in negotiating for government support. In return they have to accept controls from the authorities. This distorts their behavior and disincentivizes their effort for efficiency improvement or innovation.

The nature of the government interventions and subsidies is a kind of "cross subsidization". The key to sustaining this cross-subsidization is that downstream industries must be able to grow faster and relatively more efficient than upstream industries and the public revenues generated from downstream industries must be able to cover direct subsidies and the cost of externalities due to indirect subsidies.

3. Measuring the Sources of Growth

The widely used aggregate production function (APF) approach to TFP analysis is implicitly subject to very stringent assumptions that for all (underlying) industries "value-added functions exist and are identical across industries up to a scalar multiple" and "the aggregation of heterogeneous types of capital and labor must receive the same price in each industry" (Jorgenson, Ho and Stiroh 2005a). Given heavy government interventions and institutional problems that cause market imperfections in China, APF is inappropriate for the growth accounting exercise of the Chinese economy. Following Jorgenson, Ho and Stiroh

[5] This is conditional on whether they can repeatedly negotiate for benefits regardless their true performance. Here we assume that this is not the case.

(2005a), this study adopts Jorgenson's aggregate production possibility frontier (APPF) framework that incorporates Domar weights to account for contributions of individual industries to the growth of aggregate inputs and output as well as the growth of aggregate total factor productivity (TFP).

The aggregate production possibility frontier (APPF) approach in growth accounting to examine is first developed by Jorgenson (1966). It relaxes one of the APF's strong assumptions that all industries are subject to the same value-added production function to account for the industry origin of aggregate growth. It has been recently used in Jorgenson and Stiroh (2000), Jorgenson (2001) and Jorgenson, Ho and Stiroh (2005a, 2005b) to quantify the role of information technology (IT)-producing and IT-using industries in the US economy. In 1987, Jorgenson, Gollop and Fraumeni introduced Domar weights to the APPF framework to exercise direct aggregation across industries to account for the role of American industries in the changes of aggregate inputs. This approach has also been used recently in Jorgenson, Ho and Stiroh (2005a).

To illustrate this methodology, let us begin with a consideration of the production possibility frontier where industry gross output is a function of capital, labour, intermediate inputs and technology indexed by time. We use individual industries as building blocks which allow us to explicitly trace the sources of aggregate productivity growth and input accumulation to the underlying industries. Focusing on an industry-level production function given by equation (1), each industry, indexed by *j*, purchases distinct intermediate inputs, capital and labour services to produce a set of products:

(1) $$Y_j = f_j(K_j, L_j, M_j, T)$$

where *Y* is output, *K* is an index of capital service flows, *L* is an index of labour service flows and *M* is an index of intermediate inputs, either purchased from domestic industries or imported. Note that all input variables are indexed by time but suppressed for convenience.

Under the assumptions of competitive factor markets, full input utilization and constant returns to scale, the growth of output can be expressed as the cost-weighted growth of inputs and technological change, using the translog functional form:

(2) $$\Delta \ln Y_j = \bar{v}_j^K \Delta \ln K_j + \bar{v}_{jt}^L \Delta \ln L_j + \bar{v}_j^M \Delta \ln M_j + v_j^T$$

where $\bar{v}_j^K$, $\bar{v}_j^L$ and $\bar{v}_j^M$ are two-period average of nominal weights of input $v_j^K = \frac{P_j^K K_j}{P_j^Y Y_j}$, $v_j^L = \frac{P_j^L L_j}{P_j^Y Y_j}$ and $v_j^M = \frac{P_j^M M_j}{P_j^Y Y_j}$, respectively. Note that $v_j^K + v_j^L + v_j^M = 1$ which is controlled by industry production accounts in nominal terms. Each input as expressed in the right-hand side of equation (2) indicates the proportion of output growth accounted for respectively by the growth of capital services ($\bar{v}_j^K \Delta \ln K_j$), labour services ($\bar{v}_j^L \Delta \ln L_j$), intermediate materials ($\bar{v}_j^M \Delta \ln M_j$) and total factor productivity (v_j^T).

One of the advantages of this approach is that it can better account for each input services by different types. For example, it can account for labor services provided by different types of labor with specific demographic, educational and industrial attributes, thanks to the pioneer studies by Griliches (1960), Denison (1962) and Jorgenson and Griliches (1967). It has relaxed the usual strong assumption that treats numbers employed or hours worked as a homogenous measure of labor input. We can define the growth of total labor input as a Törnqvist quantity index of individual labour types as follows:

(3a) $$\Delta \ln L_j = \sum_h \bar{v}_{h,j} \Delta \ln H_{h,j}$$

where $\Delta \ln H_{h,j}$ indicates the growth of hours worked by each labour type *h* (with specific gender, age and education attainment) and its cost weights $\bar{v}_{h,j}$ given by two-period average shares of each type in the nominal value of labour compensation controlled by the labor income of industry production accounts.

The same user-cost approach is also applied to *K* and M to account for the contribution of different types of capital asset and intermediate input in production (with two-period type-specific cost weight defined as $\bar{v}_{k,j}$ and $\bar{v}_{m,j}$, respectively):

(3b) $$\Delta \ln K_j = \sum_k \bar{v}_{k,j} \Delta \ln Z_{k,j}, \text{ and}$$

(3c) $$\Delta \ln M_j = \sum_m \bar{v}_{m,j} \Delta \ln M_{m,j}$$

It should be noted that equations (2) through the set of (3) also explicitly express the methodological framework for our industry-level data construction that is linked to and controlled by the national production and income accounts. This point will be discussed again when we discuss the data issue in the following section.

Since aggregation is a value-added concept, equation (2) can be rewritten as:

(4) $$\Delta \ln Y_j = \bar{v}_j^V \Delta \ln V_j + \bar{v}_j^M \Delta \ln M_j$$

where V_j is the real value-added in *j* and v_j^V is the nominal share of value-added in industry gross output.

Now if rearranging equations (2) and (4), we can obtain an expression for the sources of industry value-added growth (i.e. measured in terms of input contributions):

(5) $$\Delta \ln V_j = \frac{\bar{v}_j^K}{\bar{v}_j^V} \Delta \ln K_j + \frac{\bar{v}_j^L}{\bar{v}_j^V} \Delta \ln L_j + \frac{1}{\bar{v}_j^V} v_j^T$$

The growth of aggregate value-added by the APPF approach can be expressed as weighted industry value-added in a Törnqvist index:

(6) $$\Delta \ln V = \sum_j \bar{w}_j \Delta \ln V_j$$

where w_j is the share industry value-added in the aggregate value-added. If combining equations (5) and (6), we introduce Domar weights, i.e. a ratio of each industry's share in total value-added (w_j) to the proportion of the industry's value-added in its gross output (v_j^V) and yield a new expression of aggregate value-added growth with weighted contribution of industry capital growth, industry labor growth and TFP growth:

(7) $$\Delta \ln V \equiv \sum_j \overline{w}_j \Delta \ln V_j = \sum_j \overline{w}_j \frac{\overline{v}_j^K}{\overline{v}_j^V} \Delta \ln K_j + \overline{w}_j \frac{\overline{v}_j^L}{\overline{v}_j^V} \Delta \ln L_j + \overline{w}_j \frac{1}{\overline{v}_j^V} v_j^T$$

Since the aggregate TFP growth obtained by the APPF approach can be defined as:

(8) $$v^T \equiv \sum_j \overline{w}_j \Delta \ln V_j - \overline{v}^K \Delta \ln K - \overline{v}^L \Delta \ln L$$

if subtracting equation (7) from equation (8) and rearranging, we can show how the aggregate TFP growth under APPF relates to the sources of TFP growth at the industry level and to the TFP effect of factor mobility across industries (Jorgenson, Ho and Stiroh 2005):

(9) $$\begin{aligned} v^T = & \left(\sum_j \frac{\overline{w}_j}{\overline{v}_j^V} v_j^T \right) \\ & + \left(\sum_j \overline{w}_j \frac{\overline{v}_j^K}{\overline{v}_j^V} \Delta \ln K_j - \overline{v}_K \Delta \ln K \right) \\ & + \left(\sum_j \overline{w}_j \frac{\overline{v}_j^L}{\overline{v}_j^V} \Delta \ln L_j - \overline{v}_L \Delta \ln L \right) \end{aligned}$$

in which the *reallocation* terms in the second and third brackets can be simplified by using a Greek letter ρ, that is:

(9') $$v^T = \sum_j \frac{\overline{w}_j}{\overline{v}_j^V} v_j^T + \rho^K + \rho^L$$

Equation (9) expresses the aggregate TFP growth in terms of three sources: Domar-weighted industry TFP growth, reallocation of capital and reallocation of labor across industries. This Domar weighting scheme ($\overline{w}_j / \overline{v}_j^V$), originated by Domar (1961), plays a key role in the direct aggregation across industries of the Jorgensonian growth accounting framework. A direct consequence of the Domar-aggregation is that the weights do not sum to unity, implying that aggregate productivity growth amounts to more (less) than the weighted average of industry-level productivity growth. This reflects the fact that productivity change in the production of *intermediate inputs* do not only have an "own" effect but in addition they lead to reduced or increased prices in downstream industries, and that effect accumulates through vertical links.

As clearly elaborated by Hulten (1978), the Domar aggregation establishes a consistent link between industry level and aggregate productivity growth. Productivity gains of the aggregate economy may exceed the average productivity gains across industries because flows of intermediate inputs between industries contribute to aggregate productivity by allowing productivity gains in successive industries to augment one another. Equally important, the same logic can explain productivity losses.

The next two terms reflect the impact on aggregate TFP growth of the reallocation effect of capital (ρ^K) and labor (ρ^L) across industries, respectively. Each of the reallocation term is obtained by subtracting aggregate cost-weighted factor (capital or labor) input growth from the Domar-weighted industry growth. It should be noted that both theoretically and methodologically, when these terms are not negligible, it indicates that industries do not face the same factor costs, which suggests a violation of the assumption of widely used APF. However, one should not expect a significant reallocation effect in an economy where there is a well developed market system. This is a very useful analytical tool in the case of China where strong government interventions in resource allocation may cause severe market distortions.

4. Data Issues, Industry Grouping, and Periodization

Data issues

As briefly introduced at the beginning, this study has benefited from a newly constructed economy-wide, industry-level data set from the on-going CIP Project (now downloadable from CIP 3.0 database). It is certainly beyond the scope of this study to go through a series of painstaking work behind the data.[6] Note that most of the details for the current version of the CIP data are now available in three of RIETI Discussion Papers (Wu 2015; Wu and Ito 2015; Wu, Yue and Zhang 2015) as well as their earlier (incomplete) versions for development of ideas on data construction (Wu 2008 and 2012; Wu and Yue 2010 and 2012).

In the CIP Project the principles of data construction regarding the underlying theory and data handling methodology exactly follow what expressed in equation (2) and the set of equations (3a, 3b and 3c). It should be emphasized that in both concept and practice the construction of the industry-level data is linked to and controlled by the national production and income accounts which are also cleaned up for consistencies. In this sense, the CIP database should be considered as China KLEMS database.

Some features of the CIP data worth noting. In industrial classification, we in principle adopt the 2002 version of the Chinese Standard Industrial Classification (CSIC/2002) and based on which reclassify the economy into 37 industries (Appendix Table A1).[7] The reconstruction of Chinese national accounts is based on different versions of official national accounts compiled under MPS (prior to 1992) and SNA. We also use SNA input-output accounts available for every five years since 1987, plus a MPS input-output table for 1981 that has to be converted to a SNA-type table. Following a supply-use table (SUT)

[6] The CIP project is based on Wu's China Growth and Productivity Database (Wu/CGPD) 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). CIP began in 2010 aiming to extend Wu's earlier work to all industries in the KLEMS framework.

[7] This is based on Wu's series of works to reclassify official statistics reported under different CSIC systems adopted in CSIC1972, CSIC1985 and CSIC1994 (see Wu and Yue, 2012). The current classification largely conforms to the 2-digit level industries of the ISIC (Rev. 4) and can be well reconciled with the EU-KLEMS system of classification (Timmer et al., 2007).

framework CIP has also constructed a time series of Chinese input-output accounts for 1981-2010. The nominal accounts are deflated by CIP industry-level producer price index (PPI), constructed using official PPIs for the agricultural and industrial sectors and CPI components for the service sectors (Wu and Ito 2015). Due to insufficient information on prices of services, in the present study we assume that both input and output face the same producer prices. This strong assumption is yet to be relaxed in our future analysis.[8]

For the required labor data, following earlier studies by Wu and Yue (2003, 2010 and 2012) that only focused on the industrial sector, CIP has established economy-wide employment (numbers employed and hours worked) and compensation matrices for 37 industries, cross-classified by two gender, seven age groups and 5 education categories (Wu, Yue and Zhang 2015).

The construction of net capital stock for each industry is most challenging. CIP has reworked with inappropriately complied official gross stock at historical costs to reestablish the annual flows of investment for 24 industries of the industrial sector. But it has to directly adopt official estimates of investment for the non-industrial sectors. The results are yet to be reconciled with the national accounts gross fixed capital formation data. Industry-specific investment depreciation rate is estimated using official information on asset service lives and the "standard" declining balance approach developed by Hulten and Wykoff (1981). Industry-specific investment deflator is constructed using PPIs of investment goods industries and wage index of construction workers, taking into account official investment deflator and purchase prices of industrial assets (Wu and Xu 2002; Wu 2008 and 2015).

Industry grouping

To investigate the TFP performance of industries located in different positions of the production chain which, as argued earlier, are subject to different degrees of government intervention, we categorize the 37 industries into eight groups. Following Wu (2013b, 2013c) we can first consider dividing 24 industries of the industrial sector into three groups, namely "energy", "commodities and primary input materials (C&P)", and "semi-finished and finished goods (SF&F)". C&P and SF&F have been the key drivers of China's post-reform growth. According to their "distances" from the final demand, the "energy" group stays on the top of the production chain (upstream), which is followed by C&P in the middle and SF&F closest to the end market.

The rest of the grouping cannot be easily done in terms of the "distance" from the end market. Although the agricultural sector may often be considered serving the final demand, it provides important intermediate inputs to food processing and manufacturing industries. In this sense, it should be classified as an upstream rather than downstream. Construction should also be regarded as mainly upstream although it also supplies the final goods i.e. residential housing to consumers. Next, services are divided into three groups. Services I consists of state-monopolized "strategic services", namely financial intermediaries, transportation and telecommunication. Services II covers the rest of services but excluding the SNA defined "non-market services" i.e. government administration, education and healthcare which are grouped into Services III.

[8] See Wu and Ito (2014) for a comparison of China's real value added estimated by single and double (standard) deflation approaches based on input-output accounts, respectively.

This particular grouping aims to analyze industry group-level productivity performance with respect to different types and degrees of government intervention in resource allocation. This may facilitate the on-going policy debate on China's strategic move to a new development model that can promotes efficiency and productivity-led growth rather than continuously relying on the input-driven extensive expansion over the past thirty-five years. It is easier to understand the grouping if focusing on the three industrial groups, i.e. "energy", "commodities and primary input materials" and "semi-finished and finished goods".

The "energy" group is monopolized by large, central government-owned enterprises due to its "strategic importance". In addition to easy access to public resources and subsidies, it is subject to more administrative interferences or stronger state interventions. The "commodities and primary input materials" group is the next important group that is also heavily influenced, if not completely owned, by the government. Finally, the "semi-finished and finished goods" group consists of all private enterprises including foreign invested enterprises. Although "semi-finished" industries also include some state-owned enterprises, especially in heavy machinery industry, its competitive nature makes it very difficult for the state to directly interfere its business decision. Besides, compared to upstream groups, "SF&F", especially "semi-finished" industries, are more labor-intensive and hence more in line with China's comparative advantage. We can therefore conjecture that government interventions to "SF&F" tend to be indirect through subsidies rather than administrative controls, hence leaving more room for enterprises to engage in market competitions.

We can also have conjectures about productivity implications of non-industrial groups. One should not expect heavy and direct administrative interference to the agricultural group largely because of the nature of family-based small-size farming. A reformed Chinese agriculture could have become more productive than it was under central planning because of correction to price distortions, hence improved terms of trade with the industrial and urban sectors, and deregulations on the reallocation of labor and land. As for the rest groups, the non-market Services III group is expected to be least productive as often observed in history (Griliches 1992; van Ark 1996). On the other hand, the state-monopolized "Services I" is likely to be less productive than Services II and construction.

Periodization

To better examine the impact of major policy regime shifts on the Chinese economy, especially on the productivity performance of the economy, we can divide the entire period 1980-2010 covered in the current version of the CIP data into four sub-periods, namely 1980-1991, 1992-2001, 2002-2007 and 2008-2010. In most cases, the results of the basic data work and empirical findings are reported in line with this periodization.

The first sub-period covers China's agricultural reform and early industrial reform through increased operational autonomy and planning and market double-track price system. It should be noted that this is a period that should be expected to have reform-induced shocks to the traditional planning system. It was ended by rising inflation and corruption that triggered the 1989 Tiananmen political turmoil.

The second sub-period began with Deng's call for bolder and deeper reforms in 1992 and the official adoption of the so-called "socialist market economy" in 1993, which kicked off a series of reforms to the state sector and the urban economy. In this period, wider opening-up to the western technology and foreign direct investment drove China into a new wave of investment in the world class manufacturing technology and capacity. Meanwhile deregulations to the private sector helped absorb a huge number of the former state industrial employees who lost jobs in the reform. This period ended up with a four-year long deflation caused by both overinvestment and the shock of the Asian financial crisis (1997-98).

The third sub-period began with China's WTO entry in the end 2001. It however experienced mixed changes in the economy. On one hand, WTO-induced deeper opening up to foreign trade and direct investment further directed the Chinese economy towards the market system; on the other hand, consolidated and enlarged state corporations resurged in the name of protecting and enhancing national interests in the time of accelerating globalization. Meanwhile, growth-motivated local governments, pressured by the "GDP race" with their peers, became ever more involved in local business.

It is justifiable to define the last, though rather short sub-period to begin with the global financial crisis in 2008. To reduce the impact of the crisis, the government initiated an unprecedented stimulus package of four trillion yuan, further accompanied by 18 trillion yuan from local government projects, which substantially enhanced the role of state-owned enterprises and projects under the government controls. Separating this period from others helps examine both China's productivity performance at time of the crisis and the effect of an enhanced role of the state sector.

5. Descriptive Observations from the Data Work

Before proceeding to more rigorous total factor productivity analysis in the next section, an examination of the major indicators based on the CIP 3.0 data may help explore not only the underlying efficiency and productivity performances of the Chinese economy as a whole and cross major industry groups, but also implications for the role of the state.

Observations of the aggregate economy

Let us start with some major aggregate indicators for the total economy presented in Table 1 and Figure 1. One general conclusion that can be made from these indicators is that the Chinese economy underwent an increasingly investment-driven growth over the period 1980-2010. There are some important observations to support this view.

Table 1

Annualized Growth Rate of Gross Value-Add, Hours Worked, Net Capital Stock, Labor Productivity, Capital Deepening and Capital-Output Ratio

(Percent per annum)

	Value added (Y)	Net capital stock (K)	Hours worked (H)	Y/L*	K/L*	K/Y
1980-1991	7.3	9.5	2.8	4.5	6.7	2.2
1991-2001	9.7	12.2	1.8	7.9	10.4	2.5
2001-2007	12.0	15.6	1.5	10.4	14.0	3.6
2007-2010	11.2	18.6	0.8	10.4	17.8	7.4
1980-2010	*9.4*	*12.5*	*2.0*	*7.4*	*10.5*	*3.1*

Source: Author's calculation based on CIP 3.0 database.

Note: *Labor here is measured as standardized numbers employed of 2200 hours worked per worker/year, not yet cost-weighted. See the data section for homogenous measure of labor input in empirical analysis.

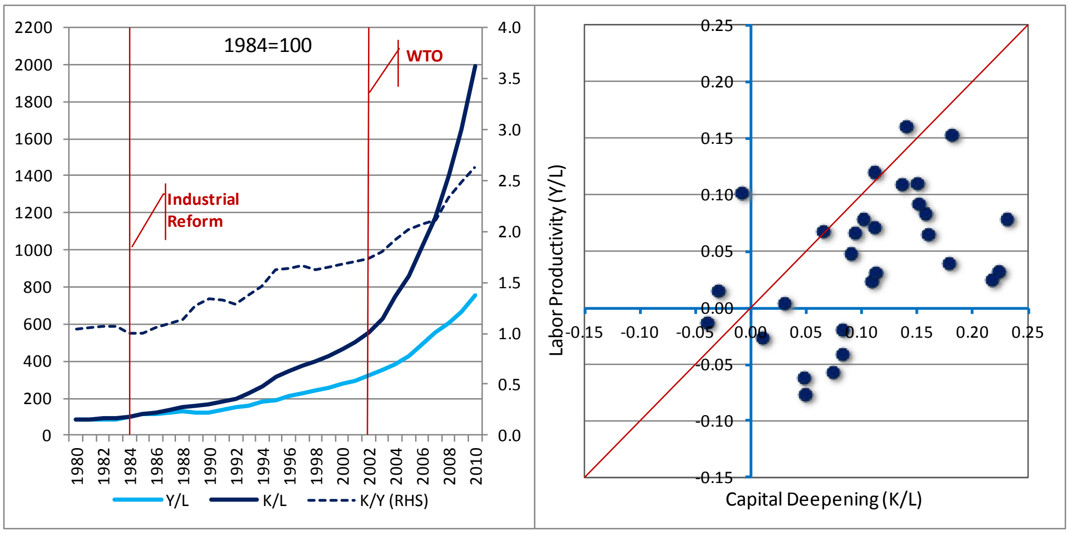
First, the growth performance of the real output, measured in gross value-added (Y), did not proportionally match the growth of the net capital stock. It appears to be that since the 1990s, an increasingly faster capital stock growth was required to maintain the same rate of output growth. Second, the sub-period in the wake of the global financial crisis in 2008-10 showed some significant change. When the growth of capital stock jumped to 18.6 percent per year from 15.6 percent per year during the post WTO period 2001-07, the growth of output somehow slowed down from 12.0 to 11.2 percent. Meanwhile, capital deepening accelerated from 14.0 to 17.8 percent per year, whereas the growth of labor productivity stagnated!

Consequently, there was an astonishing jump in the growth of capital-output (K/Y) ratio from 3.6 percent per year in 2001-07 to 7.4 percent per year in 2007-10. In terms of level measure in 1990 constant price, China's labor productivity increased from 1,760 yuan in 1980 to 16,232 yuan in 2010, whereas China's capital stock per (standardized) worker increased from 1,644 yuan to 37,479 yuan during the same period. This pushed China's capital-output (K/Y) ratio to have increased from 0.9 in 1980 to 2.4 in 2010 (derived from the CIP database).

Third, from Table 1 we can also observe that China experienced a continuous growth slowdown in the quantity of employment, measured as hours worked. This is consistent with the observation that China's policy-induced premature demographic transition has nearly exhausted the supply of working-age population by the end of 2000s (Cai 2010).

FIGURE 1

CHANGES OF LABOR PRODUCTIVITY VERSUS CAPITAL DEEPENING IN THE CHINESE ECONOMY



Source: Author's calculation based on CIP 3.0 data.

Figure 1 presents dynamic charts to substantiate the period-average observations in Table 1. The left-hand panel shows a set of 1984-based indices for labor productivity and capital deepening. The 1984 benchmark is used to show the starting point of China's full scale urban and industrial reform. It is a time-series interpretation of the "unbalanced growth" between investment and output shown in Table 1. Obviously, in terms of capital deepening China's labor productivity growth has become increasingly "costly", especially post WTO.

TABLE 2
ANNUALIZED GROWTH RATE OF GROSS VALUE-ADD, HOURS WORKED AND NET CAPITAL STOCK BY INDUSTRY GROUP
(Percent per annum)

	Agriculture			Construction			Energy			Commodities & Primary Materials (C&P)		
	VA	Net K	Hours	VA	Net K	Hours	VA	Net K	Hours	VA	Net K	Hours
1980-1991	5.8	5.1	1.4	8.3	8.4	8.9	-2.2	10.2	5.1	5.9	10.0	4.7
1991-2001	6.2	8.5	0.0	11.1	13.5	6.0	6.4	12.8	-0.8	10.6	7.8	-1.6
2001-2007	3.9	11.5	-3.7	12.3	13.5	1.8	10.1	13.9	5.5	11.8	12.9	3.9
2007-2010	4.6	19.3	-2.8	14.1	14.7	7.5	3.5	13.5	1.2	9.1	18.5	1.2
1980-2010	*5.4*	*8.9*	*-0.5*	*10.6*	*11.8*	*6.4*	*3.7*	*12.1*	*2.8*	*9.0*	*10.7*	*2.1*
	Semi-Finished & Finished Goods (SF&F)			Services I			Services II			Services III (Non-market)		
	VA	Net K	Hours	VA	Net K	Hours	VA	Net K	Hours	VA	Net K	Hours
1980-1991	11.1	9.2	2.4	11.7	10.0	5.6	11.5	10.6	6.4	7.0	11.5	4.7
1991-2001	14.6	9.2	0.1	5.8	17.7	1.7	10.1	18.0	6.9	7.6	13.3	6.4
2001-2007	15.8	13.9	7.1	13.1	13.7	4.3	11.5	19.4	5.2	12.9	21.0	5.0
2007-2010	13.7	20.7	3.0	10.5	14.9	0.7	12.9	20.5	1.8	10.2	22.6	1.6
1980-2010	*13.5*	*11.3*	*2.6*	*9.9*	*13.8*	*3.5*	*11.2*	*15.8*	*5.9*	*8.7*	*15.1*	*5.0*

Source: Author's calculation based on CIP 3.0 data.

TABLE 3
STRUCTURAL CHANGES OF THE CHINESE ECONOMY BY INDUSTRY GROUP, SELECTED BENCHMARK YEARS
(Total Economy = 1)

	Agriculture	Construction	Energy	C&P	SF&F	Services I	Services II	Services III
				Value Added				
1980	0.308	0.043	0.093	0.173	0.167	0.064	0.100	0.052
1992	0.220	0.053	0.057	0.150	0.172	0.116	0.169	0.063
2002	0.137	0.054	0.082	0.125	0.188	0.121	0.203	0.091
2008	0.107	0.060	0.087	0.137	0.191	0.122	0.210	0.087
2010	0.101	0.066	0.078	0.126	0.197	0.119	0.228	0.085
				Net Capital Stock				
1980	0.115	0.014	0.179	0.262	0.221	0.064	0.098	0.047
1992	0.074	0.013	0.185	0.252	0.206	0.077	0.129	0.064
2002	0.054	0.016	0.181	0.155	0.159	0.132	0.229	0.074
2008	0.040	0.012	0.176	0.151	0.155	0.104	0.265	0.097
2010	0.042	0.012	0.156	0.146	0.152	0.100	0.282	0.110
				Hours Worked				
1980	0.635	0.022	0.014	0.062	0.117	0.030	0.074	0.046
1992	0.541	0.044	0.018	0.075	0.112	0.038	0.110	0.063
2002	0.437	0.067	0.014	0.053	0.093	0.040	0.204	0.092
2008	0.320	0.071	0.018	0.063	0.139	0.047	0.231	0.110
2010	0.299	0.083	0.017	0.063	0.142	0.047	0.236	0.113

Source: Author's calculation based on CIP 3.0 data.

In the right-hand panel of Figure 1, we show how changes in labor productivity (Y/L) responded to changes in capital deepening (K/L) overtime. It confirms our earlier observations from a different perspective. That is, an increase in K/L did not necessarily bring out the same increase in Y/L as indicated by a 45-degree diagonal. Sometimes, an increase in capital stock per worker could be accompanied by a much slower growth or even a decline in output per worker.

Observations by industry group

To have a group-wise view, we can present the same input and output indicators as examined for the aggregate economy for each of the eight groups in Table 2 and structural changes of the economy across these groups in Table 3. To explore group-wise productivity performance in the light of government intervention and influence, let us go through changes in labor productivity and capital deepening in Table 4 and their indices and relationship in Figure 2 and 3.

Table 2 shows that over the entire period the "finished & semi-finished goods" group experienced the most rapid growth in value-added by 13.5 percent per annum. More importantly, it is also the only group that enjoyed a much faster growth in value-added than that of the growth in net capital stock. The productivity implication of this observation is well in line with our conjecture arguing that "SF&F" could be one of the most productive groups due to perhaps the least administrative controls. This of course has to be tested in more rigorous growth accounting in the next section. If shifting to sub-periods, a faster value-added growth relative to capital stock growth can be also observed in agriculture and two groups of market services (Services I and II) in 1980-91 (e.g. in agriculture 5.8 percent per annum in value-added growth compared to 5.1 percent in capital stock growth) and in "commodity & primary materials" in 1991-2001.

We can observe that Services II and III underwent the most rapid growth in capital stock in the post-WTO period (2001-07), 20.5 and 22.6 per annum, respectively (Table 2). However, in the wake of the government stimulus in 2007-10 it was "commodity & primary materials", "finished & semi-finished goods" and agriculture groups that showed the highest jump in the growth of capital stock compared to their performance in 2001-07, i.e. 18.5 versus 12.9 in "C&P", 20.7 versus 13.9 in "SF&F", and 19.3 versus 11.5 in agriculture). This suggests that these sectors, especially "SF&F" and "C&P", were the focus of the government rescue program during the global financial crisis. This may be easily understood because they were the main driver of China's post WTO growth and hence most hit by the crisis**.**

Turning to changes in employment, it shows that as one may expect, hours worked in agriculture declined absolutely by -0.5 percent per annum over the entire period, whereas hours worked in construction increased most rapidly by 6.4 percent per annum. Nevertheless, in the heydays following China's WTO entry when Chinese manufacturing began to triumph over the world, the "finished & semi-finished goods" group was the most important contributor to China's employment growth with the record high of 7.1 percent annual growth in hours worked in 2001-07.

Such divergences in input and output growth across these industry groups resulted in the structural changes of the economy in terms of value added (in nominal terms), capital stock and hours worked. As shown in Table 3, agriculture lost two thirds of its share in total value-added and capital stock, only 10.1 and 4.2 percent in 2010 compared to 30.8 and 11.5

percent, respectively, in 1980. Agriculture also lost over half of its share in total hours worked from 63.5 in 1980 to 29.9 percent in 2010. Meanwhile, the three industrial groups more or less maintained their aggregate shares (sum of the three) in total value-added (43.3 in 1980 and 40.0 in 2010) and employment (19.3 in 1980 and 22.2 in 2010), but lost about one third of their share in capital stock (declining from 66.2 in 1980 to 45.4 in 2010). This means that compared to the pre-reform period, China's industrial sector has become less capital-intensive after thirty years of market-oriented reforms, which is a significant change conforming to China's comparative advantage. Of the three groups, "SF&F" experienced the most significant increase in its share in output and employment. Besides, all types of services significantly gained their shares in all input and output measures except for the state-monopolized services (Services I) in the case of employment.

Table 4 further helps us explore the underlying efficiency problem across these groups by demonstrating dynamics of group-level labor productivity (Y/L) and capital deepening (K/L). Again, we can see that since the mid 1990s only "SF&F" shows a faster labor productivity growth relative to that of capital deepening, and hence a declining in capital-output ratio (K/Y). It appears that all other groups increasingly relied on faster capital deepening to increase labor productivity, among which "energy" and Services III show the largest gap in growth between Y/L and K/L. These changes can be more intuitively examined in terms of growth indices for each indicator and each group in Figure 2 and from a simple Y/L and K/L relationship plotting for each group in Figure 3.

Note that in Figure 2, to help inter-group comparison, all groups are presented in the same scales (both left and right-hand scales) except for "energy", Services I and III because they appear to be outliers that cannot be accommodated by the common scales. In Figure 3 it is no need to maintain the same scale in y-axis and x-axis for each group because we can use the 45-degree diagonal to pick up the "winners" and "losers" in productivity.

In Figure 2, in terms of the "relative pace" of labor productivity growth to the change of capital deepening, the best performers appear to be "SF&F" followed by "C&P" and the poorest performers appear to be "energy" and Services III groups. These are similarly observed in Figure 3. However, Figure 3 also suggests that construction and Services I performed better than average (see Figure 1).

To be emphasized again that the above examinations are only useful preparations in terms of understanding the properties of the data and intuitively exploring the distinct features of different groups for which we can conjecture the likely impact of different types of government interferences in pursuing "strategic development".

TABLE 4

ANNUAL CHANGE OF LABOR PRODUCTIVITY, CAPITAL-LABOR AND CAPITAL-OUTPUT RATIOS BY INDUSTRY GROUP

(Percent per annum)

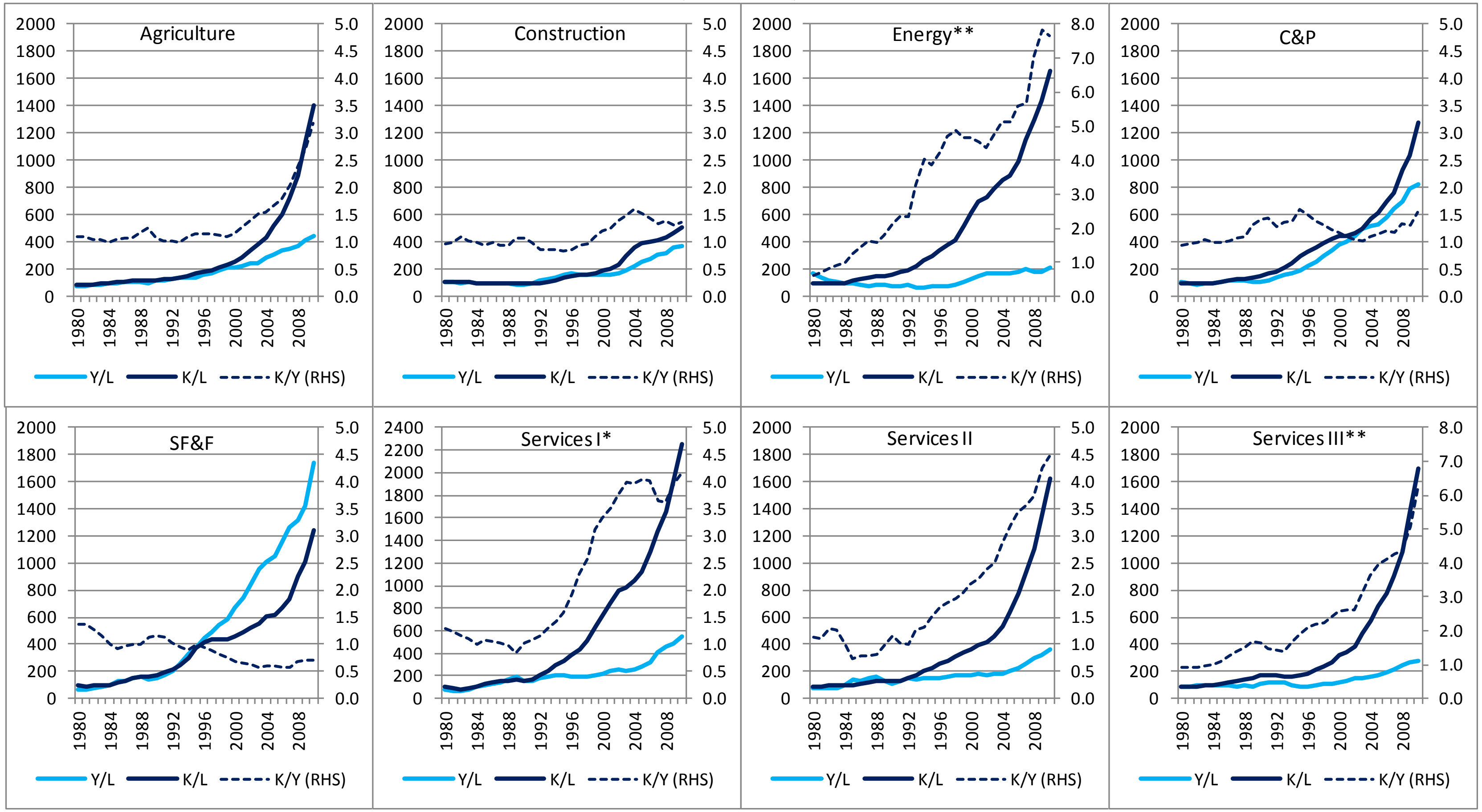
	Agriculture			Construction			Energy			Commodities & Primary Materials (C&P)		
	Y/L	K/L	K/Y	Y/L	K/L	K/Y	Y/L	K/L	K/Y	Y/L	K/L	K/Y
1980-1991	4.3	3.7	-0.6	-0.7	-0.5	0.2	-7.3	5.1	12.4	1.2	5.3	4.1
1991-2001	6.2	8.5	2.2	5.0	7.4	2.4	7.2	13.6	6.5	12.2	9.4	-2.8
2001-2007	7.6	15.2	7.6	10.4	11.7	1.2	4.6	8.4	3.8	7.9	9.0	1.1
2007-2010	7.4	22.2	14.8	6.6	7.2	0.6	2.3	12.3	10.0	7.9	17.3	9.4
1980-2010	*5.9*	*9.4*	*3.5*	*4.2*	*5.3*	*1.2*	*0.9*	*9.3*	*8.5*	*6.9*	*8.6*	*1.7*
	Semi-Finished & Finished Goods (SF&F)			Services I			Services II			Services III (Non-market)		
	Y/L	K/L	K/Y	Y/L	K/L	K/Y	Y/L	K/L	K/Y	Y/L	K/L	K/Y
1980-1991	8.7	6.8	-1.9	6.1	4.4	-1.7	5.1	4.2	-0.9	2.3	6.8	4.5
1991-2001	14.5	9.1	-5.4	4.2	16.0	11.8	3.3	11.1	7.8	1.2	6.9	5.7
2001-2007	8.8	6.8	-1.9	8.9	9.4	0.5	6.3	14.3	7.9	8.0	16.0	8.0
2007-2010	10.7	17.6	6.9	9.8	14.2	4.4	11.1	18.7	7.6	8.6	20.9	12.4
1980-2010	*10.8*	*8.6*	*-2.2*	*6.4*	*10.2*	*3.9*	*5.3*	*9.9*	*4.6*	*3.7*	*10.1*	*6.4*

Source: Author's calculation based on CIP 3.0 data.

FIGURE 2

INDICES OF LABOR PRODUCTIVITY, CAPITAL DEEPENING AND CAPITAL-OUTPUT RATIO BY INDUSTRY GROUP

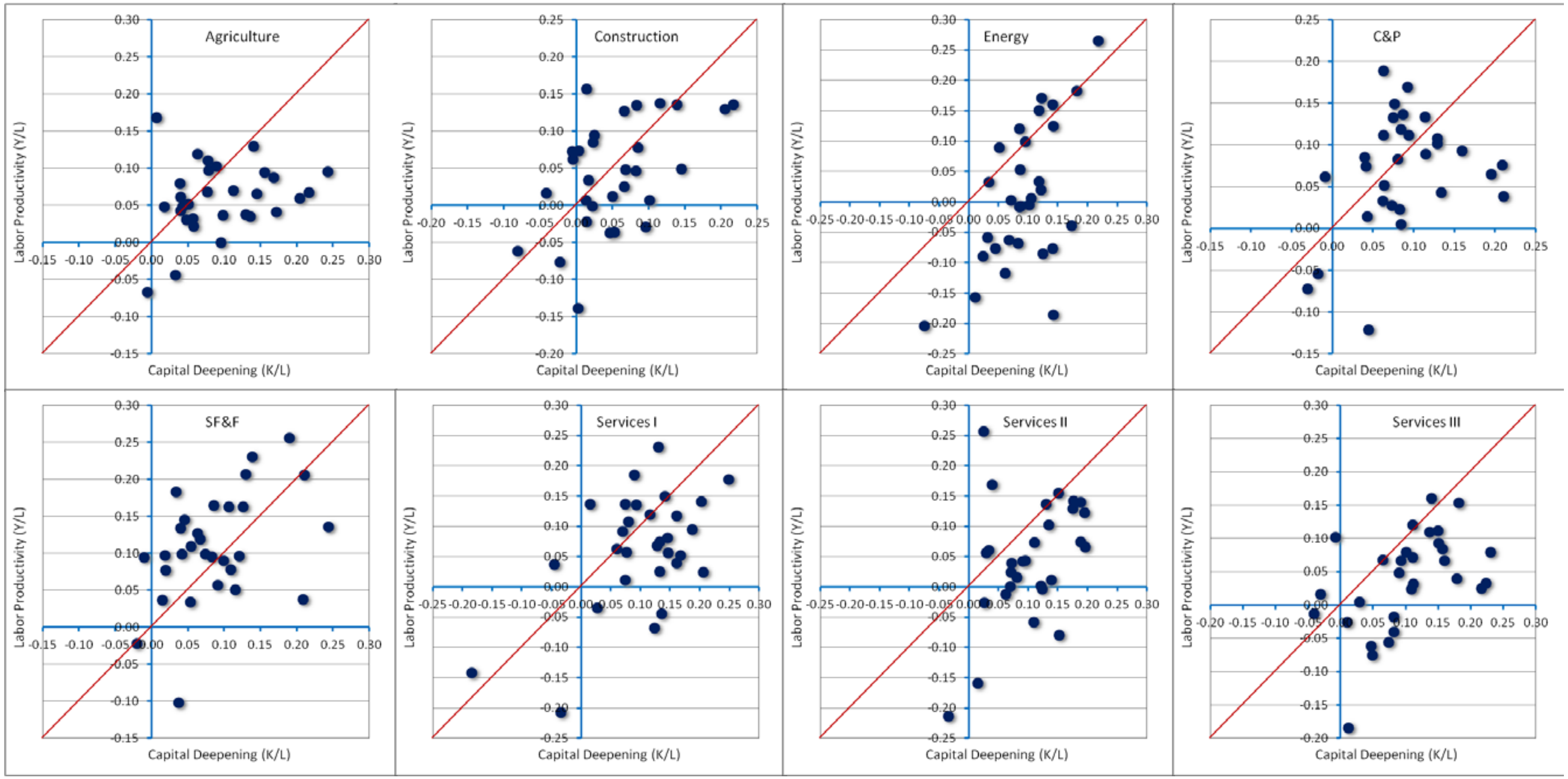
(1984 = 100)



Source: Author's calculation based on CIP 3.0 data.

Note: *Left-hand scale is different from other panels. ** Right-hand scale is different from other panels.

FIGURE 3
LABOR PRODUCTIVITY VERSUS CAPITAL DEEPENING IN THE CHINESE ECONOMY BY INDUSTRY GROUP



Source: Author's calculation based on CIP 3.0 data.

6. EMPIRICAL RESULTS

Sources of gross output growth by industry group

Let us start with an examination of industry-level sources of growth based on a gross output production function following equation (2). This is a necessary starting point because industries are building blocks of the national economy and the origins of the national productivity growth. This examination takes a direct or "simple view" of industry growth performance rather than an integrated view through sophisticated weighting such as in equation (9) in the rest part of this section. However, since the performance of each industry group is analyzed by a production function, despite its simple and direct nature, it still provides a more insightful view than what we have observed for these groups through Tables 2 to 4 and Figures 2 to 3. The results are summarized as sub-period average values of each input and output in Table 5.

TABLE 5
DECOMPOSITION OF GROSS OUTPUT GROWTH IN CHINA BY INDUSTRY GROUP
(Gross output-weighted annual growth rate in percent)

	GO	L	K	M	TFP	GO	L	K	M	TFP
	1980-1991					1991-2001				
Agriculture	6.7	0.8	1.0	2.8	2.2	7.3	0.6	0.7	3.5	2.4
Construction	7.4	2.0	0.6	5.1	-0.3	12.5	1.1	1.4	9.3	0.7
Energy	0.9	0.5	3.5	1.9	-5.0	7.0	-0.1	3.4	4.7	-1.0
C&P	7.9	0.4	2.4	5.9	-0.9	11.0	-0.1	1.4	8.0	1.6
SF&F	13.6	0.2	2.1	10.0	1.2	14.8	0.1	1.7	10.9	2.2
Services I	11.0	0.9	5.2	3.3	1.6	7.3	0.6	6.5	3.9	-3.7
Services II	11.0	1.5	2.7	5.4	1.4	9.9	1.5	6.0	4.7	-2.3
Services III	5.5	1.8	1.2	1.9	0.7	9.1	2.4	1.0	5.4	0.3
	2001-2007					2007-2010				
Agriculture	3.7	-2.4	0.8	1.4	3.9	4.6	-2.1	0.6	1.9	4.2
Construction	13.6	0.3	1.4	10.7	1.2	14.1	0.8	1.7	10.8	0.8
Energy	15.0	0.7	3.2	11.7	-0.5	2.4	0.4	2.6	1.5	-2.1
C&P	15.2	0.4	2.1	12.3	0.4	8.9	0.1	2.8	6.9	-0.9
SF&F	20.1	0.7	2.2	16.2	1.0	14.8	0.2	2.8	11.9	-0.1
Services I	13.5	1.1	4.9	6.7	0.8	10.0	1.2	6.1	4.2	-1.4
Services II	10.3	1.3	6.9	4.3	-2.2	12.8	0.5	8.1	5.9	-1.6
Services III	11.4	4.5	2.3	4.8	-0.2	10.0	6.4	2.2	4.9	-3.5

Source: Author's calculation based on CIP 3.0 data. See Equation (2).

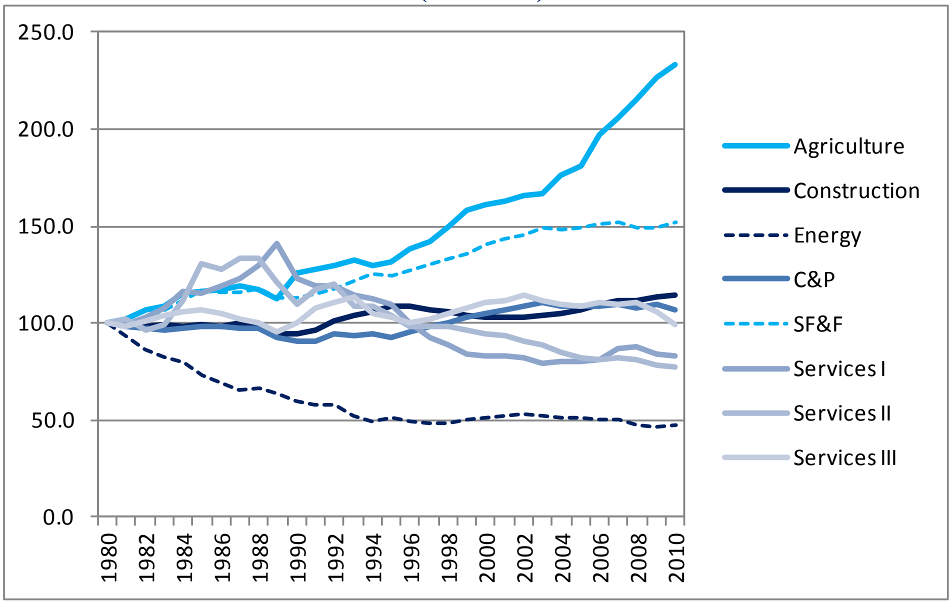
Our first, perhaps the most important observation from Table 5 is the TFP performance of China's agriculture (also see Figure 4).[9] On average, this sector achieved the highest TFP growth across all industry groups. It is also the only one that maintained a strong positive productivity growth through the three decades. In fact, since the 2000s TFP growth has become the dominant if not the only source of agricultural growth alongside the rapid decline in labor input (-2.4 percent per year in 2001-07 and -2.1 thereafter) and the slowdown of the growth of intermediate inputs. This superb performance may be able to largely explain why China has enjoyed much less inflation pressure compared to many other transition economies. Besides, as discussed earlier, although agriculture has enjoyed various subsidies, unlike the planning era it no longer receives heavy administrative interventions. Nevertheless, one should not underestimate data problems here. We use a broad concept of labor compensation

[9] It should be noted that at this stage of CIP we are unable to estimate land input and income.

in Chinese national accounts that defines the income of self-employed including all farmers as "labor income" rather than "capital income", a narrow concept as suggested by the United Nations System of National Accounts (SNA). Since a large income generated in agriculture comes from land, this broad concept overestimates the contribution of labor and hence exaggerating TFP growth.

Our second observation is about the growth and productivity performance of "semi-finished & finished" and "commodity & primary input materials" groups which have been well-known for China's growth engines since the 1990s, hence the backbone of the "world factory". Of the two groups, as discussed earlier, "SF&F" received much less government direct interference due to its competitive nature and exposure to the international market. It is clear that before the global financial crisis, both groups showed positive TFP growth (except for "C&P" in the 1980s) despite having significant increase in input materials. Nonetheless, "SF&F" appears to be more productive than "C&P" overtime (Figure 4). In the wake of the crisis, however, their TFP growth turned to negative on average.

FIGURE 4
TOTAL FACTOR PRODUCTIVITY INDEX BY INDUSTRY GROUP
(1980 = 100)



Source: As Table 5.

Next, the "energy" group presents a sharp contrast to "SF&F". As shown in Table 5 and Figure 4, it experienced heavy TFP loss in the 1980s. Yet, it experienced negative TFP growth for the rest of the entire period. Indeed, there appeared to be a significant post-WTO improvement though still staying within the negative zone (-0.5 percent per annum compared with -5.0 in 1980-91 and -1.0 in 1991-2001). However, the post crisis period has made it worse again (-2.1). Figure 4 shows that in level terms "energy" has never been able to resume its original level of TFP back to 1980. This may not have come as a big surprise to many China observers because it is a group of industries that have been almost completely monopolized by the state-owned enterprises and subject to heavy government interventions.

Lastly, let us now turn to the productivity performance of construction and three services groups. China's construction industry has somehow in general maintained a mild positive TFP growth since the 1990s, which is not often seen in many other economies. Besides, local governments-controlled primary land supply for the revenue purpose are key factors that have perhaps artificially raised the profitability of the construction business. Most services by nature are not productive. Their performance in the 1980s is exceptional and perhaps largely due to deregulations over the long suppressed service development under central planning. Overestimation of output and underestimation of price changes could be major problems to all Chinese services (Wu 2014a). Compared to Services II (market), there are more state subsidies as well as administrative controls in Services I (market monopolies) and III (non-market), these factors could be translated into different TFP performances that are not easy to disentangle. From TFP indices presented in Figure 4, we can see that Services I and II have been declining since the late 1980s, whereas Services III have maintained nearly zero TFP growth on average.

Sources of growth in the APPF framework

Following our earlier discussions in the methodology section, for an economy in reality especially that like the current Chinese economy where all industries are very likely to face different prices and they are not perfectly substitutes and additive, it is conceptually more appropriate to adopt the aggregate production function possibility frontier (APPF) approach in accounting for economy-wide sources of growth. APPF is more appropriate in the case of China where government interventions and institutional deficiencies have affected allocative efficiency and distorted incentives of producers.

TABLE 6

GROWTH IN AGGREGATE VALUE-ADDED AND SOURCES OF GROWTH IN CHINA

(Share-weighted growth rate in percent)

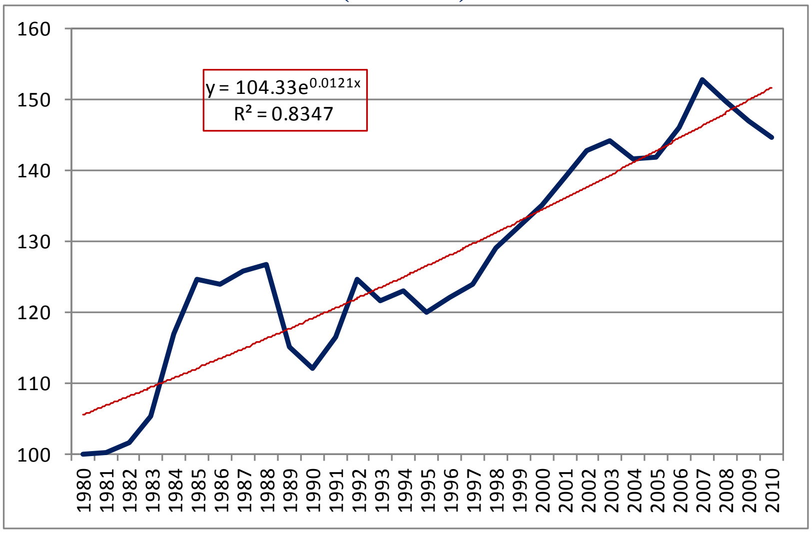
	1980-1991	1991-2001	2001-2007	2007-2010	*1980-2010*
	Contributions to value-added growth by industry				
Value-Added (APPF) (%)	7.72	9.15	11.23	10.30	*9.16*
- *Agriculture*	*1.75*	*1.18*	*0.50*	*0.48*	*1.18*
- *Construction*	*0.38*	*0.64*	*0.68*	*0.89*	*0.58*
- *Energy*	*-0.06*	*0.33*	*0.74*	*0.37*	*0.27*
- *Commodities & Primary Materials*	*0.90*	*1.49*	*1.57*	*1.21*	*1.26*
- *Semi-Finished & Finished Goods*	*1.91*	*2.69*	*2.83*	*2.54*	*2.42*
- *Services I*	*0.93*	*0.66*	*1.61*	*1.36*	*1.02*
- *Services II*	*1.50*	*1.78*	*2.37*	*2.66*	*1.89*
- *Services III (Non-market)*	*0.39*	*0.37*	*0.94*	*0.80*	*0.53*
	Contributions to value-added growth by primary factor				
Value-Added (APPF) (%)	7.72	9.15	11.23	10.30	*9.16*
- *Capital input:*	*4.95*	*6.11*	*8.49*	*10.57*	*6.61*
- Stock	4.94	6.18	8.56	10.55	*6.64*
- capital quality (composition)	0.01	-0.06	-0.07	0.02	*-0.03*
- *Labor input:*	*1.39*	*1.26*	*1.19*	*1.53*	*1.32*
- Hours	1.34	0.88	0.71	0.36	*0.96*
- Labor quality (composition)	0.05	0.38	0.48	1.17	*0.35*
- *Aggregate TFP*	*1.39*	*1.79*	*1.57*	*-1.80*	*1.24*

Source: Author's calculation based on equations (6)-(8) using CIP 3.0 data.

The upper panel of Table 6 presents the APPF-estimated value-added growth rate and its industry origin. The Chinese economy achieved a real output growth of 9.16 percent per annum based on the APPF approach. The "semi-finished & finished" group was the top contributor before the global financial crisis. It was followed by Services II (market). In the wake of the crisis, "SF&F" was overtaken marginally by Services II. On average of 1980-

2010, agriculture, "commodity & primary input materials" and Services I (state monopoly) made similar contribution to the real output growth. The lower panel of Table 6 presents the input sources of growth, i.e. contributions by prime factors, capital and labor inputs, and total factor productivity. Capital input is further decomposed into contributions of net capital stock and quality or composition of assets and labor input is further decomposed into contributions of hours worked and labor quality or composition.[10]

FIGURE 5
INDEX OF TOTAL FACTOR PRODUCTIVITY IN CHINA
(1980 = 100)



Source: Constructed based on results shown in Table 6.

Of the 9.16-percent annual output growth rate for the entire period, the contribution of capital input was 6.61, labor input 1.32 and TFP 1.24. This means that the Chinese economy relied 72.5 percent of its real value-added growth on capital input, 14 percent on labor input, and 13.5 percent on total factor productivity growth. Over the sub-periods, the contribution of capital input increased from 64 percent in the 1980s to 76 percent post WTO and even more than 100 percent in the wake of the global financial crisis. The contribution of labor input declined from 18 percent in the 1980s to 11 percent post WTO. However, this trend reversed following the crisis and the contribution of labor input rose back to 15 percent most recently (2007-10) largely attributed to quality change (11.4 percent) rather than hours worked (3.4 percent). The contribution of the quality of capital was insignificant on average.[11]

China's TFP performance was unstable over the sub-periods. Perhaps to the surprise of many, as Table 6 shows, the best TFP growth was accompanied by China's first drive of the reform of the state and urban sectors in the 1990s (1.78 percent per annum in 1991-2001 compared to 1.24 on average in 1980-2010) rather than following China's WTO entry (1.56 in 2001-07). It turned into negative in the wake of the global financial crisis (-1.80 in 2007-2010). Since this negative TFP performance is based on an observation of only three years, it may be insufficient to see if the fundamentals determining the potential growth of the

[10] Table A2 reports the details for individual industries.

[11] This is to a large extent caused by limited asset types ("structures" and "equipment") available in the current CIP database.

economy have changed. Nevertheless, the most recent significant slowdown in the official GDP growth rate from above 10 percent to around 7.5 percent per year in 2011-13 seems to suggest that China is facing serious challenges to turn productivity growth back to positive again after 2010. Had the negative TFP growth indeed continued after 2010, the TFP decline in 2007-10 might not be a short-run, cyclical phenomenon.

If these annual growth rates are translated into an index as shown in Figure 5, we can see a very volatile TFP performance around the underlying trend. The first TFP drive was clearly observed in the early 1980s associated with China's agricultural reform. This made the Chinese productivity performance staying well above the trend until its collapse following the 1989 political crisis. The TFP growth recovered in the early 1990s but only short-lived. It began to accelerate again from the late 1990s and exceeded the trend in the early 2000s. China's post-WTO period, nonetheless, only observed the resurgence of TFP in 2006-07 before its collapse in the wake of the global financial crisis.

TABLE 7

DECOMPOSITION OF AGGREGATE LABOR PRODUCTIVITY GROWTH IN CHINA

(Contributions are weighted growth in percent)

	1980-1991	1991-2001	2001-2007	2007-2010	*1980-2010*
			Growth Rates		
Value-Added Growth (APPF)	7.72	9.15	11.23	10.30	*9.16*
-Value added per hour worked	*4.89*	*7.40*	*9.67*	*9.47*	*7.14*
- Hours	*2.83*	*1.75*	*1.57*	*0.83*	*2.02*
			Contributions		
Value-Added per hour worked	4.89	7.40	9.67	9.47	*7.14*
- Capital deepening	*3.46*	*5.23*	*7.62*	*10.10*	*5.55*
- Labor quality	*0.05*	*0.38*	*0.48*	*1.17*	*0.35*
- TFP growth	*1.39*	*1.79*	*1.57*	*-1.80*	*1.24*

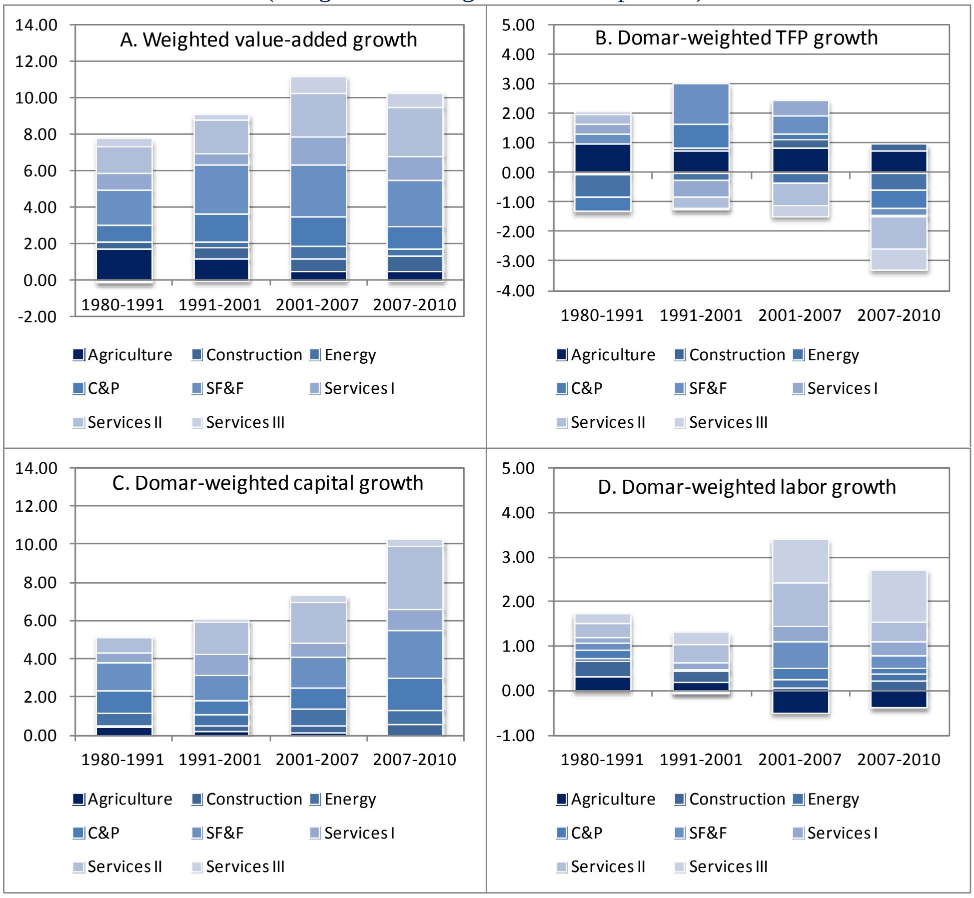
Source: Author's estimates.

Table 7 presents the results of labor productivity production function by decomposing China's aggregate value-added per hour worked into changes in capital deepening, labor quality and TFP. This enables us to separate the contribution of hours worked from the contribution of genuine labor productivity improvement and its sources. The Chinese economy benefited significantly from the increase in hours worked as the so-called "demographic bonus". This has, however, declined overtime as shown in Table 7 from 2.83 percent per annum in 1980-91 to 0.83 percent per annum in 2007-10. Although value-added per hour worked increased from 4.89 to 9.47 percent per annum, it appeared to be increasingly relying on capital deepening from 3.46 to 10.10 percent per annum. More importantly, the growth of TFP was not necessarily in line with capital deepening. For example, the government's unprecedented fiscal injection in the wake of the global financial crisis pushed up China's capital deepening, but it was accompanied by a TFP decline of -1.8 percent.

Quantifying TFP growth using Domar weights in APPF

As showed in Jorgenson, Ho and Stiroh (2005) using the US case, aggregate production function (APF) is the most restrictive among all the available approaches while the aggregate production possibility frontier (APPF) approach incorporating Domar weights is the least.[12] Introducing Domar weights under APPF allows a more complete industry view. Figure 6 illustrates the sources of value-added growth using Domar weights. This picture reveals the Domar-weighted contributions by capital, labor and TFP of individual industry groups in Panel B through D. The summation of these Domar-weighted contributions yields the industry group-weighted value-added growth in Panel A.

FIGURE 6
INDUSTRY CONTRIBUTIONS TO SOURCES OF VALUE-ADDED GROWTH
(Weighted annual growth rate in percent)



Source: Author's estimates following equations (7)-(9).

Table 8 presents two important comparisons. The first is to compare the real output growth rates estimated by APF and by APPF, which can help identify the reallocation of value added across industries. The second is to compare the aggregate TFP growth rates estimated by APPF with those obtained by the direct aggregation across industries using Domar weights. This can help identify the TFP effect of capital and labor reallocation across industries. The reallocation terms quantify the impact of these restrictions and show to what extent their violations distort our view of aggregate economic growth and its sources.

[12] Following this point, interested reader can refer to the author's recent work using the most restrictive APF approach (Wu 2014b). For the same period 1980-2010, the TFP growth estimated by the APF approach is 1.19 percent compared to 1.24 percent by the APPF approach. More importantly, the work based on APF cannot provide industry perspective as we do here under APPF.

With our first comparison presented in the top panel of Table 8, we can see that the reallocation of China's value-added growth is -0.26 for the full period, obtained by subtracting the APF value-added annual growth rate of 9.42 from the APPF value-added annual growth rate of 9.16. There are however substantial variations over sub-periods. The APF value-added grew slower than the APPF value-added for the period 1980-91, but faster for the rest sub-periods. If the value-added reallocation term is positive, it suggests that industries with relatively larger real-term shares would also have more rapid real value-added growth. This would usually be the case when prices were falling. Nevertheless, this norm is violated in the case of China as the value-added reallocation term is negative since the 1990s, suggesting that irrational resource moves happened that to some extent ignored underlying market incentives.

TABLE 8

AGGREGATE REALLOCATION EFFECTS IN THE CHINESE ECONOMY

(Top panel: annualized growth in percent. Lower panel: Domar-weighted growth in percent)

	1980-1991	1991-2001	2001-2007	2007-2010	*1980-2010*
Aggregate Production Possibility Frontier (APPF) vs. Aggregate Production Function (APF)					
Value-added Growth (APF)	7.28	9.69	11.99	11.23	*9.42*
Value-added Growth (APPF)	7.72	9.15	11.23	10.30	*9.16*
Reallocation of Value-added	0.44	-0.54	-0.75	-0.93	*-0.26*
Aggregate Production Possibility Frontier vs. Direct Domar Aggregation Across Industries					
Aggregate TFP Growth (APPF)	1.39	1.79	1.57	-1.80	*1.24*
- *Domar-weighted TFP*	*0.74*	*1.81*	*0.98*	*-2.31*	*0.84*
- Agriculture	0.99	0.75	0.82	0.76	*0.85*
- Construction	-0.05	0.12	0.29	0.22	*0.10*
- Energy	-0.76	-0.24	-0.33	-0.57	*-0.48*
- Commodities & Primary Materials	-0.50	0.77	0.21	-0.61	*0.05*
- Semi-Finished & Finished Goods	0.35	1.39	0.59	-0.27	*0.68*
- Services I	0.30	-0.58	0.55	-0.03	*0.02*
- Services II	0.36	-0.37	-0.76	-1.10	*-0.25*
- Services III (Non-market)	0.06	-0.03	-0.40	-0.71	*-0.14*
- *Reallocation of Capital Input* (ρ^K)	*0.30*	*-0.03*	*-1.15*	*-0.30*	*-0.16*
- *Reallocation of Labor Input* (ρ^L)	*0.35*	*0.01*	*1.73*	*0.81*	*0.56*

Source: Author's estimates following equation (9).

In the second panel of Table 8 we compare TFP growth estimated by the APPF approach as expressed in equation (8) with that estimated using Domar weights as expressed in equation (9). On average for the entire period, the TFP estimated without Domar weights is 1.24 percent per annum whereas the TFP estimated with Domar weights is 0.84. The much slower Domar-weighted TFP growth across industries indicates that there was accumulated inefficiency in the economy from upstream to downstream industries through their input-output links and that industries with slower TFP growth might nonetheless experience an expansion in their shares in the economy. However, over different sub-periods, the period 1991-2001 was the only time during which the Domar-weighted TFP growth (1.81) was somewhat faster than that of non-Domar-weighted TFP growth (1.79), suggesting that industries with more rapid TFP growth also enlarged their shares in the economy.

In terms of individual group contribution to the Domar-weighted annual TFP growth (see industry details in Table A2), the best performer was agriculture (0.85 percent, share-weighted growth), followed by the "SF&F" group (0.68), whereas the worst performer was the "energy" group (-0.48), followed by Services II (-0.25) and Services III (-0.14). Besides, construction also made a positive contribution of 0.10 percent. Such a sharp contrast across industry groups in TFP performance can also be observed over different sub-periods.

While the TFP performance of agriculture was significantly positive and fairly stable over all sub-periods, others were very volatile with distinct gains and losses. In 1991-2001, the “SF&F” and “C&P” groups attributed 1.39 and 0.77 percentage points to the aggregate TFP growth of 1.79, the best of all groups. However, such TFP growth could not be maintained. Following China’s WTO entry both groups slowed down their TFP growth to 0.59 and 0.21, and in the wake of the global financial crisis their TFP performance turned negative, -0.27 and -0.61, respectively. Besides, the TFP growth of the state monopolized “energy” group stayed negative over time. However, the state-dominated Services I showed positive TFP contribution in 2001-07. High and protected income together with continuous technological upgrading could be the main factors behind such a performance. The TFP growth of the rest of services deteriorated over time since the 1990s with the worst observed in the wake of the global financial crisis. In fact, findings of individual industries (Table A2) show that the total loss of TFP growth by the 10 poorest industries offsets 75 percent of the gains by the 10 top performers. Such distinctive differences in TFP growth across industries/groups may suggest serious misallocation of resources in the Chinese economy.

A more direct investigation of resource misallocation can be conducted based on equation (9). As shown in Table 8, if subtracting the Domar-weighted TFP growth from the non-Domar-weighted TFP growth we can obtain a net reallocation effect of 0.40 percentage points (i.e. subtracting 0.84 from 1.24). As expressed by equation (9), this effect consists of a positive labor reallocation effect (ρ^L) of 0.56 percentage points and a negative capital reallocation effect (ρ^K) of -0.16 percentage points.

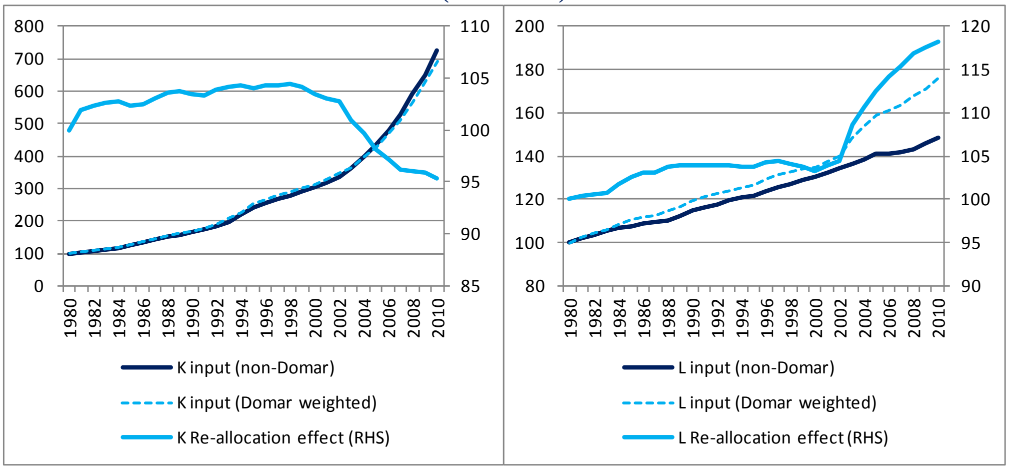
Such a magnitude of reallocation effect is not typically observed in market economies. Based on their empirical work for the US economy in 1977-2000, Jorgenson, Ho and Stiroh (2005a) showed that first, the reallocation effect was generally negligible and second, if it was non-negligible for some sub-periods, the capital and labor reallocation effects generally moved in opposite directions with positive move for capital and negative move for labor, e.g. 0.02 for ρ^K and -0.04 for ρ^L for the period 1977-2000 in Jorgenson, Ho and Stiroh (Table 8.4, 2005a). Jorgenson, Gollop and Fraumeni (1987) also reported the reallocation of capital that was typically positive and the reallocation of labor that was typically negative for the US economy for the period 1948-79. This is because capital is growing more rapidly in industries with high capital service prices, hence high returns on capital, whereas labor is growing relatively slowly in industries with high labor costs.

In the case of China, the large magnitude and unexpected sign of capital and labor reallocation effects have two important implications. First, individual industries indeed face significantly different factor prices suggesting that there are barriers to factor mobility which cause misallocation of resources in the economy. Second, corrections to the distortions through reallocation of resources can be productivity-enhancing if driven by market forces, which is good news from a much talked and long awaited structural reforms.

We find that the effect of labor reallocation was always positive over the four sub-periods. This is mainly because labor market was much less controlled than capital market and could enjoy increasing freedom of labor mobility along with reforms. Notably, the post-WTO period experienced the most significant gain from labor reallocation (1.73 in 2001-07) which could be driven by the rapid expansion of export-oriented, labor-intensive industries. Besides, the effect of labor reallocation was also strong in the wake of the global financial crisis (0.81

in 2007-10) reflecting that labor responded quickly to the changes of market conditions (Figure 7).

FIGURE 7
INDEX OF TOTAL FACTOR PRODUCTIVITY IN CHINA
(1980 = 100)



Source: Constructed using results in Table 8.

The case of capital reallocation is different (Figure 7). The early reform period was the only period that benefited from a positive effect of capital reallocation (0.30 percentage points in 1980-1991) caused by corrections to distortions inherited from the central planning. However, the effect of capital reallocation turned negative substantially following China's WTO entry in 2001-07 (-1.15 percentage points) because of the enhanced role of the government that supported the state sector resurging in upstream industries. However, we do not find a worse capital reallocation effect over the global financial crisis period. It in fact somewhat improved, though still negative (-0.30), despite unprecedented fiscal injection that benefitted mainly state-owned enterprises and state-controlled industries. This may suggest that there were high pressures forcing firms to improve income, which together with the strong gain from labor reallocation (0.81), moderated the impact of the decline of the Domar-weighted TFP (-2.31).

7. CONCLUDING REMARKS

Using the newly constructed full version CIP database, this study adopts the aggregate production possibility frontier approach in the Jorgensonian growth accounting framework incorporating Domar weights to examine the Chinese economy at the industry level for the reform period 1980-2010. It is motivated by the on-going policy debate that questions the sustainability of the China growth model especially since the mid 1990s and attempts to address the structural problems of the Chinese economy from a productivity perspective. The APPF approach incorporating Domar weights that can be directly and coherently integrated with a cross-industry analysis provides a highly appropriate analytical tool to investigate the industry origin of aggregate productivity and the effect of resource reallocation across industries in the Chinese economy.

Our preliminary results show that China achieved a TFP growth of 1.24 percent per annum for the entire period 1980-2010. This means that compared to an industry-weighted value-added growth of 9.16 percent per annum, TFP growth accounted for about 13.5 percent of the average GDP growth. This is a result that is much smaller than most of productivity studies on the Chinese economy, e.g. about 40 percent contribution by Bosworth and Collins

(2008) and by Perkins and Rawski (2008). In particular, compared to the only work in the literature that applied the same approach for the period 1982-2000 by Cao *et al.* (2009), our finding of 1.24 percent is just about half of their result of 2.51 percent (if adjusting our results for the same period of Cao *et al*. our estimate of TFP growth would be 1.50 percent).

At the industry group level, we find that, in general, industries less prone to government intervention, such as agriculture and the "semi-finished & finished" manufactures, tended to be more productive than those subject to direct government interventions, typically the "energy" group. The fact that the "SF&F" group maintained a positive TFP growth while the "energy" group experiencing persistently TFP decline clearly suggests the existence of cross-subsidization between upstream and downstream industries in which the government plays different roles to serve its strategy.

Moreover, incorporating Domar weights across industries, we find that on average 0.84 percentage points of the 1.24-percent annual TFP growth directly came from the TFP performance of industries and the rest of 0.40 came from a net factor reallocation effect in which labor played a positive role of 0.56 whereas capital played a negative role of -0.16. This allows us to address the issue of resource misallocation in the economy. The large magnitude of the reallocation effect reflects barriers to factor mobility in the economy. While the reallocation of labor has continuously contributed to productivity growth, the reallocation of capital has resulted in the opposite. We argue that institutional deficiencies in the Chinese economy that allow the government at all levels to intervene resource allocation at their discretion are responsible for resource misallocation. Therefore, disentangling government from business and allow market to correct the cost structure of industries is the key to solving China's "structural problems". Indeed, "restructuring" for a healthy and sustainable growth is the most crucial and challenging pillar of the Liconomics. Nevertheless, there is no such thing as the "right structure" without market-based resource allocation.

APPENDIX

TABLE A1
CIP/CHINA KLEMS INDUSTRIAL CLASSIFICATION AND CODE

CIP Code	EU-KLEMS Code	Grouping	Industry	
1	AtB	Agriculture	Agriculture, forestry, animal husbandry & fishery	AGR
2	10	Energy	Coal mining	CLM
3	11	Energy	Oil & gas excavation	PTM
4	13	C&P	Metal mining	MEM
5	14	C&P	Non-metallic minerals mining	NMM
6	15	Finished	Food and kindred products	F&B
7	16	Finished	Tobacco products	TBC
8	17	C&P	Textile mill products	TEX
9	18	Finished	Apparel and other textile products	WEA
10	19	Finished	Leather and leather products	LEA
11	20	SF&F	Saw mill products, furniture, fixtures	W&F
12	21t22	C&P	Paper products, printing & publishing	P&P
13	23	Energy	Petroleum and coal products	PET
14	24	C&P	Chemicals and allied products	CHE
15	25	SF&F	Rubber and plastics products	R&P
16	26	C&P	Stone, clay, and glass products	BUI
17	27t28	C&P	Primary & fabricated metal industries	MET
18	27t28	SF&F	Metal products (excluding rolling products)	MEP
19	29	Semi-finished	Industrial machinery and equipment	MCH
20	31	SF&F	Electric equipment	ELE
21	32	SF&F	Electronic and telecommunication equipment	ICT
22	30t33	SF&F	Instruments and office equipment	INS
23	34t35	Finished	Motor vehicles & other transportation equipment	TRS
24	36t37	Finished	Miscellaneous manufacturing industries	OTH
25	E	Energy	Power, steam, gas and tap water supply	UTL
26	F	Construction	Construction	CON
27	G	Services II	Wholesale and retail trades	SAL
28	H	Services II	Hotels and restaurants	HOT
29	I	Services I	Transport, storage & post services	T&S
30	71t74	Services I	Telecommunication & post	P&T
31	J	Services I	Financial Intermediations	FIN
32	K	Services II	Real estate services	REA
33	71t74	Services II	Leasing, technical, science & business services	BUS
34	L	Services III	Public administration and defense	ADM
35	M	Services III	Education services	EDU
36	N	Services III	Health and social security services	HEA
37	O&P	Services II	Other services	SER

Source: See the text.

TABLE A2
INDUSTRY CONTRIBUTIONS TO VALUE-ADDED AND TOTAL FACTOR PRODUCTIVITY GROWTH
1980-2010

	Value-Added			Total Factor Productivity		
	VA weight	VA growth	Contribution to aggregate VA growth	Domar weight	TFP growth	Contribution to aggregate TFP growth
AGR	0.204	5.42	1.18	0.319	2.83	0.85
CLM	0.016	7.21	0.11	0.031	1.03	0.02
PTM	0.018	-3.07	-0.05	0.026	-10.20	-0.26
MEM	0.005	10.66	0.06	0.013	1.59	0.02
NMM	0.006	9.35	0.05	0.012	2.15	0.03
F&B	0.027	10.89	0.29	0.121	0.25	0.03
TBC	0.012	8.07	0.09	0.018	-4.97	-0.11
TEX	0.027	7.84	0.21	0.113	-0.02	-0.03
WEA	0.009	12.74	0.11	0.034	0.64	0.03
LEA	0.004	11.48	0.05	0.019	0.39	0.01
W&F	0.007	12.83	0.09	0.024	1.22	0.03
P&P	0.011	10.26	0.12	0.038	0.42	0.02
PET	0.011	1.10	0.00	0.043	-3.88	-0.13
CHE	0.036	10.27	0.37	0.131	0.39	0.05
R&P	0.012	12.56	0.15	0.048	0.61	0.03
BUI	0.025	9.46	0.23	0.073	0.47	0.05
MET	0.031	7.38	0.22	0.128	-0.58	-0.08
MEP	0.012	12.03	0.15	0.049	0.99	0.04
MCH	0.035	11.03	0.39	0.116	1.78	0.19
ELE	0.015	14.82	0.21	0.062	1.09	0.05
ICT	0.016	24.87	0.36	0.075	3.17	0.13
INS	0.003	14.07	0.04	0.010	1.88	0.02
TRS	0.018	15.78	0.30	0.073	1.86	0.13
OTH	0.014	13.10	0.19	0.040	1.95	0.11
UTL	0.027	7.06	0.20	0.103	-1.23	-0.11
CON	0.054	10.60	0.58	0.206	0.44	0.10
SAL	0.077	12.15	0.89	0.143	2.00	0.22
HOT	0.019	11.88	0.22	0.053	-0.36	-0.02
T&S	0.052	8.61	0.45	0.100	-1.05	-0.10
P&T	0.012	15.15	0.18	0.021	4.03	0.07
FIN	0.040	11.35	0.39	0.059	2.57	0.05
REA	0.038	9.22	0.33	0.052	-8.03	-0.44
BUS	0.022	10.95	0.27	0.051	1.09	0.00
ADM	0.032	11.02	0.36	0.061	0.33	-0.01
EDU	0.025	3.71	0.10	0.043	-2.31	-0.09
HEA	0.011	6.02	0.07	0.031	-1.10	-0.04
SER	0.016	9.82	0.18	0.035	-1.29	-0.01
Sum	***1.000***		***9.16***	***2.575***		***0.84***

Source: See Tables 6 and 8.

Notes: See Table A1 for industry abbreviation. Value added and TFP growth rates are annualized raw growth rates in percent. Industry contribution to VA and TFP growth is weighted growth rate in percentage points. See equation (9) for Domar aggregation.

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