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Accounting for China’s Aggregate Growth and Productivity Performance in a Regional Industry Origin Framework

by

Zhan Li

A Dissertation Submitted to
Hitotsubashi University
In Partial Fulfillment of the Requirements
For the Degree of
Doctor of Philosophy in Economics

Graduate School of Economics
Hitotsubashi University

February 2020
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<tr>
<td>APF</td>
<td>Aggregate Production Function</td>
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<td>APPF</td>
<td>Aggregate Production Possibility Frontier</td>
</tr>
<tr>
<td>CHIP</td>
<td>Chinese Household Income Project</td>
</tr>
<tr>
<td>CIESY</td>
<td>China Industry Economy Statistical Yearbook</td>
</tr>
<tr>
<td>CIP</td>
<td>China Industry Productivity</td>
</tr>
<tr>
<td>CLSY</td>
<td>China Labor Statistical Yearbook</td>
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<tr>
<td>CPI</td>
<td>Consumer Price Index</td>
</tr>
<tr>
<td>CSY</td>
<td>China Statistical Yearbook</td>
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<td>DEA</td>
<td>Data Envelopment Analysis</td>
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<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>GO</td>
<td>Gross Output</td>
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<tr>
<td>ICT</td>
<td>Information and Communication Technology</td>
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<td>IOT</td>
<td>Input-Output Table</td>
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<tr>
<td>IPF</td>
<td>Iterative Proportional Fitting</td>
</tr>
<tr>
<td>IPI</td>
<td>Investment Price Index</td>
</tr>
<tr>
<td>ISIC</td>
<td>International Standard Industrial Classification</td>
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<tr>
<td>KLEMS</td>
<td>Capital Labor Energy Materials Services</td>
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<tr>
<td>LC</td>
<td>Labor Compensation</td>
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<tr>
<td>MPS</td>
<td>Material Product System</td>
</tr>
<tr>
<td>NBS</td>
<td>National Bureau of Statistics</td>
</tr>
<tr>
<td>NIFA</td>
<td>Newly Increased Fixed Assets</td>
</tr>
<tr>
<td>NVFA</td>
<td>Net Value of Fixed Assets</td>
</tr>
<tr>
<td>OECD</td>
<td>Organization for Economic Co-operation and Development</td>
</tr>
<tr>
<td>OVFA</td>
<td>Original Value of Fixed Assets</td>
</tr>
<tr>
<td>PIM</td>
<td>Perpetual Inventory Method</td>
</tr>
<tr>
<td>PPI</td>
<td>Producer Price Index</td>
</tr>
<tr>
<td>RDA</td>
<td>Regionally Decentralized Authoritarian</td>
</tr>
<tr>
<td>RIOT</td>
<td>Regional Input-Output Table</td>
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<tr>
<td>SFA</td>
<td>Stochastic Frontier Analysis</td>
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<tr>
<td>SNA</td>
<td>System of National Accounts</td>
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<tr>
<td>SOE</td>
<td>State-owned Enterprises</td>
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<tr>
<td>TFP</td>
<td>Total Factor Productivity</td>
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<tr>
<td>TIFA</td>
<td>Total Investment in Fixed Assets</td>
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<td>VA</td>
<td>Value Added</td>
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<td>WTO</td>
<td>World Trade Organization</td>
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Abstract

By constructing capital-labor-energy-materials-services (KLEMS) type of regional productivity accounts, this study adopts the aggregate production possibility frontier (APPF) framework and further incorporates Domar weights to account for industry and regional origins of China’s aggregate economy and total factor productivity (TFP) growth over 1992-2014. The results show that the industry structures of each region and the regional distributions of each industry at national level constantly change over time, and the value added growth contributions of individual industries to each region and that of each region to the national industry are disparate across industries and regions. Differences in capital-labor ratio make the largest contribution to differences in labor productivity growth across most regions, followed by differences in labor quality and TFP growth. Differences in capital-labor ratio, labor quality, and TFP diversely contribute to differences in labor productivity growth across industries, and differences in labor productivity growth across industries obviously differ from those across regions. The annual growth rate of aggregate value added is 8.73% with 6.06% from capital input, 0.37% from hours worked, 1.68% from labor quality, and 0.62% from TFP growth, and industry origins of aggregate value added growth are service sectors, industries that are prone to government interventions achieve relatively low or negative value added and TFP growth. The aggregate TFP growth can be further decomposed into -0.80% of Domar-weighted TFP growth, -0.37% of capital reallocation, and 1.80% of labor reallocation. The industry origins of aggregate Domar-weighted TFP growth are industrial sectors because TFP growth in nearly all service sectors is negative. The initial endowment and comparative advantage of each region may affect its growth contribution to aggregate value added and Domar-weighted TFP growth. Capital input is much more vulnerable to administrative planning rather than market mechanisms, causing its reallocation to be negative, while the positive labor reallocation benefits from relaxation of regulations on labor mobility so that the labor market is much less controlled than the capital market, which may tend to follow market mechanisms. The reallocations of capital and labor would be improved by taking regions into consideration, which may imply that allowing factor inputs to flow freely across regions is conducive to factor allocation. The net reallocation of capital and labor accounts for all aggregate TFP growth, and the growth sources of the reallocations of capital and labor inputs are quite disparate from the point of view of industry and regional perspectives, respectively.
Chapter 1: Introduction

There is no doubt that China has experienced continuous and spectacular economic growth in terms of gross domestic product (GDP) since 1978 when the reform and opening policy was implemented. According to official statistics, the average annual growth rate of the GDP between 1978 and 2015 was 9.7%. More significant growth was seen in the new millennium, and the average annual growth rate of GDP between 2000 and 2011 was 10.3%. Since 2011, the annual growth rate of GDP has gradually slowed; even so, however, it has remained around 7% in recent years.¹

1.1 Productivity: The Determinant of Sustainable Growth

One of the basic goals of economic research is understanding such rapid economic growth. Economists have been divided into two camps concerning the sources of economic growth: one camp (e.g., Hu and Khan, 1997; Kendrick, 1961; Maddison, 2007; Solow, 1957; World Bank, 1997) assigns the greatest weight to productivity improvements driven by advances in technology and the organization of production (i.e., the productivity-driven growth mode), and the other (e.g., Jorgenson and Griliches, 1967; Kim and Lau, 1994; Krugman, 1994; Y. Wu, 2003; Young, 1995) attributes output growth to factor inputs, especially capital and labor inputs (i.e., the input-driven growth mode). The latter, however, is not sustainable in the long run, not only because resources are always finite; but also, factor accumulation is subject to the law of diminishing returns. Thus, the former growth mode should be the ultimate target because higher economic growth can be achieved with the same amount of resources by improving the efficiency of resource usage or new production technology, and the focus of economic research has gradually shifted to productivity analysis. Productivity, defined as the ratio between real output and real factor inputs (Tinbergen, 1942),² represents the quantity of physical products or services that can be produced or provided per unit of factor of production. Productivity growth reflects the increase in the ability of production units to use a certain production factor to produce more output or to minimize the input of production factors to produce a certain output, which can be seen as a symbol of technological change or the technological dynamism of an economy in the long term.

¹ The official growth rate of GDP has been criticized as it exists an upward bias (H. Wu, 2000). According to H. Wu (2016a), the annual growth rate of GDP over the period 1980-2012 is 8.9%, a high speed rarely seen elsewhere, although lower than the official 9.96% during the same time period.
² Tinbergen (1942) was written in German and translated into English in 1959.
Many studies have shown that the productivity level reflects the ability of a country or region to acquire national wealth, and productivity growth is a decisive measure for improving the quality and level of national life. Furthermore, most of the growth in gross national income within a country or region is caused by improving the effectiveness and quality of human and material inputs and by raising productivity levels, not because of the use of additional labor and capital. In addition, productivity growth is closely related to the mode of economic growth, and to a large extent, it determines the sustainable development capacity of a country and its products’ international competitiveness. In fact, the core of the current comparison of international competitiveness is the comparison of total factor productivity (TFP). The difference in competitiveness among countries is mainly reflected in the gap in productivity growth among countries in industries, enterprises, and even product levels. For example, Hsieh and Klenow (2009) have argued that TFP is an important factor of differences in output per worker between rich and poor countries.

TFP is not only an important tool for analyzing the sources of economic growth; it is also an important basis for the government to formulate long-term sustainable growth policies. First, estimating TFP can help distinguish the sources of economic growth, that is, analyzing the contributions of various components (i.e., factor inputs and technological progress) to economic growth, and identifying whether the economy features input-driven growth or efficiency-based growth. This is helpful to assess the sustainability of economic growth. Second, estimating TFP is the basis for formulating and evaluating long-term, sustainable growth policies. Specifically, by comparing the contributions of TFP growth and factor inputs to economic growth, it can be determined whether economic policies should focus on increasing the amount of factor inputs or adjusting the economic structure to promote technological progress.

1.2 How to Measure Productivity Growth: Methodology and Data

Measuring the degree to which output growth is due to TFP growth is the first main challenge researchers face. The seminal contribution of Solow (1957) is the linkage between the aggregate production function (APF) and the index number approach, in which TFP is derived as the residual of gross value added growth minus the growth contribution of capital and labor inputs. There are, however, some limitations to Solow’s work. First, as Jorgenson et al. (2005) have noted, four key assumptions are necessary for the existence of an APF: (1) each industry must have a gross output production function that is separable in value added, where
value added is a function of industry capital, labor, and time (which is a proxy for technology); (2) the value added function is the same across all industries; (3) the functions that aggregate heterogeneous types of capital and labor must be identical in all industries; and (4) each specific type of capital and labor must have the same price in all industries. These four assumptions are quite stringent, and they are rarely found in reality, especially in developing countries such as China. China’s economic system is still in a dynamic transformation process, and the intrinsic characteristics and technology level of each industry determine its corresponding value added production function, which cannot be identical across industries. Furthermore, different technical levels of different industries, as well as the institutional deficiencies and even governmental interventions, are bound to cause different factor prices across industries. Consequently, the violation of the underlying assumptions leads to biases in the TFP calculation based on the APF.

Second, from the point of view of measurement, the APF approach is based on a net-output (usually value added) production function, in which TFP is calculated as the residual of the growth of net output minus that of capital and labor inputs; that is, the rest of the growth of net output not explained by capital and labor inputs is categorized as TFP growth. Given that only capital and labor inputs have been considered, this measurement of TFP introduces biases because intermediate input has not been taken into account. Many studies, however, have recognized the important role of intermediate input in economic growth (e.g., Hulten, 1978; Jorgenson et al., 2005). The connection among industries is strengthened via the industry chain, and the output of an industry may be delivered into other industries and consumed as intermediate inputs. As a result, the efficiency improvement of an industry may affect not only its own production activities, but it may also have an important impact on the efficiency improvement of other industries that heavily rely on the delivered intermediate inputs from the efficient industry; this finally leads to a remarkable influence on the aggregate economy. Omitting the important role of intermediate inputs may thus cause a serious measurement bias for TFP growth. In addition, the aggregate estimates of capital and labor derived by totaling capital and labor inputs across industries are likely to result in the aggregation bias associated with internal shifts in the composition of factor inputs.

The aggregate production possibility frontier (APPF), proposed by Jorgenson (1966) and generalized by Jorgenson and Griliches (1967), relaxes the crucial assumptions required by the APF approach, that is, the value-added function is identical across industries, and all industries face the same factor input prices. Thus, it is inappropriate to simply sum up value added across
sectors,\textsuperscript{3} which is usually done via the APF approach, to derive the economy-wide aggregate value added because, if the value added functions differ across sectors, the price of value added is no longer the same across sectors (Jorgenson et al., 2005). The principle is the same regarding aggregate measurements of capital and labor inputs. In APPF approach, according to the Divisia quantity index, the growth rate of total output is calculated as a weighted average of the growth rates of various individual outputs, and weights are defined by the relative shares of the value of individual outputs in the value of total output. Similarly, the growth rate of total input is calculated as a weighted average of growth rates of various individual inputs, and weights are defined by the relative shares of the value of individual inputs in the value of total input. This clearly differs from aggregate estimates of value added, capital input, and labor input in the APF approach, which are the sums of the corresponding measures across industries. Another major contribution of the Jorgenson-Griliches study is to disaggregate capital and labor into their component parts, thereby avoiding the aggregation bias associated with internal shifts in the composition of the inputs, e.g., the compositional bias due to a shift from long-lived structures to shorter-lived equipment in the capital stock, or the bias due to the shift toward a more educated work force (Hulten, 2001).

Jorgenson et al. (1987) have developed the APPF approach by explicitly demonstrating the role of intermediate input and, further, taking the Domar weighting scheme and resource reallocations into account, which are illustrated in turn in the following.

The APPF approach is based on a gross output production function, which also takes into account the intermediate input, and the TFP growth is calculated as the residual of gross output growth minus the growth of all inputs, including capital input, labor input, and intermediate input. The role of intermediate input cannot be ignored because of the linkages across sectors have been strengthened due to deeper industry specialization. The output of a sector may be used not only by itself, but also consumed as the intermediate input in other sectors whose output is then used by other sectors. Therefore, ultimately, the efficiency improvement of a sector might significantly affect the aggregate economy and overall TFP growth via the industry chain, which can also be reflected by the following Domar weights.

The Domar weighting scheme dates to the seminal work of Domar (1961), and the weight is defined as the ratio of a sector’s gross output to aggregate value added. A distinctive feature of Domar weights is that the sum of the weights is greater than or equal to one. The intuitive

\textsuperscript{3} In this study, the words of “industry” and “sector” can be used interchangeably.
reason is that the change of TFP in a sector creates, in general, extra output in this sector, which can have two effects: first, a part of the extra output is consumed by this sector itself as final demand, and second, another part of the extra output is delivered to other sectors and used as intermediate inputs. The increase in intermediate inputs further serves to increase output in sectors that use the intermediate goods, which further increases output, and so on. As a result, the total effect of sectoral TFP change on the aggregate TFP change is greater than the direct effects of the TFP change within a sector (Hulten, 1978). A representative example for this is the semiconductor sector. The semiconductor is now used in many sectors as an intermediate input, such as the information and communication technology (ICT) sector. Due to the rapid growth of TFP in the semiconductor-producing sector, its price has dramatically declined, and its capacity has remarkably increased. The lower cost of the intermediate input has also promoted the significant improvement of TFP in the ICT sector, which further stimulates productivity growth in those sectors that utilize ICT, and so on. As a result, the improvement of TFP in the semiconductor sector has influential impacts on the aggregate economy and TFP growth via linkages with other sectors. The Domar weighting scheme not only precisely reflects the role of intermediate inputs expanded via input-output connections among industries, but also traces the growth origins of the aggregate economy and TFP at the industry level to reflect the growth contribution of individual industries to the total economy.

The study on the impacts of resource misallocation on TFP growth dates to the work of Hsieh and Klenow (2009), who have argued that resource misallocation is a critical reason for TFP growth differentials between poor and rich countries, and TFP growth would increase if resource misallocation could be eliminated. The reallocations of primary factors of production, i.e., capital and labor, which are defined by the difference between the Domar-weighted sum of growth rates of capital input (or labor input) across sectors and the unweighted growth rate of aggregate capital input (or labor input), are estimated in the APPF approach and are also important contributors to aggregate TFP growth. Resource reallocations can reflect the contribution of changes in the sectoral distribution of capital input and labor input to the rate of aggregate TFP growth. If the reallocations are positive, this happens when capital input or labor input is not paid at the same price across sectors, which shows that capital input or labor input flows into sectors with higher prices, and such sectors achieve faster input growth rates. This is the consequence of market mechanisms, which means there are no barriers to obstruct factor mobility across sectors. In contrast, if the capital or labor is confined in sectors where
even the prices of factors of production are low due to various non-market factors, this might result in reallocations becoming negative to impede aggregate TFP growth.

Jorgenson et al. (1987) have adopted the Tornqvist index as a discrete-time approximation of the Divisia index since economic data are not continuous over time but occur in discrete-time units. Furthermore, Diewert (1976) has shown that the Tornqvist approximation of the Divisia index is an exact index number if the production function has the translog form developed by Christensen et al. (1973). To date, the full APPF approach that further incorporates the Domar aggregation scheme and the resource reallocations presented by Jorgenson et al. (1987) has been widely used to measure TFP growth.

The second challenge to measure TFP growth is to construct large historical data on inputs and outputs. There are many different productivity measures, and the choice between them depends on the purpose of productivity measurement and, in many instances, on the availability of data. Broadly, productivity measures can be classified as single-factor productivity measures, which relate a measure of output to a single measure of input, or multifactor productivity measures, which relate a measure of output to a bundle of inputs. The OECD Manual (2001) has enumerated five types of the most frequently used productivity measures, i.e., labor productivity based on gross output, labor productivity based on value added, capital-labor multifactor productivity based on value added, capital productivity based on value added, and capital-labor-energy-materials-services (KLEMS) multifactor productivity. Conceptually, KLEMS-TPF is the most appropriate tool to measure technical change by industry because the role of various intermediate inputs in production is fully acknowledged, and the Domar aggregation of KLEMS-TPF across industries provides an accurate picture of the contributions of individual industries to aggregate TFP change (OECD, 2001; O’Mahony and Timmer, 2009). Consequently, the APPF approach, together with KLEMS data, is the proper combination to measure TFP growth. The key challenge, however, to conduct KLEMS-TPF analysis based on the APPF framework is the copious data requirements because one needs price and quantity data for output and various factor inputs, including capital, labor, and intermediate inputs. Due to the reliability of the measurement of TFP, the residual strongly depends on the extent of the quality adjustments of factor inputs. Thus, one also needs price and quantity data for factor inputs at a detailed level, such as detailed types of capital assets, and more types of labor cross-classified by more dimensions. If quality

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4 The OECD stands for the Organization for Economic Co-operation and Development.
improvements in factor inputs are overlooked, the TFP residual should be expected to be higher because it also contains technological progress embodied in factor inputs.

The appropriate tool to measure industry output, intermediate inputs, and value added to finally calculate the KLEMS-type of TFP based on the APPF framework is a time series of input-output tables (IOTs), which records the detailed transactions among sectors within an economy. IOTs show the sources of various inputs in the production of each sector, whether produced by a domestic source or imported from foreign countries, and the destinations of outputs of each sector, whether purchased by some sectors and used as intermediate inputs or by a final demand element, such as consumption, investment, and exports. IOTs also record all payments to primary factors, i.e., capital and labor, involved in the production process, which are the crucial components of value added or GDP. The transactions recorded in IOTs decompose the circular flow of goods and payments illustrated in macroeconomics textbooks to the industry level (Jorgenson et al., 2005). In order to obtain various economic indicators at constant prices, the time series of industry-specific producer price indexes should be constructed. Due to the heterogeneity of capital and labor inputs, it is better to consider both inputs in detailed types, such as more types of capital assets, detailed types of labor cross-classified by gender, educational level, age, and so on. The perpetual inventory method has been widely adopted to construct net capital stock, which is the sum of the past investment in each period adjusted by the corresponding efficiency. Labor input should be measured in terms of hours worked, rather than the quantity of labor employment. The capital service and labor service, transformed from inputs’ stocks, should finally be estimated because the actual factor inputs involved in the production process are the flows of productive services from the stock of corresponding factor inputs.

1.3 Current Study of China: Industry Perspective

Perhaps limited by the availability of data, the KLEMS-TFP analysis of China based on the APPF framework has been adopted by few studies, such as those of Li et al. (1992), Ren and Sun (2009), and Cao et al. (2009). There are, however, some limitations in current studies; for example, Li et al. (1992) ignore the Domar weighting scheme and resource reallocations, Ren and Sun (2009) consider the Domar weighting scheme but nonetheless overlook resource reallocations, and there are some weaknesses in the data construction of Cao et al. (2009).

In 2010, Professor Harry X. Wu of the Institute of Economic Research, Hitotsubashi University, initiated the China Industry Productivity (CIP) Database Project, which was jointly
supported by the Research Institute of Economy, Trade, and Industry and the Institute of Economic Research. This project follows the KLEMS principles of data construction and aims to construct consistent sector-level input and output data series that satisfy analytical studies in a production function framework as well as for international comparisons of output and productivity. By the same token, gross output of an industry equals the total costs of KLEMS, and that of an economy equals the sum of the costs of KLEMS across all industries.

The main characteristics of CIP data are as follows: first, in order to solve serious inconsistencies in concept, coverage, and classification over time and across sectors in official statistics, Wu and Ito (2015) use benchmark Chinese IOTs plus national and sectoral level censuses to both conceptually and empirically reestablish the full statistical coverage of the economy in all input and output accounts as well as income accounts. In addition, they reconstruct benchmark supply-use tables by relying on official supply-use tables, construct the time series of supply-use tables by interpolating and extrapolating benchmark ones, and finally transform the time series of supply-use tables to time series of IOTs by following the Eurostat Manual (2008). They also construct the corresponding sector-specific producer price indexes (PPIs) to follow the standard double deflation to derive items at constant prices.

Second, regarding capital data, H. Wu (2015a) used the first difference of the book value of fixed assets as investment flows for industrial sectors and the newly increased fixed assets as investment flows for non-industrial sectors to construct capital stock by following the perpetual inventory method (PIM). He followed the approach of Hulten and Wykoff (1981) to construct depreciation rates and the steady-state method to estimate initial capital stock, respectively. By using an asset survey from the Ministry of Finance with adjustments, H. Wu estimated the investment price indexes (IPIs) for industrial sectors, taking their geometric mean as the IPIs for non-industrial sectors.

Third, concerning labor data, Wu et al. (2015) used various available data sources, including survey and census data, to construct employment, hours worked, and compensation matrices for detailed types of labor cross-classified by two genders, seven age groups, five education levels, and 37 industries.\footnote{Thus, each industry includes, in total, 70 types of labor.}

In a word, given solid data construction about inputs and outputs across industries, CIP data greatly contributes to measure the variables used in TFP calculation to make the results reliable. Consequently, CIP data is currently the appropriate data tool to investigate TFP
growth of China’s national economy. In addition, the APPF approach, together with CIP data, is the proper combination to measure TFP growth in China.

By using CIP data, H. Wu (2016a) adopts the APPF approach to conduct the KLEMS type of productivity analysis based on 37 industries that cover the whole economy to assess the sustainability of China’s growth model, which is important because government policies are often industry-specific, and individual industries with different degrees of government interventions may affect other industries through the input-output linkages of the economy. Another important aspect of H. Wu’s (2016a) work is that the role the central government played in the Chinese economic growth has been considered indirectly. Despite a series of reforms over past nearly four decades, the Chinese government-engineered excessive physical capital investment is still the critical contributor to the Chinese economy, which also suggests that the Chinese government continues to intervene heavily in the economy. It is essential to understand the intrinsic natures of the Chinese economic growth model by incorporating the role of the Chinese government.

1.4 Objective of This Study: Adding a Regional Dimension

Although China has achieved rapid economic growth at the national level, there is still wide economic disparity among regions (Oizumi, 2010; Liu and Cai, 2009; Shi and Zhao, 2011; Li et al., 2018; Li and Mao, 2019), suggesting that economic development patterns are characterized by growth performance at the regional level. Such insights also suggest that the national economic growth tends to be driven by the performance of a limited number of local economies within the nation (Ascani et al., 2012; Liu and Cai, 2009). Moreover, empirical evidence suggests that TFP differentials provide a relevant explanation of the uneven economic growth performance across regions (Zhang and Lu, 2013; Liu et al., 2018; Jiang and Zhang, 2018). Therefore, investigating the growth performance of the Chinese economy by only considering the industry dimension at the national level is not sufficient to provide a holistic picture to understand the Chinese economy and TFP growth.

Given that China is a large country, consisting of 31 regions (provinces),6 each industry at the national level has a regional distribution. The economic growth among regions has been quite uneven, especially between coastal regions and inland regions, and between eastern regions and western regions. Furthermore, the Chinese economic growth still heavily relies on

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6 The 31 regions cover all regions in the mainland of China, excluding Hong Kong, Macao, and Taiwan.
government-engineered excessive physical capital investment, especially at the regional level (Huang, 2012; Li and Zhou, 2005; Wu and Shea, 2008; C. Xu, 2011). Under the institution of the “regional decentralized authoritarian (RDA)” regime (C. Xu, 2011), competition among growth-motivated local governments has in a large part accounted for the spectacular economic growth of China during the last 40 years. It is inevitable that local governments intervene in resource allocation when GDP growth is established as a political performance indicator by the central government. In particular, local governments tend to adopt industry policy to instruct the flow of factor inputs among industries to stimulate regional economic growth. For example, in the central planning era, in order to achieve a major increase in economic growth to catch up with Western countries, all governments, including local ones, concentrated almost all their resources on developing heavy industries. In the reform period, under the RDA regime, local governments are inclined to affect state-owned enterprises (SOEs) and industries that play a key role in the local economic growth to achieve rapid regional economic growth in order to win the competition among their peers.

Due to different geography and endowments, the industry structure and industry policy adopted by local governments differ among regions, which not only causes economic growth and TFP growth performance across regions to be obviously heterogeneous, but also affects the regional distribution of development and productivity growth of the national industry. Meanwhile, instead of market mechanisms, such governmental interventions, as well as regional protection resulted from competition among local governments (C. Xu, 2011), cause severe resource misallocations in the Chinese economy, thus hindering productivity improvements (Hsieh and Klenow, 2009; Wei and Li, 2017; Wu and Zhang, 2016; Brandt et al., 2013).

Briefly, when studying the economic development of a large, dynamic transition economy such as China’s, we need to be aware of regional differences in growth potentials. In order to provide a holistic picture to understand TFP growth in China, it is worth adding region into the analytical framework when considering the regional origins of aggregate TFP growth in China. Moreover, by integrating regional accounts into the national account, we can also measure the magnitude of resource reallocations across industries and regions simultaneously.

The objective of this study is to combine the APPF approach by further adding the regional dimension and regional KLEMS data to analyze the economic growth and productivity performance of the Chinese economy from a regional perspective, i.e., to further consider the impacts of regional origins of industry on the overall performance of China’s economy and
TFP growth. The contributions of this study to the current literature are the followings. First, we analyze the productivity growth at a detailed sectoral level in each of 31 regions, i.e., 37 sectors in each region, which covers the whole local economy, rather than taking the local economy as a whole or focusing on broad sectors, usually the primary, secondary, and tertiary sectors. By doing so, we can investigate the role the individual sectors playing in the local economy and, further, in the overall Chinese economic growth. Second, by adding regions to the whole accounting framework, we keep the accounting identities consistent between the national account and regional accounts by redistributing the discrepancy between these two into regions using the sectoral structure of newly constructed regional data. Thus, the summation of regional accounts is equal to the national totals. The whole regional dataset can be considered from two aspects, i.e., each region consists of 37 sectors, and each sector at the national level consists of 31 regions. Given the intersection between regions and sectors, we can precisely pinpoint the impact of every regional sector on the whole economy.

Third, in order to conduct productivity analysis at regional level, for the first time, we have constructed the KLEMS type of regional productivity accounts, including output, price deflator, capital input, and labor input. Given the limited data reported in both the Chinese Statistical Yearbooks and the Regional Statistical Yearbooks, none of the above regional data is easily constructed. We have attempted to exhaust all available official statistics to construct each part of the regional productivity accounts.

In Chapter 4, we construct regional output and price deflator. The regional official statistics also contain inconsistencies in concept, coverage, and classification over time and across sectors as that in national statistics. The only choice to keep them consistent over time is to obtain sectoral data at the finest level and then regroup detailed sectors into the 37 standard sectors. We rely on the benchmark regional input-output tables (RIOTs) with detailed sectors to construct time series of sector structure and the control totals of three broad sectors, i.e., primary, secondary, and tertiary sectors, from the Regional Statistical Yearbooks to finally construct time series of panels of gross output, value added, and labor compensation of each region. The intermediate input is derived as the residual of gross output minus value added, and capital compensation is derived as the residual of value added minus labor compensation. Regarding the price deflator, due to limited price data reported in the Regional Statistical Yearbooks and the lack of other data sources, in order to keep regional price data consistent with national data, we construct sector-specific PPIs in each region by following the same principles adopted to construct national sectoral PPIs, that is, the regional official PPIs are used.
for agriculture and industrial sectors, IPI of construction and installation is used as PPI of construction sector, and regional consumer price index (CPI) and its relevant components are used to construct PPIs for service sectors.

In Chapter 5, we construct regional capital data. The regional official statistics also do not publish data regarding capital stock by the standard System of National Accounts (SNA) principles. In addition, the regional data about asset types, depreciation rates, and IPIs are scarce. We adopt the PIM approach to construct net capital stock of each region. The core variables in the PIM approach are constructed as follows: (1) As with constructing national capital stock, for industrial sectors of each region, we use the two-period difference of original value of fixed assets as investment flow, add back scrapings and further make two adjustments: one is to remove investment in residential structures, and the other is to add back productive assets not covered by the regional official industry investment statistics. We use newly increased fixed assets as the investment flow for non-industrial sectors. (2) Concerning asset types, we apply the shares of equipment and structure in the total investment of national industrial sectors to regional industrial sectors, and use the data from the China Statistical Yearbook of The Tertiary Industry to divide investment flows into equipment and structure for all service sectors. For agriculture and construction, the share of equipment and structure is set at 5:5 because there are no systematic data information about asset decompositions for these two sectors by region. (3) The national depreciation rates of each asset in every sector are applied for regions because no such data are reported in regional official statistics. (4) For the initial capital stock of each region, given that the regional capital data start in 1980, we take the values of equipment and structure by sector in 1980 from the national data and divide these two values into 31 regions based on the regional distribution by using the newly constructed regional capital data. (5) We employ the ratio of the IPI of equipment of every industrial sector to the aggregate IPI at the national level to construct IPIs of equipment of industrial sectors in each region. The IPI of equipment of non-industrial sectors is the same as the geometric average of that of industrial sectors. We adopt regional IPI of “construction and installation” as IPI of structure in each region.

In Chapter 6, we construct regional labor data. The difficulties in constructing regional labor data lie in the inconsistent industry classification over time, the lack of detailed cross-classified employment data, and the absence of hours worked and compensation data matched with employment data. We use employment data from regional statistical yearbooks and the population census to construct sectoral employment control totals for each region. We then use
various marginal employment matrices to construct full-dimensional employment matrices for benchmark years by following the iterative proportional fitting (IPF) approach. Using the sectoral employment control totals and the time series of sector structure of employment by interpolating and extrapolating full-dimensional employment matrices at benchmark years, we construct time series of full-dimensional employment matrices for each region. The corresponding hours worked and compensation data of each region are constructed by assuming that the number of average hours worked of each type of labor at the national level is the same as it is in regions, and the ratio of the hourly compensation of each type of labor to the average wage of its corresponding standard sector at national level is as same as it is in regions, respectively.

Fourth, double deflation is adopted in this study to derive real value added rather than single deflation used in the official statistics. It is not difficult to show the difference between double deflation and single deflation. In single deflation, the volume measure of gross value added is estimated by deflating current value of gross value added based on a price index, and the price index of gross value of output is usually adopted. The key assumption underlying single deflation is that price changes of gross value of output and gross value of intermediate inputs are the same, which is not reasonable. At present, along with the increasing depth of industry specialization, the linkage between industries has become closer via input and output connection; that is, the output of an industry is often used as intermediate inputs in other industries. The production activity of an industry tends to use a variety of products from other industries as intermediate inputs. The measurement of real value added of an industry is biased by simply assuming that price changes of its gross output and intermediate inputs are the same. On the other hand, double deflation method is theoretically sound to achieve items at constant prices (SNA, 2008; OECD Manual, 2001; Eurostat Manual, 2008) in which the volume measure of gross value added is obtained as the difference between the volume measure of gross value of output, which is derived by deflating current value of gross output with an appropriate output deflator, and the volume measure of gross value of intermediate inputs, which is derived by deflating current value of intermediate inputs with appropriate intermediate deflators.

The final contribution of this study is that we investigate resource reallocations across sectors and regions. In the central planning period of China, resources were allocated by

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7 The current gross value added, or GDP, is usually measured as the difference between gross value of output and gross value of intermediate inputs.
administrative planning, and most of them flowed into heavy industries and coastal regions, which affects the industry structure of regions as well as the regional distribution of industry. Such administrative planning is path-dependent even if its role is weakening during the reform era. In the reform period, in order to win the GDP contest among peers, local officials tended to adopt industry policies to support certain industries, although not all industries were covered, to stimulate local economic growth, which affected the flow of factors of production among industries. Furthermore, growth competition among local officials also affects the flow of factors of production among regions. Both administrative planning and interventions, instead of market mechanisms, are bound to cause resource misallocation. By integrating regional accounts into the national account, we can estimate the magnitude of misallocation of factors of production across sectors and regions, and the impacts of resource misallocation on the local and further on the Chinese aggregate economy and TFP growth.

1.5 Main Findings of This Study

By adopting the APPF approach and the newly constructed regional productivity accounts, this study analyzes the growth performance of China’s economy and aggregate TFP across regions over the period 1992-2014. The main findings are as follows.

First, the share of agriculture in each regional economy has declined, while that of service sectors has increased over time, which indicates that the regional industry structure has gradually transformed from agriculture to services. The regional distributions of each industry at the national level are heterogeneous, which may reflect the initial endowment and comparative advantage of each region. In addition, the value added growth contributions of individual industries to each region and that of each region to national industry differ across industries and regions.

Second, differences in capital-labor ratio, labor quality, and TFP all contribute to differences in labor productivity growth across regions over time. Specifically, differences in the capital-labor ratio make the largest contribution to differences in labor productivity growth across a majority of regions, followed by differences in labor quality, whereas TFP growth negatively contributes to labor productivity growth in most regions. Differences in capital-labor ratio, labor quality, and TFP contribute diversely to differences in labor productivity growth across industries, and differences in labor productivity growth across industries obviously differ from that across regions. Moreover, the growth sources of labor productivity across industries are different. Specifically, the capital-labor ratio growth makes the dominant
contribution to labor productivity growth of a majority of industries, such as Agriculture, Coal Mining, Metal Mining and so on, whereas TFP growth makes the crucial contribution to labor productivity growth of Chemical Materials, Rubber and Plastics, Fabricated Metal Products, and Electronic Equipment, and labor quality growth only makes the dominant contribution to labor productivity growth of Public Management. On the other hand, decreases in the labor productivity growth of some industries, such as Petroleum and Gas, Petroleum Processing, and so on, are entirely due to dramatic decreases in TFP growth.

Third, the annual growth rate of aggregate value added is 8.73% over the whole period 1992-2014, which reaches 7.54% during 1992-2001, peaks in 2001-2007 (10.11%), and slightly declines to 9.10% in 2007-2014 due to the shock from the 2008 Global Financial Crisis and the tremendous downturn tendency of the Chinese economy starting in 2012. The value added growth exhibits obvious heterogeneity across industries. The four fastest-growing industries are Wholesale, Chemical Materials, Electronic Equipment, and Finance. On the other hand, the four industries with the slowest growth rates are Petroleum and Gas, Petroleum Processing, Healthcare, and Education, and their annual growth rates of value added are negative over 1992-2014. The sectors that are much more vulnerable to governmental interventions, such as Coal Mining, Petroleum and Gas, Metal Mining, Nonmetal Mining, Tobacco, and so on, experience relatively slow or even negative value added growth, which may imply that governmental interventions are not conducive to industry value added growth.

Fourth, the annual value added growth rates of service sectors are relatively higher than those of industrial sectors, even in the last sub-period (i.e., 2007-2014). This suggests that the industry structure of the Chinese economy has gradually transformed from industry to service sectors, and the latter could be an important growth potential of the Chinese economy in the future. In addition, by considering industry value added growth changes over sub-periods, we find that the growth improvement of aggregate value added in 2001-2007 was mainly contributed by the growth improvement of service sectors compared with their growth performances in 1992-2001 because more than half of industrial sectors (14 out of 24) showed slower growth in this sub-period compared with their growth performances in the previous sub-period.

Fifth, by decomposing aggregate value added growth into four components, i.e., capital input, hours worked, labor quality, and TFP growth, we find that the Chinese economic growth still heavily relies on factor inputs, especially capital input, and TFP growth contributes 7.10% to aggregate value added growth.
Sixth, we further decompose aggregate TFP growth into three components, i.e., Domar-weighted TFP growth, the reallocation of capital input, and the reallocation of labor input, and find that the annual growth rate of Domar-weighted TFP over 1992-2014 is -0.80% and is mainly suppressed by the significant negative TFP growth of service sectors. This may suggest that, although the annual growth rate of value added of the service industry as a whole exceeds that of the entire industry, its TFP growth is lower than the latter. The aggregate Domar-weighted TFP growth is mainly contributed by TFP growth of industrial sectors. Additionally, the Chinese government issued a strategic plan in 2015, i.e., “Made in China 2025,” to boost innovations in the Chinese manufacturing to further promote TFP growth in that sector.

Seventh, TFP growth also exhibits obvious heterogeneity across industries, and industries that are vulnerable to governmental interventions are inclined to experience negative TFP growth. By considering TFP growth changes over sub-periods, we find that the growth improvement of aggregate Domar-weighted TFP in 2001-2007 is also mainly contributed by TFP growth improvement of service sectors compared with their growth performances in 1992-2001 because 16 industrial sectors show slower TFP growth in this sub-period compared with their growth performances in the previous sub-period.

Eighth, the industry structure and production efficiency of each region may reflect its initial endowment and comparative advantage, which further affects the contribution of each region to both the value added growth and the Domar-weighted TFP growth of each national industry. Given the uneven economic development and different industry structures across regions, the contribution of each region to aggregate value added and TFP growth is obviously different. Furthermore, sectors that are prone to government interventions even at the regional level tend to achieve relatively slow or even negative TFP growth, while those that are less prone to government interventions could achieve rapid value added growth and TFP growth simultaneously, which may indicate that government interventions are not conducive to efficiency improvement.

Finally, the reallocations of capital and labor inputs are significant in China. Since capital is heavily affected by administrative planning rather than market mechanisms, it grows relatively slowly in industries with high capital service prices, with the result that the reallocation of capital input is negative in the entire period. In contrast, the positive labor reallocation mainly benefits from relaxation of various restrictions on labor mobility, especially relaxation of the household registration system. The labor market is much less controlled than the capital market, and labor forces can move relatively freely across sectors, which may
indicate that labor mobility is more inclined to follow the market mechanisms. As a result, labor grows relatively rapidly in industries with high labor service prices, with the result that the reallocation of labor input is positive in the whole period. Furthermore, both the reallocations of capital and labor have been improved by adding region to the framework, which may indicate that eliminating barriers to prevent factors of production from flowing across regions is conducive to factor allocations. The TFP growth and, further, the overall economic growth would be boosted by considering China as a united market and allowing the factors of production to flow freely across sectors and regions. Finally, the significant reallocations of capital and labor inputs have important impacts on aggregate TFP growth. The labor reallocation is the most important source of aggregate TFP growth. The net reallocation of capital and labor inputs is 1.43% on average between 1992 and 2014 and completely accounts for all aggregate TFP growth.

By exploring the growth origins of the reallocations of capital and labor inputs, we find that their growth sources are quite disparate from the point of view of industry and region perspectives, respectively. Generally speaking, industries or regions with high (or low) capital input growth and high (or low) capital service prices contribute to the improvement of capital allocation, while industries or regions with high (or low) capital input growth and low (or high) capital service prices are responsible for the negative reallocation of capital input. This is also applied to labor reallocation.

1.6 Organization of This Study

The rest of this study is organized as follows. Chapter 2 reviews the existing studies about productivity growth of the Chinese economy, including those on productivity growth of the aggregate economy, industry level, and regional level. Chapter 3 introduces the APPF framework and further incorporates the Domar aggregation scheme by adding a regional dimension. Chapters 4, 5, and 6 explain procedures to construct regional productivity accounts, including output, price deflators, capital input, and labor input. Chapter 7 presents and discusses the empirical results of productivity analysis. We conclude this study in Chapter 8.
Chapter 2: Literature Review

In this chapter, we first review studies that investigate TFP growth of the Chinese aggregate economy and note their main drawbacks with respect to methodology compared to the widely used APPF approach. We also highlight the importance of measurement issues to make TFP estimation reliable and conclude that the CIP dataset is currently the most appropriate data tool to measure TFP growth in China.

Although the TFP analysis by combining the APPF approach and the CIP dataset is helpful to understand growth properties of the Chinese economy at the national level, it is not sufficient to provide a comprehensive explanation for China’s growth story. Consequently, it comes to the purpose of this study, that is, to combine the full APPF approach by further adding a regional dimension and regional KLEMS data to analyze economic growth and productivity performance of the Chinese economy from a regional perspective, i.e., to further consider the impacts of regional origins of industry on the overall performance of China’s economy and TFP growth. We cite some major studies that measure TFP growth in China from the regional perspective and then discuss their shortcomings and contributions of this study.

2.1 Chinese TFP Growth: The Aggregate Economy

In this section, we first introduce studies on TFP growth in China and concentrate on those concerning the Chinese aggregate economy. We cite some major studies and highlight their shortcomings compared to the proper combination of the APPF approach and KLEMS data widely used to measure TFP.

We then introduce several studies that adopt the APPF approach and find that there are still many drawbacks in their data construction. The CIP database project makes a major effort to solidly construct input and output data at the industry level by trying to exhaust various available official statistical yearbooks and publications, which significantly improves data measurement to make TFP residual in China more precise and reliable.

2.1.1 Literature Review

Studies on TFP in China do not have a long history due to the lack of reliable data. This field was probably stimulated by Krugman (1994), who concluded that the growth of East Asian economies was largely driven by extraordinary growth in inputs such as capital and labor rather than by gains in efficiency. Since then, the growth source of the Chinese economy has become the focus of scholars, and studies on China’s TFP growth have proliferated over the
past two decades. Numerous studies have investigated TFP performance in China from various perspectives; for example, Chow and Li (2002), Hu and Khan (1997), Maddison (2007), Wang and Yao (2003), World Bank (1997), Y. Wu (2003), and Zhang and Jiang (2014) have investigated TFP growth of the overall Chinese economy; Hu et al. (2015), Li and Li (2008), Liu and Li (2012), Wang et al. (2013), and Y. Wu (2015) have estimated TFP growth of the Chinese economy from the perspective of certain industries (see Table 2.1). Given that obvious differences among different studies, such as the time period under consideration, methodology, research objects, and factor inputs under consideration, the results of current studies are not comparable with each other, which causes the results of TFP growth of the Chinese economy to be inconclusive.

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<th>Table 2.1 Studies on TFP Growth of China: The Aggregate Economy</th>
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<td><strong>Time period</strong></td>
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<td><strong>Chinese aggregate economy</strong></td>
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<td>Zhao and Yang (2011)</td>
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<th><strong>Chinese economy, industry perspective</strong></th>
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The methodologies widely adopted in current studies are growth accounting based on the APF, data envelopment analysis (DEA), and stochastic frontier analysis (SFA). As mentioned above, the existence of the APF requires that the value-added function is identical across industries and that all industries face the same factor input prices, which are rarely met in reality, especially in developing countries, such as China. The economic system of China is still in a dynamic transformation process, and the intrinsic characteristics and technology level of each industry determine its corresponding value added production function that cannot be identical across industries. Furthermore, the institutional deficiencies, even governmental interventions, hinder the mobility of factors of production, which is bound to cause different factor prices across industries. Meanwhile, the assumption that factor input prices are the same in all industries overlooks resource reallocations. Given that the Chinese government still plays an influential role in market activities, leading markets to be imperfect and occasionally seriously distorted, market mechanisms cannot play an essential role in allocating resources, which causes serious resource misallocation in China (Hsieh and Klenow, 2009; Wei and Li, 2017; Wu and Zhang, 2016; Brandt et al., 2013). Since resource reallocations are an integral part of...
TFP,\(^8\) the fact that the former is ignored by adopting the APF approach could result in overestimating TFP growth in China.

Second, the efficient institution arrangement indicated by assumptions underlying Solow model implies that the role of the government is neutral and does nothing to intervene in market activities, which is crucial to create a competitive market. The factors of production can move freely if a market is competitive, which facilitates the full utilization of inputs. Meanwhile, under such circumstances, since there are no interventions or subsidies from the government, producers are responsible for their own profits and losses, and their goal is to constantly improve their own production technology to pursue maximum profit or minimum costs. These circumstances, however, are rarely found in China. Due to institutional deficiencies, the Chinese government has strong power over market activities and tends to adopt industry policies, sometimes even via direct administrative interventions or subsidies, to promote the development of certain industries, e.g., heavy industries in the central planning era. Such governmental interventions are not only harmful to the mobility of production factors, but they also distort producers’ incentives. The goal of producers has been shifted to spend significant time and resources (even via bribery) that could have been used to improve technology levels, to establish friendly relationships with official governors in order to get supportive policies or subsidies, which is not helpful for technology improvements and further sustainable economic growth.

Third, although the total TFP growth can be decomposed into technical progress and technical efficiency change that can be further decomposed into pure technical efficiency and scale efficiency in DEA and SFA, which is conducive to reveal the “black box” of TFP growth, the role of intermediate inputs cannot be reflected by these two approaches. The main characteristics of the DEA approach are as follows: (1) it neither requires assumptions about efficient producer behavior nor about constant returns to scale technology; (2) there is no need to assume the form of a production function; (3) the technologies and efficiency frontiers can be located according to the best-practice by using linear programming techniques based on observed data. Producers’ degree of efficiency can be determined by the distance between their actual positions and the production frontier. The main disadvantage of this approach is its stability and sensitivity to outliers; that is, the production frontier is determined by actual data and is subject to changes due to different data sources or time periods. The existence of

\(^8\) See formulas in Chapter 3, for example, Equation (3.36).
measurement errors may lead data to be located beyond the true best-practice frontier. Further, the best-practice frontier could be erroneous if the outliers are mistakenly enveloped by frontier techniques. Compared to the DEA approach, SFA overcomes the impacts of random factors and avoids measurement errors caused by outliers. However, it not only needs to assume the form of production function but also to assume the random error term and productivity obey a certain probability distribution in advance. The assumed production function and the probability distribution of the random error term do not necessarily conform to the actual situation, and incorporating subjective factors is inevitable.

Fourth, the above approaches cannot measure the impacts of resource reallocations on TFP growth. Hsieh and Klenow (2009) have found that TFP of China’s manufacturing industry would increase by 30-50% if resource misallocation could be eliminated. Despite various institutional reforms in the past few decades, the government-engineered excessive physical capital investment is still an important contributor to the Chinese economic growth; governmental intervention instead of market mechanisms is bound to cause influential impacts on resource allocation to further create important influences on TFP growth. It is important to contain resource allocations when estimating TFP growth in China.

Fifth, the current methods also fail to reflect the growth contribution of each individual industry to the overall economic growth. The endowments and technologies of different industries necessarily cause imbalances in their development. In addition, industry policies implemented by the government to support certain industries cause relative growth lagging in other industries. Thus, analyzing the contributions of sub-sectors to the overall economy not only measures the growth effect of industry policies on specific industries, but also provides guidance for the central government to further formulate policies to promote the balanced development across industries and to narrow the gap between industries.

Sixth, another shortcoming in current studies lies in the measurement of real value added. Most current studies use the official “value added price index” to deflate nominal value added. The official value added price index, however, has been widely criticized for underestimating actual price changes to overestimate the growth rate of real value added (Woo, 1998; Ren, 1997; Maddison, 2007; H. Wu, 2000 and 2002). Meanwhile, the deflation approach adopted by numerous studies is single deflation, which assumes that price changes of gross output and intermediate inputs of each industry are the same, which is not reasonable. At present, along with the increasing depth of industry specialization, the linkage between industries has become closer via input and output connection; that is, the output of an industry is often used as
intermediate inputs by other industries. The production activity of an industry tends to use a variety of products from other industries as intermediate inputs. Simply assuming that price changes of its gross output and intermediate inputs are the same biases the measurement of an industry’s real value added. Double deflation is the standard approach to derive real value added (SNA, 2008; OECD Manual, 2001; Eurostat Manual, 2008); in this approach, real value added is derived as the residual of gross output deflated by output price index and various types of intermediate inputs deflated by input price indexes.

In addition to methodologies, another important reason for the inconclusive results on TFP growth in China shown in Table 2.1 lies in the quality of the basic data used in TFP calculation. An accurate measurement of TFP growth concerns precisely measuring various types of inputs. Usually, the primary factors, capital and labor, have been considered in studies. More and more studies (e.g., Wang and Yao, 2003; Liu and Li, 2012; Chen et al., 2008) have considered additional inputs, such as human capital, land, energy, water, pollution, and environmental factors, which is helpful to estimate the actual TFP growth. However, the measurement of capital and labor inputs in current studies is improper. Most use capital stock as capital input and number of persons employed as labor input in the TFP calculation, which is conceptually inappropriate. As noted in the OECD Manual (2001), capital goods that are purchased or rented by a firm are seen as carriers of capital services that constitute the actual input in the production process. Similarly, employees hired for a certain period can be seen as carriers of the stocks of human capital and therefore repositories of labor services. Therefore, the basic inputs of an economy are the productive services of factors of production, i.e., capital services and labor services, which constitute the actual inputs in production activities. Several studies estimate effective labor input by adjusting the number of persons employed according to years of education, which still cannot sufficiently reflect the heterogeneity of the quality of education among different kinds of labor.

Although some studies also consider various intermediate inputs, they are all confined to certain industries and cannot flow across industries, and resource reallocation effects thus cannot be measured. The measurement of intermediate inputs should be based on a time series of IOTs. The linkages among sectors under the framework of IOT indicate that a sector’s production activities adopt not only a part of its own output, but also output from other sectors as intermediate inputs. Furthermore, intermediate inputs flow into sectors with higher factor prices by following market mechanisms. Thus, according to the production efficiency and
technology level of each sector, the measurement of intermediate inputs based on IOTs is conceptually appropriate.

It is possible that, due to copious data requirements, the APPF approach has not yet been widely adopted to measure KLEMS-TPF growth in China. The KLEMS-TPF analysis of China based on the APPF framework can be traced to the work of Li et al. (1992). There are, however, some limitations to their work. First, they only estimate TFP growth of each sector (in total, 34 sectors) and ignore the Domar weighting scheme, so they cannot measure the growth contribution of sectoral TFP to aggregate TFP growth and trace the aggregate TFP growth origins. Second, they overlook resource reallocations, which might result in a measurement bias in aggregate TFP growth because the former is an integral part of the latter. Third, concerning data, they estimate labor input in terms of persons employed rather than hours worked. Ren and Sun (2009) move beyond Li et al.’s work by considering the Domar weighting scheme so that they can measure the growth contribution of sectoral TFP to aggregate TFP growth and thus trace the aggregate TFP growth to the sectoral level. However, they still overlook resource reallocations, adopt “investment in fixed capital” to construct capital stock, and estimate labor input in terms of persons employed. Cao et al. (2009) are the first to adopt the full APPF approach to investigate KLEMS-TPF growth in China. There are, however, some weaknesses in their data construction. For example, the difficulties in estimating capital input include the lack of adequate deflators for different assets in earlier periods and the lack of China-specific depreciation rates. The measurement of labor input suffers from the lack of a useful annual industry estimate, especially in the years prior to 1990, and the lack of data concerning hours worked (Cao et al., 2009).

2.1.3 Solution to Shortcomings in Current Studies: The CIP Database

The CIP project, launched by Professor Harry X. Wu in 2010, attempts to exhaust various available official statistical yearbooks and publications to solidly construct industry-level data by following KLEMS principles, which ties data development, growth accounting, and production theory firmly together for the case of China.

The main characteristics of CIP data are as follows: first, due to the serious inconsistences in concept, coverage, and classification over time and across sectors in official

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statistics, Wu and Ito (2015) use benchmark Chinese IOTs plus national and sectoral level censuses to both conceptually and empirically reestablish full statistical coverage of the economy in all input and output accounts as well as income accounts. With the control totals from reconstructed national accounts and the time series of industry structure by interpolating and extrapolating that of benchmark IOTs, they construct time series of panels of gross output, gross value added, labor compensation, and capital compensation for 37 standard CIP industries. In order to construct time series of IOTs, they first reconstruct benchmark supply-use tables by relying on official ones; next, they construct time series of supply-use tables by interpolating and extrapolating benchmark ones; finally, they transform time series of supply-use tables to time series of IOTs following the Eurostat Manual (2008). Intermediate inputs can be derived from the time series of IOTs as residual of gross output minus value added.

Second, in order to obtain items at constant prices, they construct time series of sector-specific producer price indexes. Generally speaking, PPI data from official statistics are used for agriculture and industrial sectors; IPI of construction and installation is used as PPI of construction, and the CPI and its relevant components are used to construct PPIs for service sectors. Based on the constructed time series of IOTs and price indices, the standard double deflation can be conducted to derive real value added.

Third, regarding capital data, since the National Bureau of Statistics (NBS) of China has not published capital stock data by the standard SNA criterion, H. Wu (2015a) has adopted the widely used PIM to construct net capital stock. The investment flow, depreciation rate, initial capital stock, and IPI are four essential variables in PIM, which are explained in turn. Most current studies use “investment in fixed assets” as the investment flow in PIM to estimate capital stock, which is inaccurate for two main reasons: one is that the investment in fixed assets might not form the standard fixed assets in the current period, which may need a long construction period to form fixed assets; second, part of investment in fixed assets may never form fixed assets, or it might even be completely wasted (H. Wu, 2015a). For industrial sectors, H. Wu uses the two-period difference of “original value of fixed assets (OVFA, gu ding zichan yuanzhi, in Chinese)" as investment flow, adds back scraped fixed assets in the current period and, further, makes two adjustments: one is to remove non-productive assets, mainly

10 See Table 2 in Wu and Ito (2015) for details.
11 According to the official definition, OVFA is approximately equivalent to the book value of fixed assets.
12 Since OVFA is an end-of-period value, not covering fixed assets scraped in the current period, this part of fixed assets should be added back.
residential structures, and the other is to add back productive assets not covered by the official industry investment statistics. Since there are no OVFA data for non-industrial sectors, the “newly increased fixed assets (NIFA, xinzeng guding zichan, in Chinese)” are used as investment flow.

Concerning depreciation rates, H. Wu follows the approach of Hulten and Wykoff (1981), that is, \( \delta = \frac{R}{T} \), where \( \delta \), \( R \), and \( T \) represent depreciation rate, declining balance rate, and service life of assets, respectively, uses various data sources to estimate service life of each type of capital assets, and adopts the results of the declining balance rate from Hulten and Wykoff’s study to estimate depreciation rates for industrial sectors. Further, the geometric mean of depreciation rates of industrial sectors is used as depreciation rate for non-industrial sectors. This approach reduces the subjective arbitrariness of choosing depreciation rates, which is often done in current studies.

H. Wu adopts the steady-state method to estimate the initial capital stock, which assumes that growth rates of capital and output are equal when an economy is in the steady state. This method has been widely adopted in the literature, such as in Harberger (1978) and King and Levine (1994). In addition, H. Wu uses the industry-specific asset price indices for state-owned enterprises based on an asset survey by the Ministry of Finance with adjustments to estimate IPIs of industrial sectors, and the geometric mean of IPIs of industrial sectors is used as IPIs for non-industrial sectors.

Fourth, in terms of labor data, the CIP data contain detailed types of labor, specifically, two genders, seven age groups, and five education levels; thus, each industry includes 70 types of labor in total. In order to construct the number of employment, hours worked, and hour compensation corresponding to each type of labor, Wu et al. (2015) first look for various kinds of marginal matrices (which contain partial dimensions) for benchmark years from various data sources, including the population census; the 1% population sample survey; the Chinese Household Income Project; Rural, Urban and Migrant in China; and so on, and then construct full-dimensional corresponding matrices at benchmark years by applying the iterative

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13 Since the 1990s, the cut-off point of projects covered by statistics on the investment in fixed assets has undergone two adjustments. Since 1997, the cut-off point was raised from an investment of 50,000 yuan to 500,000 yuan, except investment in real estate development, farm household investment, non-farm household investment, and private investment in housing construction in urban areas and industrial and mining areas. Further, since 2011, the cut-off size of projects of investment in fixed assets rose from a total planned investment above 500,000 yuan to 5,000,000 yuan (2017 China Statistical Yearbook, page 293). Thus, investment in fixed assets that are not covered by official statistics is mainly investment projects below the official threshold for such statistics. Please see Equation (4.3) in H. Wu (2015a) on estimating investment flow.
proportional fitting approach, which is designed to integrate marginal matrices by generating the maximum likelihood estimate of each element of a matrix. According to the constructed full-dimensional matrices for benchmarks and marginal matrices in time series, they construct time series of full-dimensional matrices by linear interpolations and use data from marginal matrices as control totals for non-benchmark years. The detailed labor data are not only useful to estimate the actual labor input involved in production process, but also to precisely measure human capital growth in China.

In a word, due to solid data construction about inputs and outputs across industries, the CIP data are currently appropriate data to investigate TFP growth of China’s national economy. Therefore, the APPF approach, together with CIP data, is the proper combination to measure TFP growth in China.

2.2 Chinese TFP Growth: A Regional Perspective

Although TFP analysis by combining the APPF approach and the CIP dataset is helpful to understand growth properties of the Chinese economy at the national level, it is not sufficient to provide a comprehensive explanation of the Chinese growth story for the following reasons.

First, before the founding of the People’s Republic of China in 1949, the Chinese mainland experienced long-term wars, dramatic economic fluctuations, and great economic losses. As a result, in order to strengthen national defense, the Chinese central government adopted the central planning economic mode following the Soviet economic system to give priority to the rapid development of both heavy industries and chemical industries since 1949. The central government controlled allocation of all resources among regions, and local governments controlled allocation of all resources among industries within their jurisdictions. The governments suppressed prices of agricultural products, processing industrial products, and basic industrial products to provide raw materials at low costs to heavy chemical industries, causing uneven development among agriculture, light industries, and heavy chemical industries. It also resulted in uneven development among regions, i.e., regions with a high share of agriculture or light industries grew relatively slowly, while regions with a high share of heavy chemical industries grew relatively quickly during the central planning era.

Second, China started implementing economic reform and opening-up policy in 1978 in an attempt to transform it from the slow, inefficient, Soviet-planned economic system to a market-oriented economic growth model. In the context of economic reform, the rural household contract responsibility system gradually replaced the people’s commune economic
system starting in 1978. Farmers contracted land, and they were free to sell their own agricultural products in the market. Meanwhile, the central government adjusted the industrial focus, shifting from heavy industries to agriculture and light industries, which aroused attention to the development of agriculture, light industries, and foreign trade. Benefited from favorable geographic location, eastern coastal regions achieved dramatic growth in trade and further in regional economies.

Realizing the heterogeneous economic growth potentials across regions, the central government implemented the policy of “encouraging some regions and people to get rich first, then those who become rich first bring along other people and eventually achieve the goal of common prosperity” at the beginning of economic reform. In order to achieve the policy target, the central government established several Special Economic Zones starting in 1979, Coastal Open Cities starting in 1984, and Coastal Economic Open Areas starting in 1985, all located in eastern coastal districts, to facilitate economic growth in these regions. The rapid economic growth in eastern coastal regions further attracted more and more production factors flowing from inland and western regions, widening the economic growth gap among eastern, inland, and western regions.

Third, the institution reform is path-dependent, that is, once an institution is established, it forms a powerful group with vested interests in the existing institution. They seek to consolidate existing institutions and hinder further reforms, and they also strive to make changes conducive to consolidate and expand their vested interests. Although the goal of Chinese economic reform since 1978 has been to shift the central planning economic system to a market-oriented economic system, the reform cannot be completed overnight; instead, the Chinese central government follows a step-by-step approach to gradually reform the old economic system. Given that China underwent the central planning period for a long time, the governments at various layers cannot be asked to cede full control of administrative rights to the market overnight. Consequently, the Chinese governments still played a powerful role in market activities even during reform period. For example, the governments implemented a “double-track price system” at the beginning of reform, which was not abolished until 1990.

Fourth, under the RDA regime, given that the GDP growth rate is explicitly established by the central government as an important indicator to promote local officials, local officials tend to adopt industry policy to instruct flow of factor inputs among industries to stimulate regional economic growth. As a result, competition among growth-motivated local governments has, in a large part, accounted for the spectacular economic growth of China
during the past nearly four decades (C. Xu, 2011). Given that different geographies and endowments, industry structure and industry policy adopted by local governments differ among regions, which further causes economic growth and TFP growth performance across regions to be obviously heterogeneous.

Finally, due to the institutional deficiency, the Chinese governments rather than the market play an influential role in allocating various resources, causing severe resource misallocations, which hinders the improvement of productivity (e.g., Hsieh and Klenow, 2009; Wei and Li, 2017; Wu and Zhang, 2016; Brandt et al., 2013). The household registration system remains the largest obstacle to prevent laborers from migrating across regions. Under the RDA regime, local governors are delegated with strong power to take overall responsibility for regional economic growth within their jurisdictions. They have influence or even direct control rights over a substantial amount of resources, such as land, financial resources, energy, raw materials, and others, and they tend to allocate various resources to state-owned enterprises rather than to private enterprises because the former has a close relationship with governments. A negative effect resulted from regional competition among local governments under the RDA regime is the regional protections, which hinders the free mobility of production factors across regions.

In a word, given different geographic locations and initial endowments, plus the effect of policy, economic growth among regions has been quite uneven, and as a result, the contribution of each region to the Chinese aggregate economy is different. In addition, due to the imperfect institutional arrangement, instead of the market, the Chinese governments determine allocation of various resources, plus the growth competition among local governments limits free flow of resources across regions, deteriorating the allocation efficiency of resources. Therefore, for a large and dynamic transition economy like China’s, it is worth adding region to the whole analytical framework when considering regional origins of aggregate TFP growth in China, and measuring the magnitude of resource reallocations across industries and regions to investigate impacts of the imperfect institution on resource allocation and further on TFP growth.

The objective of this study is to combine the full APPF approach by further adding the regional dimension and regional KLEMS data to analyze economic growth and productivity performance of the Chinese economy from a regional perspective, i.e., to further consider impacts of regional origins of industry on the overall performance of China’s economy and TFP growth. According to the Domar weighting scheme, we can not only analyze the
contribution of individual industry growth to the regional economy and, further, to the Chinese aggregate economy, but also investigate impacts of local governmental interventions on industry TFP growth, then on region-wide TFP growth and, finally, on economy-wide TFP growth, which is reflected in resource reallocations across industries and regions.

The current studies on Chinese TFP analysis from the regional perspective mainly consist of two types of studies: one analyzes TFP growth of the Chinese aggregate economy based on regions, and the other explores regional origins of TFP growth of the national industry. Table 2.2 summarizes some major studies that measure TFP growth in China from these two perspectives.

<table>
<thead>
<tr>
<th>Table 2.2 Studies on TFP Growth of China from a Regional Perspective</th>
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<tr>
<td><strong>Time period</strong></td>
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<tr>
<td><strong>Chinese economy, regional perspective</strong></td>
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<tr>
<td>Li and Liu (2015)</td>
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<td>Sun et al. (2010)</td>
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<td>Wang et al. (2010)</td>
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<td>Zhang and Lu (2013)</td>
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<td>Zhou and Han (2009)</td>
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<td><strong>Chinese industry, regional perspective</strong></td>
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<td>Chen et al. (2008)</td>
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<td>Liu and Zhang</td>
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<td>Yuan and Xie</td>
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Notes: See Table 2.1.
Source: Author’s collection.

Similar to Table 2.1, the inconclusive results about Chinese TFP growth from a regional perspective shown in Table 2.2 are mainly due to various differences among different studies, such as methodology, research objects, and the main inputs in consideration. Furthermore, the main problems in current studies that investigate Chinese TFP growth from a regional perspective are similar to those in studies that investigate TFP growth of the Chinese aggregate economy, i.e., the application of the APF, DEA and SFA approaches, the omission or inappropriate measurement of intermediate input, the omission of the Domar aggregation scheme and resource reallocations, and so on. Currently, there are no studies that cover all regions in China to estimate TFP across relatively detailed sectors. Due to the significant data requirements, the KLEMS-TFP analysis based on the APPF approach has not been adopted in current studies to measure TFP growth in China from a regional perspective. Most current studies focus either on productivity growth of broad sectors instead, usually three broad sectors, i.e., primary, secondary, and tertiary sectors; on industrial sectors; or on service sectors that do not cover the whole local economy because the official statistics also only report relatively detailed data for “above-designated size” industrial sectors and service sectors.

### 2.3 Contributions of This Study

In order to overcome above shortcomings in existing studies, for the first time, this study adopts the widely used APPF approach and regional KLEMS data to analyze Chinese TFP growth from a regional perspective. The contributions of this study to the literature are illustrated as follows.
First, in order to conduct productivity analysis at regional level, we extend the CIP database to regions by following KLEMS principles not only to reconstruct regional output data at industry level based on regional input and output tables to keep industry classification and data coverage consistent between regional accounts and the national account, but also to construct capital input and labor input data at regional industry level. The newly constructed regional data cover all regions in China, i.e., 31 regions, and each region consists of 37 sectors so that we can provide a more comprehensive picture of China’s growth model during 1992-2014. The role of individual sectors and regions played in the overall Chinese economic growth can also be investigated with the detailed regional data. The detailed procedures to construct regional KLEMS data are explained in Chapters 4, 5, and 6.

Second, with the constructed time series of RIOTs and PPIs at industry level, we adopt the standard double deflation at regional level. As stated earlier, the single deflation adopted in current studies does not sufficiently consider price changes in gross output and intermediate inputs, causing a biased estimate of value added at a constant price. Double deflation is the preferred methodology for deriving an estimate of value added in volume terms because gross output and intermediate inputs are deflated separately by proper deflators. The time series of RIOTs is constructed by combining time series of sector structure, derived by the interpolation and extrapolation of sector structure of RIOTs with detailed sectors at benchmark years, and control totals from regional yearbooks. In order to reflect price changes of each region while maintaining consistency with national price data, we follow the same principles adopted to construct national sectoral PPIs to construct regional sector-specific PPIs.

Third, as Jorgenson et al. (1987) have shown, an important source of aggregate TFP growth in the APPF approach is the Domar-weighted TFP. In this study, the Domar-weighted TFP is the weighted sum of sectoral or/and regional TFP growth with corresponding weights. Therefore, the aggregate TFP growth can be traced to the sources of growth at sectoral or/and regional level, and the contributions of sectoral or/and regional TFP growth to aggregate TFP growth can also be accurately pinpointed. Meanwhile, based on the Domar aggregation scheme, this study unifies the two current perspectives to investigate TFP growth in China from the regional perspective listed in Table 2.2, i.e., we first aggregate TFP growth rates at industry level to obtain region-wide TFP growth rates that are further aggregated to economy-wide TFP growth rate with corresponding weights in each step.

Fourth, as stated above, resource allocation creates crucial impacts on TFP growth, especially for China where local governments still play an important role in economic activities.
instead of market mechanisms. The reallocation effects of primary factors of production, i.e., capital and labor, on TFP growth are estimated in this study, and they are defined by the difference between the Domar-weighted sum of growth rates of capital or labor inputs across sectors or/and regions and the unweighted growth rate of aggregate capital or labor inputs.\textsuperscript{14} The resource reallocations in this study include those across sectors within a region, across regions given a certain sector, and across different sectors and regions, thus measuring the comprehensive resource reallocations in the Chinese economy and reflecting the contribution of resource utilization efficiency across sectors or/and regions to aggregate TFP growth. If there are no barriers to obstruct factor mobility across sectors and regions, factor inputs tend to flow into sectors or regions where they are paid at higher prices if factor input prices differ among sectors and regions. This creates positive reallocations, and those sectors or regions with higher factor input prices achieve faster input growth, promoting Chinese aggregate TFP to increase. In contrast, due to the existence of local governmental interventions in market activities,\textsuperscript{15} factor inputs cannot flow freely among sectors and regions, which could cause factor inputs to be confined to certain sectors and regions even if their service prices are low. This might result in negative reallocations to impede aggregate TFP growth. Thus, resource reallocation is an appropriate tool to investigate impacts of institutional deficiencies and local governmental interventions on the Chinese TFP growth.

\textsuperscript{14} For example, see Equation (3.36) for resource reallocations within a region.

\textsuperscript{15} For example, in order to maintain the amount of employment, the governments instruct banks to provide SOEs with loans even if their efficiency of resource usage is low.
Chapter 3: Methodology

In this chapter, we first introduce the development of methodology to measure TFP, and then follow the line of bottoms-up to introduce the APPF approach by further adding a regional dimension. That is, we begin with introducing the methodology used to measure TFP growth at industry level, then for regions, and finally for the Chinese economy as a whole.

3.1 Development of Methodology for Measuring TFP

The measurement of TFP dates to Solow (1957), who linked the production function and the index number approach. In Solow’s paper, the APF can be expressed as:

\[ Y = AF(K, L) \]  

where \( Y \), \( K \), and \( L \) represent output, capital input, and labor input, respectively. \( A \) is the Hicksian neutral technical change, which increases the efficiency of both capital input and labor input to the same extent.\(^{16}\)

The nominal value of gross output is defined as:

\[ p^Y Y = p^K K + p^L L \]  

where \( p^K \), \( p^L \), and \( p^Y \) are prices of capital input, labor input, and output, respectively.

Taking the total logarithmic differentials of Equation (3.1) with respect to time, we derive the growth rate of output as:

\[ \frac{\dot{Y}}{Y} = \frac{\partial Y}{\partial K} \frac{\dot{K}}{K} + \frac{\partial Y}{\partial L} \frac{\dot{L}}{L} + \frac{\dot{A}}{A} \]  

where \( \dot{x} \) denotes the change in consecutive periods.

This expression indicates that growth rate of real gross output can be factored into growth rates of capital input and labor input, both of which are weighted by their output elasticities, and growth rate of Hicks-neutral technology.

The output elasticities in above equation are not directly observable, but under the assumption that firms are price-takers in factor markets, each input is paid the value of its marginal product, that is,

\[ \frac{\partial Y}{\partial K} = \frac{p^K}{p^Y} \text{ and } \frac{\partial Y}{\partial L} = \frac{p^L}{p^Y} \]  

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\(^{16}\) Time subscripts are suppressed for convenience wherever possible; the same is true for subsequent equations.
Then, relative prices can be substituted for corresponding marginal products. This, in turn, converts the unobserved output elasticities into observable income shares, $v^K$ and $v^L$. The Equation (3.3) then becomes:

$$\frac{\dot{Y}}{Y} = v^K \frac{\dot{K}}{K} + v^L \frac{\dot{L}}{L} + \frac{\dot{A}}{A}$$

Or, $\frac{\dot{A}}{A} = \frac{\dot{Y}}{Y} - v^K \frac{\dot{K}}{K} - v^L \frac{\dot{L}}{L}$

where $v^K = \frac{p^K}{pY}$ and $v^L = \frac{p^L}{pY}$.

As shown in Equation (3.5), $\frac{\dot{A}}{A}$ represents TFP growth, also called the Solow residual, which measures the remaining portion of output growth not explained by growth in capital input and labor input. It is a “measure of our ignorance” because various factors comprising TFP are lumped together as a “left-over” factor, including not only wanted factors (e.g., technical innovation and research and development activities), but also unwanted factors (e.g., measurement error, omitted variables, and model misspecification).

Solow’s derivation of the TFP residual is the growth rate of a Divisia index, a continuous time index related to the discrete time chain index. This linkage is crucial for using discrete time data to conduct Solow’s continuous formulation. Meanwhile, the TFP residual can still be interpreted as the continuous shift in an APF. As Hulten (2001) has noted, however, Solow showed that the production function shown in Equation (3.1) and the marginal productivity conditions shown in Equation (3.4) lead to the growth rate form in Equation (3.5). He did not show that a researcher who starts from Equation (3.5) necessarily returns to the term $A$ in the production function. This problem is called “path dependence”. Path dependence does not guarantee the uniqueness of a Divisia index used in the calculation of the TFP residual. As a result, it is possible that the calculation in Equation (3.5) could lead somewhere other than $A$, thus causing a misinterpretation of the conventional TFP residual. This problem has been addressed by Hulten (1973), who showed that the Solow conditions are both necessary and sufficient to guarantee the uniqueness of the Divisia index. That is, the expression in Equation (3.5) yields a unique index only if the partial derivatives of a production function are equal to the prices used to compute the index, i.e., the marginal productivity pricing conditions shown in Equation (3.4). The path-independent Divisia index guarantees that the TFP residual in Solow’s procedures is uniquely associated with the shift in the production function.
However, there are some challenges to Solow’s work. First, as mentioned before, the application of an APF requires that the value added function is identical across industries, which is hardly the case due to different production characteristics and technology levels across industries. The same is true for the functions that summarize heterogeneous types of capital input and labor input across industries into the economy-wide aggregates. Second, intermediate input is omitted. The important role of intermediate input is disseminated via the industry chain. The productivity improvement of a certain industry could ultimately significantly influence aggregate TFP growth. As a result, the omission of intermediate input would result in a biased estimate of TFP growth. Third, the calculation procedure of Solow’s model from the production function to the TFP residual does not necessarily require the assumption that the production function exhibits constant returns to scale. Constant returns are actually needed to estimate the return to capital input as a residual of value added minus the return to labor input. In addition, the assumption that the market is perfect is crucial for the Solow model, which guarantees that the assumption of marginal cost pricing holds. However, when imperfect competition leads to marginal costs greater than a price, for example, the Solow residual would yield a biased estimate of TFP growth. Finally, the assumption that technical change is Hicksian neutral is valid if innovation improves the marginal productivity of all inputs equally. This strong assumption is violated if factor-augmenting technical change occurs. Hulten (2001) has shown that the residual is the share weighted average of the rates of factor augmentation if the technical change augments the marginal productivity of each input separately, which still measures the change in TFP. This also enhances the point that TFP growth is not the same as technical change because a change in the income shares can cause TFP to increase or decrease even if the underlying rate of technical change remains unchanged. Despite the above challenges to Solow’s work, it can still provide a yardstick to measure TFP growth. Furthermore, by considering modification of each precondition while keeping others unchanged, researchers can examine the impacts of each precondition on TFP measurement.

A less restrictive approach is the APPF approach, proposed by Jorgenson (1966) and generalized by Jorgenson and Griliches (1967). The APPF approach follows the basic assumptions of neoclassical growth theory, but it allows output prices to be different across industries that are assumed to be the same across industries in the APF approach. In the APPF approach, the growth rate of aggregate output is calculated as a weighted sum of growth rates of individual industry output by using the relative shares of the value of individual industry output in the value of total output as weights. By doing so, it captures different contributions
to the aggregate economy that originate from different industries. Jorgenson and Griliches have also remarkably contributed to measure the relevant variables used in Solow’s TFP calculation. They disaggregate factor inputs into their detailed component parts, thereby avoiding the aggregation bias associated with internal shifts in the composition of the inputs. Similarly, based on the Divisia index approach, the growth rate of each type of factor input is calculated as a weighted average of growth rates of various individual inputs, and weights are defined by the relative shares of the value of individual input in the value of the corresponding factor input. In sum, Jorgenson and Griliches firmly tied data development, growth accounting, and production theory together.

Given that economic data come in discrete-time form rather than in continuous-time form, it is necessary to find a discrete-time approximation to implement the continuous-time theory of the TFP residual developed by Solow. Diewert (1976) has addressed this issue and shown that the Tornqvist approximation to the Divisia index is an exact index number if the production function has the translog form developed by Christensen et al. (1973). Assuming that the production function takes the translog form, and adopting the Tornqvist index, Jorgenson et al. (1987) have fully developed the APPF approach by further taking the Domar weighting scheme and resource reallocations into account. As stated in Chapter 2, the Domar aggregation can measure the growth contribution of individual industry to the aggregate economy and trace growth sources of the aggregate economy at industry level. Resource reallocation measures the contribution of changes in industry distribution of all types of factors of production to aggregate TFP growth. Another major contribution of Jorgenson et al. (1987) is that the production function is based on a gross output production function, not a value added concept, and the role of intermediate input played in economic growth is explicitly exhibited. To date, the full APPF approach has been widely adopted to measure TFP growth.

In the next section, we follow the line of bottoms-up to introduce the APPF approach used in this study to measure TFP growth by further adding a regional dimension. That is, we begin with introducing the methodology used to measure TFP growth at industry level, then for regions, and finally for the Chinese economy as a whole.
3.2 Industry Growth

The gross output production function is a function of capital input, labor input, intermediate input, and TFP, that is,

\[ Y_{i,j} = F_{i,j}(K_{i,j}, L_{i,j}, X_{i,j}, T_{i,j}) \]  

(3.6)

where \( Y_{i,j}, K_{i,j}, L_{i,j}, X_{i,j}, \) and \( T_{i,j} \) are gross output, capital input, labor input, intermediate input, and TFP of industry \( i \) in region \( j \), respectively. In this study, we have 37 industries and 31 regions, that is, \( i = 1, \ldots, 37 \) and \( j = 1, \ldots, 31 \). The intermediate input is a concept based on an IOT. In the IOT framework, we assume that every industry produces one type of output, and the output of an industry can either be consumed by this industry itself or delivered to others and used by the latter as intermediate inputs. In addition, each industry uses a different mix of outputs from other industries as intermediate inputs.

Several aspects should be noted about the production function in Equation (3.6). First, the variables \( K_{i,j}, L_{i,j}, \) and \( X_{i,j} \) are each the aggregate of many detailed components, which are discussed later. Second, we assume that the industry production function is separable in these aggregates. Third, the production function itself is indexed by industry \( i \) in region \( j \) because we do not impose any cross industries and regions restrictions in the industry-level analysis. Finally, it reflects the explicit role of intermediate input (Jorgenson et al., 2005).

The value of gross output of each industry is exactly equal to the sum of values of various factor inputs, that is,

\[ p_{i,j}^Y Y_{i,j} = p_{i,j}^K K_{i,j} + p_{i,j}^L L_{i,j} + p_{i,j}^X X_{i,j} \]  

(3.7)

where \( p_{i,j}^Y, p_{i,j}^K, p_{i,j}^L, \) and \( p_{i,j}^X \) are output price, capital service price, labor input price, and the intermediate input price of industry \( i \) in region \( j \), respectively.

Taking the total logarithmic differentials of Equation (3.6) with respect to time, we derive the growth rate of gross output as:

\[ \frac{Y_{i,j}}{Y_{i,j}} = \frac{\partial Y_{i,j}}{\partial K_{i,j}} \frac{K_{i,j}}{K_{i,j}} + \frac{\partial Y_{i,j}}{\partial L_{i,j}} \frac{L_{i,j}}{L_{i,j}} + \frac{\partial Y_{i,j}}{\partial X_{i,j}} \frac{X_{i,j}}{X_{i,j}} + \frac{\partial Y_{i,j}}{\partial T_{i,j}} \frac{T_{i,j}}{T_{i,j}} + \frac{\partial Y_{i,j}}{\partial A_{i,j}} \frac{A_{i,j}}{A_{i,j}} \]  

(3.8)

where \( \frac{A_{i,j}}{A_{i,j}} \) represents TFP growth, defined as:

\[ \frac{A_{i,j}}{A_{i,j}} = \frac{\partial A_{i,j}}{\partial Y_{i,j}} \frac{Y_{i,j}}{Y_{i,j}} \]  

(3.9)
The TFP term represents impacts on productivity of industry $i$ in region $j$ that result from technological progress, the allocative efficiency of resources, and so on.

Under the assumption that firms are price-takers in factor markets, each input is paid the value of its marginal product, that is,

$$\frac{\partial v_{i,j}}{\partial K_{i,j}} = \frac{\partial v_{i,j}}{\partial L_{i,j}} = \frac{\partial v_{i,j}}{\partial X_{i,j}} = \frac{\partial v_{i,j}}{\partial A_{i,j}} = \frac{\partial Y_{i,j}}{\partial v_{i,j}} \quad (3.10)$$

The Equation (3.8) then becomes:

$$\frac{Y_{i,j}}{Y_{i,j}} = \frac{K_{i,j}}{K_{i,j}} + \frac{L_{i,j}}{L_{i,j}} + \frac{X_{i,j}}{X_{i,j}} + \frac{A_{i,j}}{A_{i,j}}$$

(3.11)

where $v_{i,j}^K$, $v_{i,j}^L$, and $v_{i,j}^X$ are factor inputs shares in gross output of industry $i$ in region $j$, i.e.,

$$v_{i,j}^K = \frac{p_i^k K_{i,j}}{L_{i,j}}, \quad v_{i,j}^L = \frac{p_i^l L_{i,j}}{L_{i,j}}, \quad \text{and} \quad v_{i,j}^X = \frac{p_i^x X_{i,j}}{L_{i,j}} \quad (3.12)$$

We use the discrete time-based Tornqvist index approach to approximate the growth rate in continuous time; the rate of growth of gross output in Equation (3.11) can then be written as the Tornqvist aggregation of growth rates of all factor inputs and TFP, i.e.,

$$\Delta \ln Y_{i,j} = \sigma_{i,j}^K \Delta \ln K_{i,j} + \sigma_{i,j}^L \Delta \ln L_{i,j} + \sigma_{i,j}^X \Delta \ln X_{i,j} + \sigma_{i,j}^T \quad (3.13)$$

where $v_{i,j}^T$ represents growth rate of TFP of industry $i$ in region $j$, and $\sigma_{i,j,t}^K$, $\sigma_{i,j,t}^L$, and $\sigma_{i,j,t}^X$ are the two-period averages of $v_{i,j}^K$, $v_{i,j}^L$, and $v_{i,j}^X$, i.e.,

$$\sigma_{i,j,t}^K = \frac{v_{i,j,t}^K + v_{i,j,t-1}^K}{2}, \quad \sigma_{i,j,t}^L = \frac{v_{i,j,t}^L + v_{i,j,t-1}^L}{2}, \quad \text{and} \quad \sigma_{i,j,t}^X = \frac{v_{i,j,t}^X + v_{i,j,t-1}^X}{2}. \quad (3.14)$$

We also assume that capital input, labor input, and intermediate input of industry $i$ in region $j$ are the functions of corresponding individual components, respectively, i.e.,

$$K_{i,j} = \varphi_1(K_{i,j}, \ldots, K_{k,i,j})$$

$$L_{i,j} = \varphi_2(L_{i,j}, \ldots, L_{l,i,j})$$

$$X_{i,j} = \varphi_3(X_{i,j}, \ldots, X_{x,i,j}) \quad (3.15)$$

where $k$, $l$, and $x$ represent detailed types of corresponding factor input. $K_{k,i,j}$, $L_{l,i,j}$, and $X_{x,i,j}$ represent capital input of type $k$, labor input of type $l$, and intermediate input of type $x$ of industry $i$ in region $j$, respectively. In this study, we consider 2 types of capital input, i.e., equipment and structure, and 70 types of labor input for each industry, that is, $k = 2$ and $l =$

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17 In this study, the growth rate in consecutive times is approximated by the log difference during two time periods, i.e., $\Delta \ln x = \ln x_t - \ln x_{t-1}$ represents growth rate between period $t - 1$ and $t$. 

39
We construct time series of IOT that cover 37 industries for each region in Chapter 4, and the total number of intermediate inputs consumed by each industry is thus 37, that is, $x = 37$.

The nominal values of various inputs are the sum of values of individual components, that is,

$$ p_{i,j}^K K_{i,j} = \sum_k p_{k,i,j}^K K_{k,i,j} $$

$$ p_{i,j}^L L_{i,j} = \sum_l p_{l,i,j}^L L_{l,i,j} $$

$$ p_{i,j}^X X_{i,j} = \sum_x p_{x,i,j}^X X_{x,i,j} $$  \hspace{1cm} (3.16)

where $p_{k,i,j}^K$, $p_{l,i,j}^L$, and $p_{x,i,j}^X$ are capital service price of type $k$, labor input price of type $l$, and intermediate input price of type $x$ of industry $i$ in region $j$, respectively.

Similarly, the growth rates of capital input, labor input, and intermediate input of industry $i$ in region $j$ can be approximately expressed as the weighted sum of growth rates of each type of inputs based on the Tornqvist quantity index, and the weights are defined as the shares of each type of inputs in the corresponding total inputs, that is,

$$ \Delta \ln K_{i,j} = \sum_k \sigma_{k,i,j} \Delta \ln K_{k,i,j} $$

$$ \Delta \ln L_{i,j} = \sum_l \sigma_{l,i,j} \Delta \ln L_{l,i,j} $$

$$ \Delta \ln X_{i,j} = \sum_x \sigma_{x,i,j} \Delta \ln X_{x,i,j} $$  \hspace{1cm} (3.17)

The weights are given as:

$$ v_{k,i,j} = \frac{p_{k,i,j}^K K_{k,i,j}}{\sum_k p_{k,i,j}^K K_{k,i,j}} \text{ and } \tilde{v}_{k,i,j,t} = \frac{v_{k,i,j,t} + v_{k,i,j,t-1}}{2} $$

$$ v_{l,i,j} = \frac{p_{l,i,j}^L L_{l,i,j}}{\sum_l p_{l,i,j}^L L_{l,i,j}} \text{ and } \tilde{v}_{l,i,j,t} = \frac{v_{l,i,j,t} + v_{l,i,j,t-1}}{2} $$

$$ v_{x,i,j} = \frac{p_{x,i,j}^X X_{x,i,j}}{\sum_x p_{x,i,j}^X X_{x,i,j}} \text{ and } \tilde{v}_{x,i,j,t} = \frac{v_{x,i,j,t} + v_{x,i,j,t-1}}{2} $$  \hspace{1cm} (3.18)

The 70 types of labor input of each industry cover two genders, five education levels, and seven age groups. Please see Chapter 6 for details.
The nominal value of value added of industry $i$ in region $j$ is defined as the residual of gross output minus intermediate input, i.e.,

$$p_{i,j}^y V_{i,j} = p_{i,j}^y Y_{i,j} - p_{i,j}^x X_{i,j}$$

(3.19)

where $p_{i,j}^y$ and $V_{i,j}$ are value added price and the real value added of industry $i$ in region $j$, respectively.

Taking the total differentials of Equation (3.19) with respect to time, we derive the growth rate of real value added as:\footnote{We can simultaneously derive the growth rate of price of value added as $\frac{\Delta \ln p_{i,j}^y}{\sigma_{i,j}^l} = \frac{\Delta \ln p_{i,j}^y}{\sigma_{i,j}^l} \frac{\Delta \ln Y_{i,j} - \sigma_{i,j}^l \Delta \ln X_{i,j}}{\sigma_{i,j}^l}$, which can be approximately expressed as $\Delta \ln p_{i,j}^y = \frac{\Delta \ln p_{i,j}^y - \sigma_{i,j}^l \Delta \ln p_{i,j}^y}{\sigma_{i,j}^l}$.}

$$\frac{\nu_{i,j}}{\nu_{i,j}} = \frac{p_{i,j}^y X_{i,j} (Y_{i,j} - p_{i,j}^x X_{i,j})}{p_{i,j}^y Y_{i,j}}$$

(3.20)

The above equation can be approximately expressed as:

$$\Delta \ln V_{i,j} = \Delta \ln Y_{i,j} - \sigma_{i,j}^l \Delta \ln X_{i,j}$$

(3.21)

where $\sigma_{i,j}^l$ is the two-period average of nominal share of value-added in industry gross output, i.e., $\nu_{i,j}^V = \frac{p_{i,j}^y Y_{i,j}}{p_{i,j}^y Y_{i,j}}$ and $\nu_{i,j}^V = \frac{v_{i,j}^V + v_{i,j}^V - 1}{2}$.

Combining Equations (3.13) and (3.21), we can obtain an expression of the sources of industry value added growth:

$$\Delta \ln V_{i,j} = \sigma_{i,j}^l \Delta \ln K_{i,j} + \sigma_{i,j}^l \Delta \ln L_{i,j} + 1 \nu_{i,j}^V$$

(3.22)

Some attention should be paid to real value added, which has been a focus of debate among economists. Real value added has widely been adopted as a measure of output for productivity analysis, particularly stimulated by the seminal paper of Solow (1957), as well as for the determination of industries’ contributions to GDP growth. However, there is no fundamental agreement on the meaning of real value added or its price. To understand what it represents, we first describe how it is calculated. Real value added is calculated using two main methods.

The first method is deflation. This approach includes single deflation and double deflation. In single deflation, real value added is obtained by directly deflating value added at
the current price, usually derived by the difference between gross output and intermediate input at current prices, with the output price index or the intermediate input price index. While in double deflation, real value added is derived by the difference between gross output and intermediate input at constant prices, which are derived by deflating gross output and intermediate input at current prices with the output price index and the intermediate input price index, respectively.

The second method is extrapolation. This approach includes single extrapolation and double extrapolation. In the former case, real value added is obtained by extrapolating value added from a base year with either the volume index of output or that of intermediate input. In the latter case, output and intermediate input from a base year are extrapolated, respectively, by using the volume index of output and the volume index of intermediate input, and the difference between them is defined as real value added in each period.

As explained in Chapter 2, the main disadvantage of single deflation (or single extrapolation) lies in the assumption that price changes of output keep the same proportions as those of intermediate input, which is not reasonable. Theoretically, the ideal method to obtain real value added is double deflation (e.g., SNA, 2008; OECD Manual, 2001; Eurostat Manual, 2008) in which price changes of output and intermediate input are sufficiently taken into account, and real value added is obtained by the difference between deflated output and intermediate input. In this sense, real value added refers to the contribution of factors of production to create the value of products and services, and it corresponds to incomes received by the owners of these factors. Gross valued added is equal to net output.

In this study, we also adopt double deflation to derive real value added. However, we work on growth rate of real value added rather than on levels. As shown in Equation (3.2), the growth rate of real value added can be calculated by growth rate of output minus that of intermediate input with proper weights.

### 3.3 Region-wide Growth

By following the APPF approach, the growth rate of regional value added, $\Delta lnV_j$, can be defined as a Tornqvist index of growth rates of industry value added, that is,

$$\Delta lnV_j = \sum_i \bar{w}_{i,j} \Delta lnV_{i,j}$$

(3.23)

where $V_j$ is the real value added of region $j$. 
The weights are given as:

\[ w_{i,j} = \frac{p^V_{i,j}}{\Sigma p^V_{i,j}} \text{ and } \bar{w}_{i,j,t} = \frac{w_{i,j,t} + w_{i,j,t-1}}{2}. \] (3.24)

The nominal value of regional value added is equal to the sum of values of industry value added, that is,

\[ p_j^V v_j = \sum_i p^V_{i,j} v_{i,j} \] (3.25)

where \( p_j^V \) is value added price of region \( j \).

Combining Equations (3.22) and (3.23), we obtain:

\[ \Delta \ln V_j = \sum_i \bar{w}_{i,j} \Delta \ln V_{i,j} = \sum_i \left( \frac{\bar{w}_{i,j}}{\bar{v}_{i,j}} \sigma^K_{i,j} \Delta \ln K_{i,j} + \frac{\bar{w}_{i,j}}{\bar{v}_{i,j}} \sigma^L_{i,j} \Delta \ln L_{i,j} + \frac{\bar{w}_{i,j}}{\bar{v}_{i,j}} \sigma^V_{i,j} \Delta \ln \right) \] (3.26)

where \( \bar{w}_{i,j} \) is the size of industry \( i \)'s value added in the total value added of region \( j \); \( \bar{v}^K_{i,j} \), \( \bar{v}^L_{i,j} \), and \( \bar{v}^V_{i,j} \) are shares of capital income, labor income, and value added in gross output of industry \( i \) in region \( j \), respectively.

The above equation states that the growth rate of value added in region \( j \) is a weighted average of growth rates of capital input, labor input, and TFP of individual industries within the region, and the main weight is the Domar weight (Domar, 1961). The usual Domar weight is defined as the ratio of industry gross output to aggregate value added, which is decomposed into two proportions in Equation (3.26): one is each industry’s share in regional total value added (\( \bar{w}_{i,j} \)), and the other is the share of industry value added in its gross output (\( \bar{v}^V_{i,j} \)). We call the ratio \( \frac{\bar{w}_{i,j}}{\bar{v}^V_{i,j}} \) “industry Domar weights within a region”. The distinctive feature of Domar weights is that the sum of the weights is greater than or equal to one. The intuitive reason is that the change of either capital input, labor input, or TFP in a sector creates, in general, extra output in this sector, which can have two effects: one is that a part of the extra output is consumed by this sector itself as final demand, and the other is that another part of the extra output is sold to other sectors and used as intermediate inputs. The increase in intermediate inputs further serves to increase output in those sectors using the intermediate goods, which further increases output, and so on. As a result, the total effect of changes in the sectoral capital input, sectoral labor input, or sectoral TFP on regional output change is greater than the direct effects of changes of capital input, labor input, and TFP within a sector itself (Hulten, 1978).
The growth rate of TFP of region $j$ is defined as:

$$\frac{A_j}{A_j} = \frac{V_j}{V_j} = \frac{u_j^k R_j}{K_j} - \frac{u_j^L L_j}{L_j} \quad (3.27)$$

where $K_j$, $L_j$, and $A_j$ are total capital input, total labor input, and TFP of region $j$, respectively.

The weights are defined as:

$$u_j^k = \frac{\sum_i \sum_k p_{ik,i,j}^K K_{k,i,j}}{\sum_i \sum_k p_{ik,i,j}^K K_{k,i,j} + \sum_i \sum_l p_{il,i,j}^L L_{l,i,j}} \quad (3.28)$$

$$u_j^L = \frac{\sum_i \sum_l p_{il,i,j}^L L_{l,i,j}}{\sum_i \sum_k p_{ik,i,j}^K K_{k,i,j} + \sum_i \sum_l p_{il,i,j}^L L_{l,i,j}}$$

The Equation (3.27) can be approximately expressed as:

$$v_j^T = \Delta ln V_j - \bar{a}_j^T \Delta ln K_j - \bar{a}_j^L \Delta ln L_j \quad (3.29)$$

The weights are given as:

$$\bar{a}_j^k = \frac{u_j^k + u_j^K}{2} \text{ and } \bar{a}_j^L = \frac{u_j^L + u_j^L}{2} \quad (3.30)$$

The first term on the right-hand side of Equation (3.29) represents the growth rate of value added in region $j$; the second term represents the contribution of increases in capital input to local economic growth of region $j$ when capital input in all sectors grows at the same rate (in this case, the rate of growth of capital input in each sector is equal to the rate of growth of capital input in the local economy overall).\(^{20}\) The third term represents the corresponding contribution from labor input. The left-hand side, $v_j^T$, represents the growth rate of TFP in region $j$ under above assumptions.

\(^{20}\) Proof: The contribution of increases in capital input of all asset types to value added growth of industry $i$ in region $j$ is $\sum_k \frac{\partial f_{ij}}{\partial K_{k,i,j}} \frac{K_{k,i,j}}{V_{i,j}}$, where $f_{ij}$ is the value added production function, a function of capital input, labor input, and TFP of industry $i$ in region $j$.

Assuming the factor market is competitive, then $\frac{\partial f_{ij}}{\partial K_{k,i,j}} = \frac{p_{ij}^K}{p_{ij}^L}$, and we obtain $\sum_k \frac{\partial f_{ij}}{\partial K_{k,i,j}} \frac{K_{k,i,j}}{V_{i,j}} = \sum_k p_{ij}^K K_{k,i,j} \frac{K_{k,i,j}}{V_{i,j}}$. The value added share of industry $i$ in region $j$ is $\frac{p_{ij}^K V_{i,j}}{\sum_i p_{ij}^L V_{i,j}}$. Thus, the contribution of increases in capital input of all asset types of industry $i$ to total value added growth in region $j$ can be expressed as:

$$\sum_i \frac{p_{ij}^K V_{i,j}}{\sum_i p_{ij}^L V_{i,j}} \sum_k p_{ij}^K K_{k,i,j} \frac{K_{k,i,j}}{V_{i,j}}$$

When capital input in all sectors grows at the same rate, i.e., $\frac{K_{k,i,j}}{K_{k,j}} = \frac{K_{k,j}}{K_{k,j}}$, we obtain the following equation:

$$\sum_i \frac{p_{ij}^K V_{i,j}}{\sum_i p_{ij}^L V_{i,j}} \sum_k p_{ij}^K K_{k,i,j} \frac{K_{k,i,j}}{V_{i,j}} = \sum_i \frac{p_{ij}^K V_{i,j}}{\sum_i p_{ij}^L V_{i,j}} \sum_k p_{ij}^K K_{k,i,j} \frac{K_{k,i,j}}{V_{i,j}} = \frac{u_j^k}{u_j^k} \frac{K_{i,j}}{K_{j}}$$

Thus, the second term on the right-hand side of Equation (3.29) is the approximation of above equation. The proof for the third term is similar.
The quantities of capital input of type $k$ and of labor input of type $l$ in region $j$ are the sum across industries:

$$K_{k,j} = \sum_i K_{k,i,j}$$

$$L_{l,j} = \sum_i L_{l,i,j} \quad (3.31)$$

We also assume that capital input and labor input of region $j$ are the functions of corresponding individual components, respectively, i.e.,

$$K_j = \varphi_4(K_{1,j}, \ldots, K_{k,j})$$

$$L_j = \varphi_5(L_{1,j}, \ldots, L_{l,j}) \quad (3.32)$$

The nominal values of capital input and labor input of region $j$ are the sum of values of individual components:

$$P^K_j K_j = \sum_i \sum_k P^K_{k,i,j} K_{k,i,j}$$

$$P^L_j L_j = \sum_i \sum_l P^L_{l,i,j} L_{l,i,j} \quad (3.33)$$

where $P^K_j$ and $P^L_j$ are capital service price and labor input price of region $j$, respectively.

The growth rates of capital input and labor input of region $j$ can be approximately expressed as the weighted sum of growth rates of each type of inputs based on the Tornqvist quantity index, and the weights are defined as the shares of each type of inputs in the corresponding total inputs, that is,

$$\Delta \ln K_j = \sum_k \sigma_{k,j} \Delta \ln K_{k,j}$$

$$\Delta \ln L_j = \sum_l \sigma_{l,j} \Delta \ln L_{l,j} \quad (3.34)$$

The weights are given as:

$$\nu_{k,j} = \frac{\sum_i P^K_{k,i,j} K_{k,i,j}}{\sum_i \sum_k P^K_{k,i,j} K_{k,i,j}}$$

$$\nu_{l,j} = \frac{\sum_i P^L_{l,i,j} L_{l,i,j}}{\sum_i \sum_l P^L_{l,i,j} L_{l,i,j}} \quad (3.35)$$

Combining Equations (3.26) and (3.29), we obtain an expression for the region-wide growth rate of TFP as:
The first term on the right-hand side of above equation represents the Domar-weighted industry TFP growth rates. The terms in the first bracket represent the difference between the contribution from the weighted average of growth rates of capital input across sectors to local economic growth and that by assuming capital input increases at the same rate across sectors. The weights in the first term eventually produce relative shares of capital income of each sector in total value added of region \( j \), which does not assume factor price equalization across sectors. The weight in the second term represents the share of total capital income in total value added of region \( j \), which implies that capital receives the same service price in all sectors. Thus, the first bracket reflects efficiency gains as a result of the reallocation of capital across sectors. The terms in the second bracket reflect efficiency improvements as a result of the reallocation of labor across sectors.

Equation (3.36) also states that the region-wide TFP growth comes from three contributors: the Domar-weighted industry TFP growth rates, the reallocation of capital input, and the reallocation of labor input, which confirms the point of Hsieh and Klenow (2009) that resource reallocation is a crucial factor that affects TFP growth. When resource reallocations are not zero, industries do not face the same factor input price, which indicates that the precondition of the widely used APF is not met. In addition, if an economy’s market system is perfect, resource reallocations should be small or even negligible. In contrast, if the market system is imperfect or even seriously distorted, resource reallocations should be significantly non-zero. Therefore, this is an appropriate tool to analyze impacts of local governments’ interventions on resource allocation in a regional economy (H. Wu, 2015b). The two brackets in Equation (3.36) reflect resource reallocations across industries within a region. Meanwhile, Equations (3.26) and (3.36) also show how much each industry contributes to value added, capital input, labor input, and TFP of a regional economy via “industry Domar weights within a region \( \left( \frac{\varphi_{i,j}}{\varphi_{i,j}} \right) \),” which can trace industry origins of regional economic growth.
The second term on the right-hand side of Equation (3.36) can be rewritten as:

\[
\begin{align*}
\sum_i \left( \frac{\partial_j \sigma_{ij}^K}{\sigma_{ij}^K} \Delta \ln K_{i,j} - \bar{\sigma}_j^K \Delta \ln K_j \right) \\
= \sum_i \left( \frac{\partial_j \sigma_{ij}^K}{\sigma_{ij}^K} \sigma_{ij}^K - \bar{\sigma}_j^K \sigma_{ij}^K \right) \Delta \ln K_{i,j} + \bar{\sigma}_j^K \left( \sum_i \sigma_{ij}^K \Delta \ln K_{i,j} - \Delta \ln K_j \right) \\
= \sum_i \left( \frac{\bar{\sigma}_{ij}^K \sigma_{ij}^K - \sigma_{ij}^K \bar{\sigma}_j^K}{\sigma_{ij}^K} \right) \left( \Delta \ln K_{i,j} - \Delta \ln K_j \right) + \bar{\sigma}_j^K \left( \sum_i \sigma_{ij}^K \Delta \ln K_{i,j} - \Delta \ln K_j \right)
\end{align*}
\] (3.37)

where \( \bar{\sigma}_{ij}^K \) is defined as:

\[
\bar{\sigma}_{ij}^K = \frac{\sum_k \rho_{k,j} K_{k,i,j}}{\sum_k \rho_{k,j} K_{k,i,j}} \quad \text{and} \quad \bar{\sigma}_j^K = \frac{w_{i,j}^K + w_{i,j,t-1}}{2} 
\] (3.38)

The value of \( \bar{\sigma}_{ij}^K \) is equal to the ratio of capital income of industry \( i \) in region \( j \) to the macro-level value added of region \( j \). The value of this coefficient shows the percentage increase in regional GDP for a 1% increase in capital input in industry \( i \). The value of \( \sigma_{ij}^K \) shows the percentage increase in regional GDP for a 1% increase in capital input in industry \( i \) when the average service price of capital across different types of capital in industry \( i \) equals the region-wide average service price of capital, i.e., \( \sum_k \rho_{k,j} K_{k,i,j} = \sum_k \rho_{k,j} K_{k,i,j} \). Thus, the first term on the right-hand side of Equation (3.37) denotes the inter-industry reallocation effect of capital input. If the industry-level growth rate of capital input is larger than the region-wide average growth rate of capital input, i.e., \( \Delta \ln K_{i,j} > \Delta \ln K_j \), in industries where the industry-level capital service price is higher than the region-level average capital service price, i.e., \( \sum_k \rho_{k,j} K_{k,i,j} > \sum_k \rho_{k,j} K_{k,i,j} \), and if the industry-level growth rate of capital input is smaller than the region-wide average growth rate of capital input, i.e., \( \Delta \ln K_{i,j} < \Delta \ln K_j \), in industries where the industry-level capital service price is lower than the region-level average capital service price, i.e., \( \sum_k \rho_{k,j} K_{k,i,j} < \sum_k \rho_{k,j} K_{k,i,j} \), there is a positive inter-industry reallocation of capital input (Fukao et al., 2012).

The second term on the right-hand side of Equation (3.37) can be approximately rewritten in discrete time version as:

\[
u_j^K \sum_i \left\{ \frac{\sum_k \rho_{k,j} K_{k,i,j}}{\sum_k \rho_{k,j} K_{k,i,j}} \left( \frac{\rho_{k,j} K_{k,i,j} - \rho_{k,j} K_{k,i,j}}{\sum_k \rho_{k,j} K_{k,i,j}} \right) \Delta \ln K_{k,i,j} \right\} \] (3.39)

Thus, we can interpret the second term on the right-hand side of Equation (3.37) as the reallocation of changes in capital composition within each industry. Suppose that the relative
price of type \( k \) capital to the average value of prices for other types of capital in industry \( i \) is lower than the region-level average relative price of type \( k \) capital; an increase of capital input of this type in industry \( i \) improves resource allocation and further raises TFP growth rate of region \( j \) (Fukao et al., 2012).

Similarly, the third term on the right-hand side of Equation (3.36) can be decomposed into two parts: one is the inter-industry reallocation of labor input, and the other is the reallocation of changes in labor composition within each industry.

3.4 Economy-wide Growth

The sources of aggregate economic growth can be investigated from two perspectives: one starts from the industry level and then extends to regions; the other begins with the regional level and then extends to industries, and both are illustrated in turn in the following.

3.4.1 Economy-wide Growth: Industry Perspective

In this sub-section, we first analyze economy-wide economic growth from the industry perspective. By following the APPF approach, the growth rate of aggregate value added from the industry perspective, \( \Delta lnV_i \), can be defined as a Tornqvist index of growth rates of industry value added, that is,

\[
\Delta lnV_i = \sum_j \varpi_i \Delta lnV_{ij} \tag{3.40}
\]

where \( V_i \) is aggregate value added from the industry perspective.

The weights are given as:

\[
w_i = \frac{\sum_j p^{ij}_i V_{ij}}{\sum_j p^{ij}_i V_{ij}} \text{ and } \varpi_{i,t} = \frac{w_{it,t} + w_{it,t-1}}{2}. \tag{3.41}
\]

The growth rate of value added of industry \( i \) at the national level can be further expressed as a Tornqvist index of growth rates of value added of industry \( i \) in region \( j \), that is,

\[
\Delta lnV_i = \sum_j \varpi_{ij}^t \Delta lnV_{i,j} \tag{3.42}
\]

The weights are given as:

\[
w_{ij} = \frac{p^{ij} V_{ij}}{\sum_j p^{ij} V_{ij}} \text{ and } \varpi_{ij,t} = \frac{w_{ij,t} + w_{ij,t-1}}{2}. \tag{3.43}
\]
Inserting Equation (3.42) into (3.40), we obtain:

$$\Delta \ln V_i = \sum_i \sum_j \vec{\omega}_i \vec{\omega}_j^T \Delta \ln V_{i,j}$$  

(3.44)

Further inserting Equation (3.22) into (3.44), we obtain:

$$\Delta \ln V_i = \sum_i \sum_j \left( \vec{\omega}_i \vec{\omega}_j^T \frac{\sigma_{i,j}^K}{\sigma_{i,j}^L} \Delta \ln K_{i,j} + \vec{\omega}_i \vec{\omega}_j^T \frac{\sigma_{i,j}^L}{\sigma_{i,j}^L} \Delta \ln L_{i,j} + \vec{\omega}_i \vec{\omega}_j^T \nu_{i,j}^T \right)$$  

(3.45)

The above equation states that the growth rate of aggregate value added from the industry perspective is a weighted average of growth rates of capital input, labor input, and TFP of industry $i$ in region $j$, and the main weight is the Domar weight ($\frac{\sigma_{i,j}^K}{\sigma_{i,j}^L}$), which we call the “industry and region Domar weights in an economy.”

The growth rate of aggregate TFP from the industry perspective is defined as:

$$\frac{\dot{A}_i}{A_i} = \frac{\dot{V}_i}{V_i} - \frac{\dot{K}_i}{K_i} - \frac{\dot{L}_i}{L_i}$$  

(3.46)

where $K_i$, $L_i$, and $A_i$ are aggregate capital input, aggregate labor input, and aggregate TFP, respectively.

The weights are defined as:

$$u_i^K = \frac{\sum_i \sum_j \sum_k P_{k,i,j}^K K_{k,i,j}}{\sum_i \sum_j \sum_k P_{k,i,j}^K + \sum_i \sum_j \sum_l P_{l,i,j} L_{l,i,j}}$$  

$$u_i^L = \frac{\sum_i \sum_j \sum_l P_{l,i,j} L_{l,i,j}}{\sum_i \sum_j \sum_k P_{k,i,j}^L + \sum_i \sum_j \sum_l P_{l,i,j} L_{l,i,j}}$$  

(3.47)

Equation (3.46) can be approximately expressed as:

$$\dot{v}_i^T = \Delta \ln V_i - \dot{u}_i^K \Delta \ln K_i - \dot{u}_i^L \Delta \ln L_i$$  

(3.48)

The weights are given as:

$$\bar{a}_{i,t}^K = \frac{u_{i,t}^K + u_{i,t-1}^K}{2} \text{ and } \bar{a}_{i,t}^L = \frac{u_{i,t}^L + u_{i,t-1}^L}{2}$$  

(3.49)

The first term on the right-hand side of Equation (3.48) represents the growth rate of aggregate value added from the industry perspective; the second term represents the contribution of increases in capital input to economic growth when capital input in all sectors grows at the same rate (in this case, the rate of growth of capital input in each sector is equal to the rate of growth of capital input in the economy overall); and the third term represents the
corresponding contribution from labor input.  The left-hand side, \( v_i^T \), represents the growth rate of aggregate TFP under above assumptions.

The economy-wide quantities of capital input of type \( k \) and of labor input of type \( l \) are the sum across industries, which are further the sum across regions:

\[
K_k = \sum_i K_{k,i} = \sum_i \sum_j K_{k,i,j} \\
L_l = \sum_i L_{l,i} = \sum_i \sum_j L_{l,i,j}
\]

(3.50)

We also assume that capital input and labor input of aggregate economy are the functions of corresponding individual components, respectively, i.e.,

\[
K_i = \varphi_d(K_1, ..., K_k) \\
L_i = \varphi_f(L_1, ..., L_l)
\]

(3.51)

The growth rates of capital input and labor input of the aggregate economy can be approximately expressed as the weighted sum of growth rates of each type of inputs based on the Tornqvist quantity index, and the weights are defined as the shares of each type of inputs in the corresponding total inputs, that is,

\[
\Delta \ln K_i = \sum_k \vartheta_k \Delta \ln K_k \\
\Delta \ln L_i = \sum_l \vartheta_l \Delta \ln L_l
\]

(3.52)

The weights are defined as:

\[
v_k = \frac{\Sigma_i \Sigma_j p_{i,j}^K p_{i,j}^{K_{k,i,j}}}{\Sigma_i \Sigma_j p_{i,j}^K p_{i,j}^{K_{k,i,j}}} \quad \text{and} \quad \vartheta_k = \frac{v_{k,t} + v_{k,t-1}}{2}
\]

(3.53)

\[
v_l = \frac{\Sigma_i \Sigma_j p_{i,j}^L p_{i,j}^{L_{l,i,j}}}{\Sigma_i \Sigma_j p_{i,j}^L p_{i,j}^{L_{l,i,j}}} \quad \text{and} \quad \vartheta_l = \frac{v_{l,t} + v_{l,t-1}}{2}
\]

Inserting Equation (3.45) into (3.48), we obtain an expression for the growth rate of the economy-wide TFP from the industry perspective as:

---

21 The proof is similar to the one in footnote 20.
\[ v_i^T = \sum_i \sum_j \frac{\omega_j \sigma_{i,j}}{\sigma_j^K} v_{i,j}^T + \left( \sum_i \sum_j \frac{\omega_j \sigma_{i,j}}{\sigma_j^V} \bar{v}_i^K \Delta \ln K_{i,j} - \bar{v}_i^F \Delta \ln K_i \right) \]
\[ + \left( \sum_i \sum_j \frac{\omega_j \sigma_{i,j}}{\sigma_j^V} \bar{v}_i^L \Delta \ln L_{i,j} - \bar{v}_i^F \Delta \ln L_i \right) \]
\[ = \sum_i \sum_j \frac{\omega_j \sigma_{i,j}}{\sigma_j^V} v_{i,j}^T + \rho_i^K + \rho_i^L \]  

(3.54)

This expression considers the effects of both industry and region on resource allocation. The last two terms, \( \rho_i^K \) and \( \rho_i^L \), reflect the comprehensive resource reallocations in an economy, including resource reallocations across industries within a region, resource reallocations across regions given a certain industry, and resource reallocations across different industries and regions. Equations (3.45) and (3.54) show how much each regional industry contributes to aggregate value added, aggregate capital input, aggregate labor input, and aggregate TFP via “industry and region Domar weights in an economy \( \frac{\omega_j \sigma_{i,j}}{\sigma_j^V} \),” which can trace both industry and region origins of aggregate economic growth.

We further decompose the aggregate resource reallocations into two components, i.e., industry effect and regional effect:

\[ \rho_i^K = \left( \sum_i \frac{\omega_j \sigma_{i,j}}{\sigma_j^V} \bar{v}_i^K \Delta \ln K_{i,j} - \bar{v}_i^F \Delta \ln K_i \right) + \sum_j \left( \sum_i \frac{\omega_j \sigma_{i,j}}{\sigma_j^V} \bar{v}_i^K \Delta \ln K_{i,j} - \frac{\omega_j}{\sigma_j^V} \bar{v}_i^K \Delta \ln K_i \right) \]
\[ \rho_i^L = \left( \sum_i \frac{\omega_j \sigma_{i,j}}{\sigma_j^V} \bar{v}_i^L \Delta \ln L_{i,j} - \bar{v}_i^F \Delta \ln L_i \right) + \sum_j \left( \sum_i \frac{\omega_j \sigma_{i,j}}{\sigma_j^V} \bar{v}_i^L \Delta \ln L_{i,j} - \frac{\omega_j}{\sigma_j^V} \bar{v}_i^L \Delta \ln L_i \right) \]  

(3.55)

where the \( \bar{v}_i^K \), \( \bar{v}_i^L \), and \( \bar{v}_i^V \) are defined as:

\[ v_i^K = \frac{\Sigma_j \rho_j^K \sigma_{i,j}}{\Sigma_j \rho_j^V \sigma_{i,j}} \quad \text{and} \quad \sigma_i^K = \frac{v_i^K + v_i^{K-1}}{2} \]
\[ v_i^L = \frac{\Sigma_j \rho_j^L \sigma_{i,j}}{\Sigma_j \rho_j^V \sigma_{i,j}} \quad \text{and} \quad \sigma_i^L = \frac{v_i^L + v_i^{L-1}}{2} \]
\[ v_i^V = \frac{\Sigma_j \rho_j^V \sigma_{i,j}}{\Sigma_j \rho_j^V \sigma_{i,j}} \quad \text{and} \quad \sigma_i^V = \frac{v_i^V + v_i^{V-1}}{2} \]  

(3.56)

The quantities of capital input of type \( k \) and of labor input of type \( l \) of industry \( i \) are the sum across regions:
We also assume that capital input and labor input of industry \( i \) are the functions of corresponding individual components, respectively, i.e.,

\[
K_i = \varphi_b(K_{1,i}, ..., K_{k,i})
\]

\[
L_i = \varphi_b(L_{1,i}, ..., L_{l,i})
\]

The growth rates of capital input and labor input of industry \( i \) can be approximately expressed as the weighted sum of growth rates of each type of inputs based on the Tornqvist quantity index, and the weights are defined as the shares of each type of inputs in the corresponding total inputs, that is,

\[
\Delta \ln K_i = \sum_k \vartheta_{k,i} \Delta \ln K_{k,i}
\]

\[
\Delta \ln L_i = \sum_l \vartheta_{l,i} \Delta \ln L_{l,i}
\]

The weights are defined as:

\[
v_{k,i} = \frac{\sum_k I_{k,i} \rho_{k,i}^j K_{k,i,j}}{\sum_j \sum_k I_{k,i} \rho_{k,i}^j K_{k,i,j}} \quad \text{and} \quad \vartheta_{k,i,i} = \frac{v_{k,i} + v_{k,i-1}}{2}
\]

\[
v_{l,i} = \frac{\sum_l I_{l,i} \rho_{l,i}^j L_{l,i,j}}{\sum_j \sum_l I_{l,i} \rho_{l,i}^j L_{l,i,j}} \quad \text{and} \quad \vartheta_{l,i,i} = \frac{v_{l,i} + v_{l,i-1}}{2}
\]

The terms in the first bracket of the first equation of Equation (3.55) represent the difference between the contribution from the weighted average of growth rates of capital input across sectors to economic growth and that by assuming capital input increases at the same rate across sectors, this reflects the efficiency gains as a result of the reallocation of capital across sectors. The terms in the second bracket of the first equation of Equation (3.55) represent the difference between the contribution from the weighted average of growth rates of capital input across regions to economic growth and that by assuming capital input increases at the same rate across regions within sector \( i \), it reflects the efficiency gains as a result of reallocation of capital across regions within sector \( i \). Further, aggregation across sector \( i \) represents the total regional effect on the reallocation of capital. Similarly, two brackets in the second equation of Equation (3.55) represent efficiency improvements as a result of the reallocation of labor across sectors and as a result of reallocation of labor across regions, respectively.
The sign of the aggregate resource reallocation of capital input (and labor input) depends on the comprehensive result of both industry and regional effects. For example, if resources are allocated to industries with high-use efficiency and are further allocated to regions where resource use efficiency is also high, the aggregate resource reallocation is positive, which is ultimately conducive to aggregate TFP growth.

In order to explore industry origins of resource reallocations, we further decompose the first term on the right-hand side of the first equation of Equation (3.55) as we have done for Equation (3.37) as follows:

\[
\sum_{i} \tilde{w}_{i}^{K} \bar{v}_{i}^{K} \Delta lnK_{i} - \tilde{w}_{i}^{K} \Delta lnK_{i}
\]

\[
= \sum_{i} \left( \frac{\tilde{w}_{i}^{K}}{\bar{v}_{i}^{K}} - \bar{v}_{i}^{K} a_{i}^{K} \right) \Delta lnK_{i} + a_{i}^{K} \left( \sum_{i} \bar{v}_{i}^{K} \Delta lnK_{i} - \Delta lnK_{i} \right)
\]

\[
= \sum_{i} \left( \frac{\tilde{w}_{i}^{K}}{\bar{v}_{i}^{K}} - \bar{v}_{i}^{K} a_{i}^{K} \right) \left( \Delta lnK_{i} - \Delta lnK_{j} \right) + a_{i}^{K} \left( \sum_{i} \bar{w}_{i}^{K} \Delta lnK_{i} - \Delta lnK_{i} \right)
\]

where \( \bar{w}_{i}^{K} \) is defined as:

\[
\bar{w}_{i}^{K} = \frac{\sum_{k} p_{k,i}^{K} K_{k,i}}{\sum_{k} \sum_{l} p_{k,i}^{K} K_{k,i}} \text{ and } \tilde{w}_{i}^{K} = \frac{w_{i,i}^{K} + w_{i,i-1}^{K}}{2}.
\]

The second term on the right-hand side of Equation (3.61) can be approximately expressed in discrete time version as:

\[
u_{i}^{K} \sum_{i} \left\{ \sum_{k} p_{k,i}^{K} K_{k,i} \sum_{k} \left[ \left( \frac{p_{k,i}^{K} K_{k,i}}{\sum_{k} p_{k,i}^{K} K_{k,i}} - \frac{p_{k,i}^{K} K_{k,i}}{\sum_{k} p_{k,i}^{K} K_{k,i}} \right) \Delta lnK_{k,i} \right] \right\}
\]

The first term on the right-hand side of Equation (3.61) can be interpreted as the inter-industry reallocation of aggregate capital input. If the industry-level growth rate of capital input is larger than the economy-wide average growth rate of capital input, i.e., \( \Delta lnK_{i} > \Delta lnK_{i} \), in industries where the industry-level capital service price is higher than the economy-level average capital service price, i.e., \( \sum_{k} p_{k,i}^{K} K_{k,i} > \sum_{k} p_{k,i}^{K} K_{k,i} \), and if the industry-level growth rate of capital input is smaller than the economy-wide average growth rate of capital input, i.e., \( \Delta lnK_{i} < \Delta lnK_{i} \), in industries where the industry-level capital service price is lower than the economy-level average capital service price, i.e., \( \sum_{k} p_{k,i}^{K} K_{k,i} < \sum_{k} p_{k,i}^{K} K_{k,i} \), there is a positive inter-industry reallocation of aggregate capital input. The second term on the right-hand side of Equation (3.61) can be interpreted as the reallocation of changes in capital composition within each industry.
A similar decomposition applies to the reallocation of aggregate labor input. The first term on the right-hand side of the second equation of Equation (3.55) can be decomposed into two parts: one is the inter-industry reallocation of aggregate labor input, and the other is the reallocation of changes in labor composition within each industry.

### 3.4.2 Economy-wide Growth: Regional Perspective

In this sub-section, we analyze the economy-wide economic growth from the regional perspective. By following the APPF approach, the growth rate of aggregate value added from the regional perspective, $\Delta lnV_j$, can be defined as a Tornqvist index of growth rates of regional value added, that is,

$$\Delta lnV_j = \sum_j \varphi_j \Delta lnV_j$$  \hspace{1cm} (3.64)

where $V_j$ is aggregate value added from the regional perspective.

The weights are defined as:

$$w_j = \frac{\sum_{l} \nu_{ij}^j}{\sum_{l} \nu_{ij}^l} \text{ and } \varphi_{j,t} = \frac{w_{j,t} + w_{j,t-1}}{2}$$  \hspace{1cm} (3.65)

Inserting Equation (3.23) into (3.64), we obtain:

$$\Delta lnV_j = \sum_j \sum_i \varphi_{j,i} \Delta lnV_{i,j}$$  \hspace{1cm} (3.66)

Further inserting Equation (3.22) into above equation, we obtain:

$$\Delta lnV_j = \sum_j \sum_i \left( \frac{\varphi_{j,i}}{\varphi_{j,i}} \varphi_{j,i} \Delta lnK_{i,j} + \frac{\varphi_{j,i}^l}{\varphi_{j,i}^l} \varphi_{j,i}^l \Delta lnL_{i,j} + \frac{\varphi_{j,i}^v}{\varphi_{j,i}^v} \varphi_{j,i}^v \right)$$  \hspace{1cm} (3.67)

Similar to Equation (3.45), the above equation states that the growth rate of aggregate value added from the regional perspective is a weighted average of growth rates of capital input, labor input, and TFP of industry $i$ in region $j$, and the main weight is the Domar weight ($\frac{\varphi_{j,i}}{\varphi_{j,i}}$), which we also call “industry and region Domar weights in an economy.”

The growth rate of aggregate TFP from the regional perspective is defined as:

$$\frac{\dot{A}_j}{A_j} = \frac{\psi_j}{V_j} - \frac{w_j^k K_j}{K_j} - \frac{w_j^l L_j}{L_j}$$  \hspace{1cm} (3.68)

---

22 Actually, the Domar weights in Equation (3.45) and Equation (3.67) are equivalent.
where $K_j$, $L_j$, and $A_j$ are aggregate capital input, aggregate labor input, and aggregate TFP, respectively.

The weights are defined as:

$$u_j^K = \frac{\sum_j \sum_k \sum_{k,i,j} P_{k,i,j} K_{k,i,j}}{\sum_j \sum_k \sum_{k,i,j} P_{k,i,j} K_{k,i,j} + \sum_j \sum_l \sum_{l,i,j} P_{l,i,j} L_{l,i,j}}$$

$$u_j^L = \frac{\sum_j \sum_l \sum_{l,i,j} P_{l,i,j} L_{l,i,j}}{\sum_j \sum_k \sum_{k,i,j} P_{k,i,j} K_{k,i,j} + \sum_j \sum_l \sum_{l,i,j} P_{l,i,j} L_{l,i,j}}$$

Equation (3.68) can be approximately expressed as:

$$v_j^T = \Delta ln V_j - \bar{a}_j^K \Delta ln K_j - \bar{a}_j^L \Delta ln L_j$$

The weights are given as:

$$\bar{a}_j^K = \frac{u_j^K + u_{j-1}^K}{2}$$

$$\bar{a}_j^L = \frac{u_j^L + u_{j-1}^L}{2}$$

The first term on the right-hand side of Equation (3.70) represents the growth rate of aggregate value added from the regional perspective; the second term represents the contribution of increases in capital input to economic growth when capital input in all regions grows at the same rate (in this case, the rate of growth of capital input in each region is equal to the rate of growth of capital input in the economy overall); and the third term represents the corresponding contribution from labor input. The left-hand side, $v_j^T$, represents the growth rate of aggregate TFP under above assumptions.

The economy-wide quantities of capital input of type $k$ and of labor input of type $l$ are the sum across regions, which further are the sum across industries:

$$K_k = \sum_j K_{k,j} = \sum_j \sum_l K_{k,i,j}$$

$$L_l = \sum_j L_{l,j} = \sum_j \sum_l L_{l,i,j}$$

Equation (3.72)

We also assume that capital input and labor input of the aggregate economy are the functions of corresponding individual components, respectively, i.e.,

$$K_j = \varphi_{10}(K_1, ..., K_k)$$

$$L_j = \varphi_{11}(L_1, ..., L_l)$$

Equation (3.73)

The growth rates of capital input and labor input of the aggregate economy can be approximately expressed as the weighted sum of growth rates of each type of inputs based on
the Tornqvist quantity index, and the weights are defined as the shares of each type of inputs in the corresponding total inputs, that is,

\[
\Delta \ln K_j = \sum_k \sigma_k \Delta \ln K_k
\]

\[
\Delta \ln L_j = \sum_l \sigma_l \Delta \ln L_l
\]

The weights are defined as:

\[
v_k = \frac{\sum_j \sigma_j^k \rho_k^j \sigma_{k,j}}{\sum_j \sigma_j^k \rho_k^j \sigma_{k,j}} \quad \text{and} \quad \tilde{\sigma}_{k,t} = \frac{v_{k,t} + \nu_{k,t} - 1}{2}
\]

\[
v_l = \frac{\sum_j \sigma_j^l \rho_l^{j,l} \sigma_{l,j}}{\sum_j \sigma_j^l \rho_l^{j,l} \sigma_{l,j}} \quad \text{and} \quad \sigma_{l,t} = \frac{v_{l,t} + \nu_{l,t} - 1}{2}
\]

Inserting Equation (3.67) into (3.70), we obtain an expression for the growth rate of the economy-wide TFP from the regional perspective as:

\[
v_j^T = \sum_j \sum_l \frac{\sigma_j^l \sigma_{l,j}}{\tilde{\sigma}_{l,j}} v_{l,j}^T + \left( \sum_j \sum_l \frac{\sigma_j^l \sigma_{l,j}}{\tilde{\sigma}_{l,j}} \tilde{\sigma}_{l,j} \Delta \ln K_{i,j} - \tilde{\alpha}_j^T \Delta \ln K_j \right)
\]

\[
+ \left( \sum_l \sum_j \frac{\sigma_j^l \sigma_{l,j}}{\tilde{\sigma}_{l,j}} \tilde{\sigma}_{l,j} \Delta \ln L_{i,j} - \tilde{\alpha}_j^L \Delta \ln L_j \right)
\]

\[
= \sum_j \sum_l \frac{\sigma_j^l \sigma_{l,j}}{\tilde{\sigma}_{l,j}} v_{l,j}^T + \rho_j^K + \rho_j^L
\]

Similar to Equation (3.54), this expression considers effects of both industry and region on resource allocation. The last two terms, \(\rho_j^K\) and \(\rho_j^L\), reflect the comprehensive resource reallocations in an economy, including resource reallocations across industries within a region, resource reallocations across regions given a certain industry, and resource reallocations across different industries and regions. Equations (3.67) and (3.76) show how much each regional industry contributes to aggregate value added, aggregate capital input, aggregate labor input, and aggregate TFP via “industry and region Domar weights in an economy \((\frac{\sigma_j^l \sigma_{l,j}}{\tilde{\sigma}_{l,j}})\),” which can trace both industry and region origins of aggregate economic growth.

We further decompose the aggregate resource reallocations into two components, i.e., industry effect and regional effect:
\[
\rho^K_j = \left( \sum_j \frac{\sigma_j^K}{\sigma_j^K} \Delta \ln K_j - \bar{\sigma}_j^K \Delta \ln K_j \right) + \sum_j \left( \sum_i \frac{\sigma_{i,j} \Delta \ln K_{i,j} - \bar{\sigma}_{i,j} \Delta \ln K_{i,j}}{\sigma_{i,j}} \right)
\]
\[
\rho^L_j = \left( \sum_j \frac{\sigma_j^L}{\sigma_j^L} \Delta \ln L_j - \bar{\sigma}_j^L \Delta \ln L_j \right) + \sum_j \left( \sum_i \frac{\sigma_{i,j} \Delta \ln L_{i,j} - \bar{\sigma}_{i,j} \Delta \ln L_{i,j}}{\sigma_{i,j}} \right)
\]

where the \( \bar{\sigma}_j^K \), \( \bar{\sigma}_j^L \), and \( \bar{\sigma}_j^V \) are defined as:

\[
v^K_j = \frac{\sum_i \rho^K_{i,j}}{\sum_i \rho^K_{i,j}} \quad \text{and} \quad \sigma^K_{i,t} = \frac{v^K_{i,t} + v^K_{i,t-1}}{2}
\]
\[
v^L_j = \frac{\sum_i \rho^L_{i,j}}{\sum_i \rho^L_{i,j}} \quad \text{and} \quad \sigma^L_{i,t} = \frac{v^L_{i,t} + v^L_{i,t-1}}{2}
\]
\[
v^V_j = \frac{\sum_i \rho^V_{i,j}}{\sum_i \rho^V_{i,j}} \quad \text{and} \quad \sigma^V_{i,t} = \frac{v^V_{i,t} + v^V_{i,t-1}}{2}
\]

The quantities of capital input of type \( k \) and of labor input of type \( l \) of region \( j \) are the sum across industries:

\[
K_{k,j} = \sum_i K_{k,i,j}
\]
\[
L_{l,j} = \sum_i L_{l,i,j}
\]

We also assume that capital input and labor input of region \( j \) are the functions of corresponding individual components, respectively, i.e.,

\[
K_j = \varphi_{12}(K_{1,j}, ..., K_{k,j})
\]
\[
L_j = \varphi_{13}(L_{1,j}, ..., L_{l,j})
\]

The growth rates of capital input and labor input of region \( j \) can be approximately expressed as the weighted sum of growth rates of each type of inputs based on the Tornqvist quantity index, and the weights are defined as the shares of each type of inputs in the corresponding total inputs, that is,

\[
\Delta \ln K_j = \sum_k \bar{\sigma}_{k,j} \Delta \ln K_{k,j}
\]
\[
\Delta \ln L_j = \sum_l \bar{\sigma}_{l,j} \Delta \ln L_{l,j}
\]
The weights are defined as:

\[
\begin{align*}
v_{k,i} &= \frac{\sum_i r^k_{k,i} p_{k,i}}{\sum_i r^k_{k,i}} \quad \text{and} \quad \tilde{v}_{k,i} = \frac{v_{k,i} + v_{k,i-1}}{2} \\
v_{l,i} &= \frac{\sum_i r^l_{l,i} p_{l,i}}{\sum_i r^l_{l,i}} \quad \text{and} \quad \tilde{v}_{l,i} = \frac{v_{l,i} + v_{l,i-1}}{2} 
\end{align*}
\] (3.82)

The terms in the first bracket of the first equation of Equation (3.77) represent the difference between the contribution from the weighted average of growth rates of capital input across regions to economic growth and that by assuming capital input increases at the same rate across regions, it reflects efficiency gains as a result of the reallocation of capital across regions. The terms in the second bracket of the first equation of Equation (3.77) represent the difference between the contribution from the weighted average of growth rates of capital input across sectors to economic growth and that by assuming capital input increases at the same rate across sectors within region \( j \), it reflects efficiency gains as a result of the reallocation of capital across sectors within region \( j \). Aggregation across region \( j \) represents the total industry effect on the reallocation of capital. Similarly, two brackets in the second equation of Equation (3.77) represent efficiency improvements as a result of the reallocation of labor across regions and as a result of the reallocation of labor across sectors, respectively.

The sign of aggregate resource reallocation of capital input (and labor input) depends on the comprehensive result of both industry and regional effects. For example, if resources are allocated to regions with high-use efficiency and are also further allocated to sectors where resource use efficiency is also high, the aggregate resource reallocation is positive, which is ultimately conducive to aggregate TFP growth.

In order to explore regional origins of resource reallocations, we further decompose the first term on the right-hand side of the first equation of Equation (3.77) as we have done for Equation (3.55) as follows:

\[
\begin{align*}
\sum_j \frac{\partial j}{\partial k} \sigma^j \Delta lnK_j - \sigma_j \Delta lnK_j \\
= \sum_j \left( \frac{\partial j}{\partial j} \sigma^j - \sigma_j \sigma^j \right) \Delta lnK_j + \sigma^j \left( \sum_j \sigma_j \Delta lnK_j - \Delta lnK_j \right) \\
= \sum_j \left( \frac{\partial j}{\partial j} \sigma^j - \sigma_j \sigma^j \right) \left( \Delta lnK_j - \Delta lnK_j \right) + \sigma^j \left( \sum_j \sigma_j \Delta lnK_j - \Delta lnK_j \right)
\end{align*}
\] (3.83)
where \( \varpi_j^K \) is defined as:

\[
\varpi_j^K = \frac{\sum_k p_{K,k,j}^K}{\sum_k \Sigma_k p_{K,k,j}^K} \text{ and } \varpi_{j,t}^K = \frac{w_{j,t}^K + w_{j,t-1}^K}{2}
\]  

(3.84)

The second term on the right-hand side of Equation (3.83) can be approximately expressed in discrete time version as:

\[
u_j^K \sum_j \left\{ \frac{\sum_k p_{K,k,j}^K}{\sum_k \Sigma_k p_{K,k,j}^K} \sum_k \left[ \left( \frac{p_{K,k,j}^K}{\sum_k p_{K,k,j}^K} - \frac{p_{K,k,j}^K}{\Sigma_k p_{K,k,j}^K} \right) \Delta ln K_{k,j} \right] \right\}
\]  

(3.85)

The first term on the right-hand side of Equation (3.83) can be interpreted as the inter-region reallocation of aggregate capital input. If the region-level growth rate of capital input is larger than the economy-wide average growth rate of capital input, i.e., \( \Delta ln K_j > \Delta ln K_f \), in regions where the region-level capital service price is higher than the economy-level average capital service price, i.e., \( \sum_k p_{K,k,j}^K K_{k,j} > \sum_k p_{K,k,j}^K K_{k,j} \), and if the region-level growth rate of capital input is smaller than the economy-wide average growth rate of capital input, i.e., \( \Delta ln K_j < \Delta ln K_f \), in regions where the region-level capital service price is lower than the economy-level average capital service price, i.e., \( \sum_k p_{K,k,j}^K K_{k,j} < \sum_k p_{K,k,j}^K K_{k,j} \), there is a positive inter-region reallocation of aggregate capital input. The second term on the right-hand side of Equation (3.83) can be interpreted as the reallocation of changes in capital composition within each region.

A similar decomposition applies to the reallocation of aggregate labor input. The first term on the right-hand side of the second equation of Equation (3.77) can be decomposed into two parts: one is the inter-region reallocation of aggregate labor input, and the other is the reallocation of changes in labor composition within each region.
Chapter 4: Measuring Output and Price Deflators by Sector and Region

In order to conduct regional productivity analysis by following methodology in Chapter 3, we need to construct regional productivity accounts that include output accounts, price deflator, capital input, and labor input. We introduce procedures to construct regional output accounts and price deflators in this chapter, and leave the construction of regional capital input and labor input for the next two chapters.

This chapter explains how to measure output and price deflators by sector and region, which is crucial for productivity analysis. Gross output is defined as goods or services produced within a producer unit that become available for use outside the unit. This is a gross measure in the sense that it represents the value of sales and net additions to inventories without, however, allowing for the purchase of intermediate inputs. When the purchase of intermediate inputs is deducted from gross output, one obtains a measure of value added. In this sense, value added is a net measure. However, it may not be considered a net measure in the sense that it includes the value of depreciation or consumption of fixed capital (OECD Manual, 2001).

When TFP measures are based on a gross output production function, TFP growth approximates the rate of neutral, disembodied technical change that can be the result of research and development that leads to improve production processes; technical change can be the consequence of learning-by-doing or imitation. It is called “disembodied” because it is not physically tied to any specific factor of production; rather, it affects inputs proportionally. This form of technical change is also called “Hicks-neutral” and is “output augmenting” when it raises the maximum output that can be produced with a given level of primary and intermediate inputs, and without changing the relationship between different inputs (OECD Manual, 2001).

As is mentioned in the OECD Manual, TFP measures could be based on a value added concept where value added is considered a firm’s output, and only primary inputs are taken as a firm’s inputs. Value added-based productivity measures reflect an industry’s capacity to contribute to economy-wide income and final demand. In this sense, they are valid complements to gross output-based measures. As stated in Chapter 2, however, value added-based productivity measures ignore the important role of intermediate inputs; this is an important reason why we adopt the APPF approach in this study. In order to obtain real value added, most current studies adopt single deflation, in which real value added is derived by deflating nominal value added, which is the difference between gross output and intermediate
inputs at current prices, with one price index (usually the output deflator). The underlying assumption behind single deflation is that price changes of gross output and intermediate inputs of an industry are the same, which is not reasonable. We adopt the standard double deflation in this study, in which real value added is derived as the residual of nominal gross output deflated by output deflator minus nominal intermediate inputs deflated by intermediate input deflators. The prerequisite to conduct double deflation is to construct time series of PPIs for every industry and transaction parts of intermediate inputs for each region.

This chapter is organized as follows. We first introduce definitions and features of Chinese regional official statistics about output data and note the gaps between Chinese official statistics and the international standards for measuring output data. We then explain steps adopted to construct output data by sector and region. We further illustrate how to construct time series of PPIs for every industry and transaction parts of intermediate inputs for every region in order to finally conduct double deflation approach.

4.1 Features of Regional Official Output Statistics

This section is divided into two parts: the first introduces the official statistics about industrial sectors, and the second introduces those for non-industrial sectors.

4.1.1 Industrial Sectors

The Chinese regional statistical yearbooks publish three output indicators for industrial sectors: gross industrial output value at the current price, gross industrial output value at a constant price, and gross industrial value added at the current price.

According to 2010 China Statistical Yearbook (CSY, pages 570-571), the value added of industry refers to the final results of the industrial production of industrial enterprises in money terms during the reference period. Industrial value-added can be calculated by two approaches: the production approach, i.e., gross industrial output value minus intermediate input plus value-added tax, and the income approach, i.e., income for various factors used in the course of production, including the depreciation of fixed assets, remuneration of labor, net of production

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23 Fu (2009) has discussed various problems of Chinese regional official statistics about industrial sectors.
24 Like GDP, the gross industrial output value is also reported at a constant price. As economy grows, changes will take place in the price structure of industry, and the base period for the measurement of constant-price gross industrial output value and GDP thus needs to be adjusted every few years in order to better reflect the impact of price change on industry and the economy. The constant-price base periods used are 1952, 1957, 1970, 1980, 1990, 2000, 2005, 2010 and 2015 and the current base period is 2015 (2017 CSY, page 55).
tax, and operating surplus. The value added of industry in the Chinese Statistical Yearbook is calculated by the production approach, and each item is explained as follows.

(1) Gross industrial output refers to the total achievements of industrial production activities during a given period. Gross industrial output includes value of finished products, income from external processing, and value of change in semi-finished products between the end and the beginning of the reference period. The old definition of gross industrial output value was modified during the 1995 National Industrial Census. The revised (new) definition of gross industrial output value consists of three components: value of the finished products during the reference period, income from processing for external parties, and value of change in semi-finished products between the end and the beginning of the reference period. Therefore, since 1995, the gross industrial output value obtained by the new method has been used in the calculation.

(2) Industrial intermediate input refers to purchased goods and paid services consumed during the industrial production of enterprises. Fees paid for services include those paid for services provided by material production sectors (industry, agriculture, wholesale and retail trade, construction, transport, post, and telecommunications) and by non-material production sectors (insurance, banking, culture, education, scientific research, health and medical care, public administration, etc.). The determination of industrial intermediate input follows the principle that goods and services must be purchased from outside and included in gross industrial output, and that goods and services are inputted into production and consumed (including low-value consumables) during the reference period. Industrial intermediate input includes five components, namely the direct consumption of materials, industrial intermediate input in the manufacturing cost, industrial intermediate input in the management cost, industrial intermediate input in the marketing cost, and expenditure on interest.

(3) Value-added tax refers to the amount of value added tax that should be paid by enterprises during the reference period. It is the sum of tax on sales, export rebate, and transferred tax on purchases of the current year, minus the tax on purchases of the current year. The value added tax payable for small-size enterprises is determined by the taxable sales of the year multiplied by the tax rate.

4.1.2 Non-industrial Sectors

Non-industrial sectors include agriculture, construction, and service sectors. Regional statistical yearbooks report gross output value and value added for agriculture and construction.
Thus, intermediate input of these two sectors can be calculated as the residual between gross output value and value added.

For service sectors, in the regional domestic products part, regional statistical yearbooks usually report regional domestic products for transportation, storage and post, wholesale and retail trade, hotels and catering, finance, real estate, and other service sectors. In addition, based on the income approach components of regional domestic products, regional statistical yearbooks further report four components of regional domestic products by detailed service sectors, i.e., compensation of employees, net taxes on production, depreciation of fixed assets, and operating surplus.

4.2 Problems in Regional Official Output Statistics

The prerequisite of accurately conducting productivity analysis is to make precise measurements about input and output. Several gaps exist between the raw data from Chinese regional official statistical yearbooks and the standard indicators actually used in empirical analysis. As a result, the empirical results are biased and unreliable if researchers directly use the raw data collected from Chinese regional official statistical yearbooks without any adjustments. This section discusses problems of the official data in details.

4.2.1 Problems in Industrial Sectors

The first problem is that industry classification is not consistent during the time period considered in this study, i.e., 1992-2014. The National Economic Industry Classification and Code-National Standard (guojiabiaozhun in Chinese, GB/T4754 for notation) was first launched in 1984 and further amended in 1994, 2002, and 2011. The main changes of industry classification between two adjacent benchmarks are illustrated as follows.

First, the main differences between industry classifications of 1984 and 1994 for industrial sectors are shown in Table 4.1. Specifically, compared with GB/T4754-1984, the changes of industrial sectors in the 1994 version of industry classification are the followings:
(1) The sectors of “Mining of Building Materials and Other Nonmetal Ores”, “Sewing Industry”, “Chemical Industry”, and “Manufacturing of Building Materials and Other Nonmetallic Mineral Products” have changed names to “Mining of Nonmetal Ores”, “Manufacturing of Clothing and Other Fiber Products”, “Manufacturing of Chemical Raw Materials and Chemical Products”, and “Manufacturing of Non-metallic Mineral Products”, respectively; see No. 1, 5, 10, and 11 in Table 4.1. (2) The sectors of “Salt Mining”, “Feeding
Industry”, and “Manufacturing of Arts and Crafts” have been categorized into upper-level sectors, that is, “Mining of Nonmetal Ores”, “Food Processing Industry”, and “Other Manufacturing”, respectively; see No. 2, 4, and 7. (3) The sector of “Manufacturing of Food” has been decomposed into “Food Processing Industry” and “Manufacturing of Food”, and the sector of “Machinery Industry” has been decomposed into “Manufacturing of General Machinery” and “Manufacturing of Special Equipment”, respectively; see No. 3 and 12. (4) The sectors of “Printing Industry”, “Petroleum Processing”, “Coking, Production and Supply of Gas”, “Manufacturing of Instrumentation, and Other Measuring Instruments and Meters”, and “Other Industry” have been adjusted to “Printing Industry and Reproduction of Recording Media”, “Petroleum Processing and Coking Industry”, “Production and Supply of Gas”, “Manufacturing of Instrumentation, and Culture, Office Machinery”, and “Other Manufacturing”, respectively; see No. 6, 8, 9, 14, and 15. Finally, the sector of “Manufacturing of Weapons and Ammunition” is newly increased; see No. 13.

Table 4.1 Changes of Industry Classifications of Industrial Sectors: 1984 vs. 1994

<table>
<thead>
<tr>
<th>No.</th>
<th>Changes</th>
<th>1984</th>
<th>1994</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>name</td>
<td>Mining of Building Materials and Other Nonmetal Ores (12)</td>
<td>Mining of Nonmetal Ores (10)</td>
</tr>
<tr>
<td>2</td>
<td>included</td>
<td>Salt Mining (13)</td>
<td>Salt Mining (103), included in Mining of Nonmetal Ores (10)</td>
</tr>
<tr>
<td>3</td>
<td>decomposed</td>
<td>Manufacturing of Food (17/18)</td>
<td>Food Processing Industry (13) and Manufacturing of Food (14)</td>
</tr>
<tr>
<td>4</td>
<td>included</td>
<td>Feeding Industry (21)</td>
<td>Feeding Industry (131), included in Food Processing Industry (13)</td>
</tr>
<tr>
<td>5</td>
<td>name</td>
<td>Sewing Industry (24)</td>
<td>Manufacturing of Clothing and Other Fiber Products (18)</td>
</tr>
<tr>
<td>6</td>
<td>contents</td>
<td>Printing Industry (29)</td>
<td>Printing Industry and Reproduction of Recording Media (23)</td>
</tr>
<tr>
<td>7</td>
<td>included</td>
<td>Manufacturing of Arts and Crafts (31)</td>
<td>Manufacturing of Arts and Crafts (431), included in Other Manufacturing (43)</td>
</tr>
<tr>
<td>8</td>
<td>contents</td>
<td>Petroleum Processing (34)</td>
<td>Petroleum Processing and Coking Industry (25)</td>
</tr>
<tr>
<td>9</td>
<td>contents</td>
<td>Coking, Production and Supply of Gas (35)</td>
<td>Production and Supply of Gas (45)</td>
</tr>
<tr>
<td>10</td>
<td>name</td>
<td>Chemical Industry (36/37)</td>
<td>Manufacturing of Chemical Raw Materials and Chemical Products (26)</td>
</tr>
<tr>
<td>11</td>
<td>name</td>
<td>Manufacturing of Building Materials and Other Non-metallic Mineral Products (45/46)</td>
<td>Manufacturing of Non-metallic Mineral Products (31)</td>
</tr>
<tr>
<td>No.</td>
<td>Status</td>
<td>Industry Description</td>
<td>Classification</td>
</tr>
<tr>
<td>-----</td>
<td>--------</td>
<td>----------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>12</td>
<td>decomposed</td>
<td>Machinery Industry (53/55)</td>
<td>Manufacturing of General Machinery (35) and Manufacturing of Special Equipment (36)</td>
</tr>
<tr>
<td>13</td>
<td>new</td>
<td></td>
<td>Manufacturing of Weapons and Ammunition (39)</td>
</tr>
<tr>
<td>14</td>
<td>contents</td>
<td>Manufacturing of Instrumentation, and Other Measuring Instruments and Meters (63)</td>
<td>Manufacturing of Instrumentation, and Culture, Office Machinery (42)</td>
</tr>
<tr>
<td>15</td>
<td>contents</td>
<td>Other Industry (66)</td>
<td>Other Manufacturing (43)</td>
</tr>
</tbody>
</table>

Source: Author’s collection from NBS, and the numbers or letters in parentheses are industry codes in various versions of standard industry classifications.

Further, in GB/T4754-2002 (see Table 4.2 for details), the main changes are the followings: (1) The sector of “Logging and Transport of Timber and Bamboo” has been categorized into “Forestry”, which is a sub-sector of “Agriculture, Forestry, Animal Husbandry, and Fishery”, and the sector of “Manufacturing of Weapons and Ammunition” has been categorized into “Manufacturing of Special Equipment”; see No. 1 and 4. (2) The sectors of “Manufacturing of Clothing and Other Fiber Products” and “Petroleum Processing and Coking Industry” have been adjusted to “Manufacturing of Textile Wearing Apparel, Footwear and Hats” and “Processing of Petroleum, Coking, and Processing of Nuclear Fuels”, respectively; see No. 2 and 3. (3) The sectors of “Manufacturing of Electronic and Communication Equipment” and “Other Manufacturing” have changed names to “Manufacturing of Communication Equipment, Computer, and Other Electronic Equipment”, and “Manufacturing of Artwork and Others”, respectively; see No. 5 and 6. Finally, the sector of “Recycling and Disposal of Waste Resources and Materials” is newly increased; see No. 7.
### Table 4.2 Changes of Industry Classifications of Industrial Sectors: 1994 vs. 2002

<table>
<thead>
<tr>
<th>No.</th>
<th>Changes</th>
<th>1994</th>
<th>2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>included</td>
<td>Logging and Transport of Timber and Bamboo (12)</td>
<td>Logging and Transport of Timber and Bamboo (022), finally included in Agriculture, Forestry, Animal Husbandry, and Fishery (A)</td>
</tr>
<tr>
<td>2</td>
<td>contents</td>
<td>Manufacturing of Clothing and Other Fiber Products (18)</td>
<td>Manufacturing of Textile Wearing Apparel, Footwear and Hats (18)</td>
</tr>
<tr>
<td>4</td>
<td>included</td>
<td>Manufacturing of Weapons and Ammunition (39)</td>
<td>Manufacturing of Weapons and Ammunition (3663), finally included in Manufacturing of Special Equipment (36)</td>
</tr>
<tr>
<td>5</td>
<td>name</td>
<td>Manufacturing of Electronic and Communication Equipment (41)</td>
<td>Manufacturing of Communication Equipment, Computer, and Other Electronic Equipment (40)</td>
</tr>
<tr>
<td>6</td>
<td>name</td>
<td>Other Manufacturing (43)</td>
<td>Manufacturing of Artwork and Others (42)</td>
</tr>
<tr>
<td>7</td>
<td>new</td>
<td></td>
<td>Recycling and Disposal of Waste Resources and Materials (43)</td>
</tr>
</tbody>
</table>

Source: See Table 4.1.

Further, in GB/T4754-2011 (see Table 4.3 for details), the main changes are the followings: (1) The two sectors of “Support Service Activities for Mining” and “Repair Services of Metal Products, Machinery, and Equipment” are newly increased, see No. 1 and 11;\(^{25}\) (2) The sectors of “Manufacturing of Beverage” and “Recycling and Disposal of Waste Resources and Materials” have changed names to “Manufacturing of Wine, Beverage, and Refined Tea” and “Comprehensive Utilization of Waste Resources”, respectively; see No. 2 and 10. (3) The sectors of “Manufacturing of Textile Wearing Apparel, Footwear, and Hats”, “Manufacturing of Leather, Fur, Feather, and Their Products”, “Manufacturing of Culture,

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\(^{25}\) In 2013, in order to better reflect the development of China’s three broad industries and meet the needs of the three broad industries divisions by national economic accounting, service industry statistics, and other statistical investigations, the NBS has further revised the scopes of three broad industries based on GB/T4754-2011 and first officially named the tertiary industry as the service industry. The new scope of three industries are as follows: the primary industry refers to “Agriculture, Forestry, Animal Husbandry, and Fishery” excluding “Support Service Activities for Agriculture, Forestry, Animal Husbandry, and Fishery”; the secondary industry consists of four broad industries, that is, “Mining (excluding “Support Service Activities for Mining”), “Manufacturing (excluding “Repair Services of Metal Products, Machinery and Equipment”), “Production and Supply of Electricity, Heat, Gas, and Water,” and “Construction”; and the tertiary industry includes all industries excluded by the primary and secondary industries, further including “Support Service Activities for Agriculture, Forestry, Animal Husbandry, and Fishery”, “Support Service Activities for Mining”, and “Repair Services of Metal Products, Machinery, and Equipment”. Therefore, these two sectors have been categorized into the service industry since 2013.
Education, and Sports Goods”, “Manufacturing of Instrumentation, and Culture, Office Machinery”, and “Manufacturing of Artwork and Others” have been adjusted to “Manufacturing of Textile Wearing Apparel and Ornament”, “Manufacturing of Leather, Fur, Feather, and Their Products, and Footwear”, “Manufacturing of Articles for Culture, Education, Artwork, Sports, and Entertainment Activities”, “Manufacturing of Instrumentation”, and “Manufacturing of Others”, respectively; see No. 3, 4, 5, 8, and 9. (4) The two sectors of “Manufacturing of Rubber Products” and “Manufacturing of Plastics Products” are combined together as one sector of “Manufacturing of Rubber and Plastics Products”; see No. 6. Last, the sector of “Manufacturing of Transportation Equipment” has been decomposed into “Manufacturing of Motor Vehicles” and “Manufacturing of Railway Locomotives, Ships and Boats, Air and Spacecraft, and Other Transportation Equipment”; see No. 7.

Table 4.3 Changes of Industry Classifications of Industrial Sectors: 2002 vs. 2011

<table>
<thead>
<tr>
<th>No.</th>
<th>Changes</th>
<th>2002</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>new</td>
<td>Support Service Activities for Mining (11)</td>
<td>Manufacturing of Others (41)</td>
</tr>
<tr>
<td>2</td>
<td>name</td>
<td>Manufacturing of Beverage (15)</td>
<td>Manufacturing of Wine, Beverage, and Refined Tea (15)</td>
</tr>
<tr>
<td>3</td>
<td>contents</td>
<td>Manufacturing of Textile Wearing Apparel, Footwear, and Hats (18)</td>
<td>Manufacturing of Textile Wearing Apparel and Ornament (18)</td>
</tr>
<tr>
<td>4</td>
<td>contents</td>
<td>Manufacturing of Leather, Fur, Feather, and Their Products (19)</td>
<td>Manufacturing of Leather, Fur, Feather, and Their Products, and Footwear (19)</td>
</tr>
<tr>
<td>6</td>
<td>combined</td>
<td>Manufacturing of Rubber Products (29) and Manufacturing of Plastics Products (30)</td>
<td>Manufacturing of Rubber and Plastics Products (29)</td>
</tr>
<tr>
<td>7</td>
<td>decomposed</td>
<td>Manufacturing of Transportation Equipment (37)</td>
<td>Manufacturing of Motor Vehicles (36) and Manufacturing of Railway Locomotives, Ships and Boats, Air and Spacecraft, and Other Transportation Equipment (37)</td>
</tr>
<tr>
<td>8</td>
<td>contents</td>
<td>Manufacturing of Instrumentation, and Culture, Office Machinery (41)</td>
<td>Manufacturing of Instrumentation (40)</td>
</tr>
<tr>
<td>9</td>
<td>contents</td>
<td>Manufacturing of Artwork and Others (42)</td>
<td>Manufacturing of Others (41)</td>
</tr>
<tr>
<td>10</td>
<td>name</td>
<td>Recycling and Disposal of Waste Resources and Materials (43)</td>
<td>Comprehensive Utilization of Waste Resources (42)</td>
</tr>
<tr>
<td>11</td>
<td>new</td>
<td>Repair Services of Metal Products, Machinery, and Equipment (43)</td>
<td>Comprehensive Utilization of Waste Resources (42)</td>
</tr>
</tbody>
</table>

Source: See Table 4.1.

These changes make the Chinese industry classification more accurate and further align it with international industry classification, which also makes it possible to conduct economic empirical analysis across countries. However, both Chinese Statistical Yearbooks and Regional Statistical Yearbooks only report data at the two-digit sectoral level, which makes it difficult
to keep industry classification consistent with different versions of standards for the classification of national economic sectors.

The second problem regarding official statistics is that data coverage is inconsistent over time. “Industrial enterprises with independent accounting systems” was used for 1992-1997 in official statistics. In 1998, the NBS adjusted the scope of industrial statistics into two layers: those above the designated size and those below the designated size. The scope of industrial enterprises above the designated size included all state-owned industrial enterprises and the non-state-owned industrial enterprises with annual revenue from principal business over 5,000,000 yuan from 1998 to 2006; all industrial enterprises with annual revenue from principal business over 5,000,000 yuan from 2007 to 2010; and all industrial enterprises with annual revenue from principal business above 20,000,000 yuan since 2011 (2017 CSY, page 412). This not only makes data incomparable before and after the main time points, such as 1998 and 2011, but also underestimates the role of industrial sectors when directly using the data from official statistics without any adjustments because the latter omits “below designated size” industrial sectors. On the other hand, the official statistics do not publish any data about below-designated-size industrial sectors. As a result, in order to cover all industrial sectors, researchers have to estimate below-designated-size industrial sectors in every time period, and it is possible that different researchers provide different results because methodologies they adopted are not the same.

The third problem about official statistics is that the summation of value added of all “above designated size” industrial sectors is close to the national industrial sector total in 2005, and it becomes larger than the national total from 2007. If “below designated size” industrial sectors are added back, the discrepancy between the summation of all industrial sectors and the national total should become even larger. This is seldom mentioned by the officials, and needless to say, there are no adjustments to the official statistics.

The fourth problem concerning official statistics is that they do not report the indicator of value added of industry after 2007, nor the indicator of gross industrial output value after 2011. Therefore, researchers need to estimate these two indicators using their own methodologies in order to obtain the related time series data. Some discrepancies among different researchers’ results are inevitable.
### 4.2.2 Problems in Non-industrial Sectors

Unlike industrial sectors, the concepts of “above designated size” and “below designated size” do not exist in non-industrial sectors. The official statistics cover all layers for non-industrial sectors. As in industrial sectors, the main problem in non-industrial sectors is the standards for classification of their activities.

As stated above, the standards for industry classification were first launched in 1984, and were further amended in 1994, 2002, and 2011. The different versions of classifications of non-industrial sectors are shown in the following table.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Construction</td>
<td>Construction</td>
<td>Construction</td>
<td>Construction</td>
</tr>
<tr>
<td>4</td>
<td>Transportation, Post and Telecommunications</td>
<td>Transportation, Storage, Post and Telecommunications</td>
<td>Transportation, Storage and Post Industry</td>
<td>Transportation, Storage and Post Industry</td>
</tr>
<tr>
<td>5</td>
<td>Business, Public Catering, Materials Supplies and Sales, and Storage</td>
<td>Wholesale, Retail Trade, and Catering Industry</td>
<td>Wholesale and Retail Trades</td>
<td>Wholesale and Retail Trades</td>
</tr>
<tr>
<td>6</td>
<td>Hotel and Catering Services</td>
<td>Hotel and Catering Services</td>
<td>Hotel and Catering Services</td>
<td>Hotel and Catering Services</td>
</tr>
<tr>
<td>7</td>
<td>Finance and Insurance</td>
<td>Finance and Insurance</td>
<td>Financial Intermediation</td>
<td>Financial Intermediation</td>
</tr>
<tr>
<td>8</td>
<td>Real Estate Management, Utilities, Services to Households, and Consulting Services</td>
<td>Real Estate</td>
<td>Real Estate</td>
<td>Real Estate</td>
</tr>
<tr>
<td>9</td>
<td>Scientific Research and Polytechnical Services</td>
<td>Scientific Research and Polytechnical Services</td>
<td>Scientific Research, Technical Services, and Geological Exploration Industry</td>
<td>Scientific Research, Technical Services, and Geological Exploration Industry</td>
</tr>
<tr>
<td>10</td>
<td>Leasing and Business Services</td>
<td>Leasing and Business Services</td>
<td>Leasing and Business Services</td>
<td>Leasing and Business Services</td>
</tr>
<tr>
<td>12</td>
<td>Social Services</td>
<td>Management of Water Conservancy, Environment, and Public Facilities</td>
<td>Management of Water Conservancy, Environment, and Public Facilities</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Education, Culture, Art, Radio, and Television</td>
<td>Education, Culture, Art, Radio, Film, and Television</td>
<td>Education</td>
<td>Education</td>
</tr>
<tr>
<td>18</td>
<td>Others</td>
<td>Others</td>
<td>International Organizations</td>
<td>International Organizations</td>
</tr>
</tbody>
</table>

Source: See Table 4.1. The industry classification for the service industry is from the perspective of category, that is, a higher level than that for industrial sectors that is based on two-digit industry codes.

For agriculture in our standard 37 sectors, the main change in these four versions of industry classification in Table 4.4 is that it includes “Water Management Industry” in the 1984 version of industry classification, which is excluded in other versions of industry classification. Furthermore, the NBS adjusted a sub-sector of agriculture, i.e., “Support Service Activities for Agriculture, Forestry, Animal Husbandry, and Fishery”, to the service industry from 2013.\(^{26}\)

Following Marxist principles, the service sectors were classified into two categories: the material service sector and the non-material service sector in GB/T4754-1984. The former includes Transportation, Post and Telecommunications, and Business, Public Catering, Materials Supplies and Sales and Storage, and the latter includes the rest of service sectors. However, with the in-depth development of economic system reform and the gradual establishment of a socialist market economic system, the structure of the national economy has experienced a marked change. The “Industrial Classification and Codes for National Economic Activities” (GB/T4754-1984) formulated in 1984 did not adapt to the needs for the macroeconomic management of the national economy and statistical work for two reasons: one is that the GB/T4754-1984 prominently reflected the situation of the secondary industry, while

\(^{26}\) See footnote 25 for details.
the classification of the tertiary industry was relatively crude; the second reason is that the GB/T4754-1984 failed to strictly follow industries’ own characteristics and natures.

In order to resolve above two issues, the NBS revised the standard and formulated the “Industrial Classification and Codes for National Economic Activities” (National Standard Revision Scheme) in 1994, which was denoted as GB/T4754-1994.

The new GB/T4754-1994 closely combined the new tendency of China’s economic system reform and the new situation that emerged after institutional restructuring and change of the government’s functions. Moreover, it broke the boundary of division of sectors, eliminated the impact of product economic models on industry classification, and fully reflected the tertiary industry and the emerging industries with a promising future. At the same time, it actively absorbed the experiences of industry classification standards in various countries around the world and tried to move closer to the United Nations International Standard Industrial Classification (ISIC) to meet the needs of macro management, national economic accounting, and international comparison. The new standard can basically be linked to the ISIC Revision 3 formulated in 1988.

In particular, the new GB/T4754-1994 separates “Real Estate Management” from “Real Estate Management, Utilities, Services to Households, and Consulting Services” and combines it with the emerging “Real Estate Development and Operation Industry” and “Real Estate Agency and Brokerage Industry” to form the category of “Real Estate”. The remaining proportion of “Real Estate Management, Utilities, Services to Households, and Consulting Services” is renamed as “Social Services”. In light of international standards, the “Business, Public Catering, Materials Supplies and Sales, and Storage” is revised to “Wholesale, Retail Trade, and Catering Industry” excluding “Storage”. The “Water Management Industry” is separated from “Agriculture, Forestry, Animal Husbandry, Fishery, and Water Management Industry” and forms the category of “Geological Exploration and Water Management Industry” together with “Geological Exploration Industry”.

With the further rapid development of the national economy and adjustment of industrial structure, many emerging industries have emerged, and the development of modern service industries has accelerated. The activities of information technology, business economy, intermediary agencies, resources and environmental protection, and intellectual property rights have developed rapidly. At the same time, China’s opening up to the outside world has further expanded, and international exchanges have increased. In particular, after the accession to the
World Trade Organization (WTO) in 2001, the need for integration with international standards has become more urgent, and the previous standards have been difficult to adapt to new situations. Therefore, the NBS further revised the “Industrial Classification and Codes for National Economic Activities” (GB/T4754-1994) and formulated the “Industrial Classification for National Economic Activities” (GB/T4754-2002) in 2002.

This new standard mainly relies on the actual conditions of China’s industry development and follows the homogeneity principles of economic activities of international standards to revise previous industry classification standards. Meanwhile, it actively refers to the contents of the United Nations International Standard Industrial Classification of All Economic Activities (ISIC/Rev. 3) to align the newly revised standards with international classification standards.

The new standard categorizes industry according to the homogeneity principles of economic activities of international standards, strengthens the classification of the tertiary industry and adds many activity categories in the service industry. The six sectors of “Information Transmission, Computer Services, and Software Industry”, “Hotel and Catering Services”, “Leasing and Business Services”, “Management of Water Conservancy, Environment, and Public Facilities”, “Education”, and “International Organizations” have been increased. In addition, according to the actual situation, the names and contents of some categories in GB/T4754-1994 have been adjusted and integrated. The adjusted categories mainly include: “Transportation, Storage and Post Industry”, “Wholesale and Retail Trades”, “Financial Intermediation”, “Services to Households and Other Services”, “Health, Social Security, and Social Welfare Industries”, “Culture, Sports, and Entertainment”, and “Public Management and Social Organizations”. The two previous categories of “Geological Exploration and Water Management Industry” and “Others” have been eliminated, and their activities have been classified into new categories of “Scientific Research, Technical Services, and Geological Exploration Industry”, “Management of Water Conservancy, Environment, and Public Facilities”, and other related industries.

Based on the actual situation of China’s social and economic development, the NBS further revised the GB/T4754-2002 in 2011 to maintain the integrity, scientificity, and observability of the economic structure and industrial structure; to ensure that the national statistics and accounting truly reflect China’s economic structure and industrial structure; and to follow international classification principles, such as the “International Standard Industrial Classification” Fourth Edition (ISIC/Rev.4) promulgated by the United Nations in 2007.
Compared with GB/T4754-2002, the new GB/T4754-2011 adjusts the names and order of categories. For example, the “Information Transmission, Computer Services, and Software Industry” is renamed as “Information Transmission, Software and Information Technology Services”, the “Scientific Research, Technical Services, and Geological Exploration Industry” is renamed as “Scientific Research and Technical Service Industry”, the “Services to Households and Other Services” is renamed as “Services to Households, Repair, and Other Services”, and the “Health, Social Security, and Social Welfare Industries” is renamed as “Health and Social Services”. However, the number of main categories of overall industry remains unchanged, which ensures the continuity of industry classification.

In addition, in order to reflect China’s growing Internet, information technology, finance, film, and television entertainment industries, new categories such as “Internet Access and Related Services”, “Information System Integration Services”, and other middle classes have been increased.

As a result, as with industrial sectors, with the limited data reported in the official statistical yearbooks, it is also difficult for researchers to reconcile different versions of standards for classification of non-industrial sectors, especially the service sectors, to keep industry classification consistent over time.

4.2.3 Problems about Level and Growth Rate of Official Data

The official data are widely criticized as underestimating the level of GDP (Maddison, 2007; World Bank, 1997; H. Wu, 2000) and overestimating real growth rate of GDP (Woo, 1998; Ren, 1997; Maddison, 2007; H. Wu, 2000 and 2002).

Two major reasons have been advanced to explain why China’s official statistics underestimate the level of GDP. The first is because of the under-coverage effect. For industrial sectors, as stated before, the coverage is “industrial enterprises with independent accounting systems” for 1992-1997, “all state-owned industrial enterprises and the non-state-owned industrial enterprises above designated size” for 1998-2006,27 “all industrial enterprises above designated size” for 2007-2010, and the volume of annual revenue was further raised from 5,000,000 to 20,000,000 since 2011 at sectoral level. The official statistics are not capable of conducting statistics to sufficiently cover the entire industrial sectors. The quickly emerging non-state sectors, especially small-sized rural enterprises, are not included in official statistics.

27 The criterion of “above designated size” is that annual revenue from the principal business is over 5,000,000 yuan for 1998-2010, which increases to 20,000,000 yuan in 2011.
This is mainly because the activities of these enterprises are outside the state planning and administrative controls. On the other hand, the small-sized enterprises also have strong incentives to underreport their output to avoid high tax obligations (H. Wu, 2000). Therefore, it is difficult for official statistics to cover this part of economic activities, and thus, they simply publish data of “above designated size” industrial sectors about which they are confident. For service sectors, due to the long history of adopting the Material Products System (MPS) in China’s statistical system, the contribution of service sectors is usually underestimated, especially those sectors that are categorized as non-material service sectors, which are considered to be nonproductive. The amendments of standards for industry classification in 1994, 2002, and 2011 have gradually strengthened the classification of service sectors, and more and more service activities are covered in the official statistics. This change of industry classification reflects the fact that the Chinese statistical system has shifted from MPS to SNA. Moreover, with the development of globalization, especially after entering into the WTO in 2001, the linkage between China and the international market has become closer. It is also essential for officials to adopt international standard industrial classification in order to conduct international comparisons.

The second reason why China’s official statistics underestimate the level of GDP is rooted in the price distortion effect. In China, prices of industrial products used to be set at a high level, and those of agricultural products and services used to be set at a low level. By doing so, more resources flowed into heavy industries, which would then achieve further development. Officials in the late of 1950s adopted this strategy when they set an ambitious target that concentrated more resources to develop heavy industries to catch up with Western countries in just a few years. Despite various price reforms in the later years, the standard of high prices for some manufactured commodities and low prices for rural products and services is still in use. With the rapid development of service sectors, the share of service sectors as a whole in the total Chinese economy has gradually increased and exceeded that of industry from the year 2001. The overall Chinese GDP is substantially undervalued due to this price distortion.

On the other hand, the officials are inclined to overestimate real growth rate of the Chinese GDP. This is mainly for two reasons: one is the output price deflators used in the Chinese statistical system, and the other results from institutional effects (H. Wu, 2000).

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28 The share is derived from the official nominal value added of each industry.
In order to obtain GDP at a constant price, the set of price indices is essential. The fixed base year of the Laspeyres formula is commonly used to obtain items at a constant price. The Laspeyres price index ($L_p$) is defined as a weighted arithmetic average of the price relatives using the value shares of the reference period 0 as weights (SNA 2008, paragraph 15.16), which can be illustrated as the following:

$$L_p = \frac{\sum_{i=1}^{n} p_i^1 q_i^0}{\sum_{i=1}^{n} p_i^0 q_i^0} \tag{4.1}$$

where $p_i^0$ and $q_i^0$ are price and quantity in period 0 of $i = 1, \ldots, n$ products. Similarly, expressions with superscript $t$ refer to period $t$.

Following the Soviet-style statistical system, China adopted the “comparable price” system to construct GDP deflators to obtain GDP at a constant price starting in the early 1950s. In the history of China’s official statistics, the following benchmark years have been adopted: 1952, 1957, 1970, 1980, 1990, and 2000. Since 2000, the NBS has shortened the time interval between two benchmark years, and three benchmark years have been used, that is, 2005, 2010, and 2015, and the current base period is 2015. In each benchmark year, the officials first obtain the sets of average prices of representative products, which are used as “constant prices” to assemble GDP deflator. The officials provide price manuals, which enterprises use as references and are required to report their outputs in both current and constant prices.

However, the price inflation is underestimated under such a price system, and thus real growth rate of China GDP is overestimated. This is mainly for the following reasons. First, the substitution bias, also known as the Gerschenkron effect (Gerschenkron, 1951), is introduced because of the long interval between two base years, for example, the 13-year interval between the two base years of 1957 and 1970, or the 10-year interval after the base year of 1957. Moreover, according to above Laspeyres price index formula, $L_p$ can be defined as the change in value of a basket of products whose composition is kept fixed to what it was in the reference period 0 (SNA 2008, paragraph 15.17). With the development of society and the economy, the Chinese economy has gradually shifted from a central planning economy to a market-oriented economy. Various price regulations implemented in the central planning period have been gradually relaxed, especially after China started its economic reform and opening up policy in 1978. As a result, the fixed weights of the base year of products in the basket used in the Laspeyres price index formula ignore substitution effects because prices of those products fall,

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29 See footnote 24 for details.
and consequently, their consumption finally rises and vice versa over a long time period; thus, a higher rate of volume growth tends to occur in years close to current year (United Nations 2003, paragraph 13.14). This effect becomes even more serious given that the market gradually plays a more important role in the Chinese economy. Second, the officials do not provide any information about the criteria used to choose the “representative products” that appear in price manuals or about how to use the average prices of these representative products to construct “constant prices” and, further, to assemble the GDP deflator. Therefore, the state-listed prices (which are always at a low level) are covered, and prices of other market-dominated transactions (which are always at a high level) are not sufficiently covered (Maddison, 2007).

Third, along with the rapid development of the market economy, more and more new kinds of products have been created, and these are not listed in price manuals of the base years. It is difficult to determine counterparts to match these new products based on the price manuals. Consequently, the overall price level is underestimated.

The second reason that has been advanced to explain the upward bias of the Chinese GDP growth rate is because of the institutional effect. In China, output and price data are collected and processed through a long-established statistical reporting system at various levels of government. This process can easily be influenced by GDP growth-motivated local officials and the managers of SOEs to provide upward-biased data (H. Wu, 2007 and 2013). In addition, according to C. Xu (2011), the fundamental institution that accounts for the high growth rate of the Chinese economy over the past four decades is the RDA regime, which is characterized as the combination of political centralization and economic regional decentralization. On the one hand, the Chinese national government has highly centralized the political and personnel governance structure. The governors of regions are appointed by the national government, and one of the criteria used to appoint local officials is regional economic growth performance. High economic growth performance could be interpreted as evidence of the local officials’ superior management ability in the view of the national government. On the other hand, the governance of the regional economy is delegated to local governments. In order to achieve high growth of a regional economy, local officials have a strong incentive to intervene in the market behaviors of enterprises (usually through SOEs) because they have powerful influence or even direct control rights over a large amount of resources, such as land, financial resources, raw materials, and so on. Local officials are rewarded with special privileges if the economic growth performance within their jurisdictions exceeds certain threshold levels set by the
national government. For above two reasons, the intrinsic nature of this RDA regime tends to exaggerate the growth rate of GDP by local governments.

4.2.4 Problems with Integrating Regional Accounts with the National Account

Another problem concerning official statistics is that the summation of all regions’ data cannot match up with the national account and is frequently larger than the national totals. One of the reasons for the discrepancy has been mentioned above; under the RDA regime, appointments, promotion, and even demotions of local governors are highly centralized by the central government who uses regional economic growth as an important indicator to assess the management ability of local governors. In order to obtain promotion opportunities, local governors spare no efforts to expand the regional economy within their jurisdictions to compete with their peers, as in a “promotion qualifying competition” (Yang and Zheng, 2013) or “GDP tournament” (Zhou, 2007). Moreover, exaggerating regional economic growth figures is another possible means some local governors, if not all, adopt when they realize that they cannot out-compete their counterparts simply by working harder. Local governors control the appointments of the administrative leaders of local statistical bureaus who are responsible for collecting and calculating local data. Even if a local governor requests a higher regional growth rate (which is conducive to his or her promotion), which may violate the Statistics Law, it is difficult or even impossible for the leaders of local statistical bureaus to refuse this request because their promotions and even depositions are controlled by local governors (Holz, 2005). As a result, the regional growth data collected and calculated by local statistic bureaus tend to be exaggerated.

Second, double accounting is widely considered an important reason for the discrepancy between national data and regional data (e.g., Ma, 2012; Peng, 2009). The current principles of the statistics of regional economy are based on the registration location of companies instead of their local operation units. With the rapid development of the Chinese economy, the number of large-scale companies operating their businesses across regions and industries has gradually increased. Some outputs of a company located in a region flow into another region and are used as intermediate inputs or final goods by other companies. When calculating regional statistics, it is difficult to accurately calculate the specific shares of these large companies in each geographical area, and finally, this part of data is frequently calculated into several local statistics simultaneously, which creates the double accounting problem.
Third, missing original data, especially data of “below designated size” industrial sectors and service sectors, is another reason for discrepancy between national and regional data. The data concerning “above designated size” industrial sectors are reported by local statistical bureaus, whereas the data of “below designated size” industrial sectors are mainly collected via sample survey. Some industries can only be measured and estimated by using various professional statistical materials and financial data of various departments. Since these indicators are calculated using data from various aspects of society, multiple conversions are likely to make it difficult to guarantee data quality (Guan and Chen, 1999). X. Xu (2006) has noted that the lack of original data in many industries and projects has increased biases in the statistics of service sectors and “below designated size” industrial sectors. Therefore, the final data generated by regional and central governments are often inconsistent.

Fourth, the institutional arrangement of the Chinese statistical system plays an important role in accounting for the discrepancy. Here, we briefly introduce the institutional structure of the Chinese statistical system. Based on the top-down mode, Chinese governments are divided into five levels: the central, provincial, city-level, county-level, and township-level governments. All sub-level governments are directly governed by the central government, or the State Council, and the statistical work throughout all sub-level governments is organized and coordinated by the NBS, which is a division under the direct management of the State Council. The central government establishes a centralized and unified statistical system and implements a statistical management mode of “unified leadership, hierarchical responsibility (tongyi lingdao, fenji fuze, in Chinese)”; that is, the State Council establishes the NBS, local governments at or above the county level establish independent local statistical bureaus, and township-level governments either set up statistical stations or are equipped with statisticians who are mainly responsible for the specific coordination and management of statistical work. According to the needs of work, the NBS establishes survey corps in each province, as well as survey teams in each city and in one-third of the counties. The investigation agencies are directly affiliated to the NBS, such survey corps and survey teams are subject to vertical management by the NBS, and they mainly undertake tasks of investigating the important statistical data required by the NBS for national macroeconomic control and national economic accounting. The main means of collecting data are via sample surveys. This kind of statistical system causes discrepancies because the main way of collecting data for the NBS is sampling surveys conducted by local branches, which are relatively independent from the statistical approaches of local statistical bureaus.
4.3 Procedures of Constructing Regional Output Data

In order to resolve drawbacks in regional official statistics, this section explains how we construct regional output data to keep data coverage and industry classification consistent during the time period under consideration. RIOTs are used to construct regional output data. The main reasons why RIOTs are adopted are as follows.

First, the symmetric input and output table, transformed from supply and use tables, serves as an integral part of national accounts. The supply and use framework focuses on the production in an economy, which is a crucial part of national accounts. Meanwhile, it shows where goods and services are produced and where they are used, i.e., used as intermediate inputs by some sectors, consumed by final consumption, used as capital goods to form gross capital formation, or exported to foreign countries. Most macroeconomics indicators, such as value added, investment, consumption, and so on, are included in this framework. Therefore, the supply and use framework is recommended for compiling national accounts data, both in current prices as well as in constant prices (Eurostat Manual, 2008). As far as the author knows, Wu and Ito (2015) are the first to reconstruct Chinese national accounts based on the supply and use framework. Since there are no supply and use tables at regional level, we take for granted that the RIOTs are transformed from regional supply and use tables. Thus, the RIOTs are adopted in this study.

Second, the most important characteristic of the input and output table is that sectors are linked to each other by the input-output relationship because outputs of some sectors can be used as intermediate inputs by other sectors. As a result, the efficiency improvements in some sectors are bound to affect production efficiency of other sectors that use outputs from the efficient sectors as intermediate inputs and further advance the whole economy. This can also be seen in reality. For instance, the output of semiconductor sector is a key input for ICT sector. Most outputs of semiconductor sector are invisible at the aggregate level because semiconductor products are mainly used as intermediate inputs by other sectors rather than consumed by final demand as consumption or investment goods. This is important since semiconductor intermediate inputs play a key role in the improvements in the quality and performance of other products, such as computers. Due to the sharp acceleration in the price decline of semiconductors during the past few decades, and the fact that they are the key components of modern ICT, the price of ICT has also declined dramatically, which provides powerful economic incentives for the diffusion of ICT. In addition, the development of ICT deployment has significantly improved the efficiency of those sectors that rely heavily on ICT,
such as Finance, Wholesale Trade, and so on, which are denoted as ICT-using sectors in Jorgenson et al. (2005). They also conclude that ICT plays an important role in the growth resurgence of the American economy since 1995.

Third, RIOT covers all statistical calibers for industrial sectors, which means that it includes “industrial enterprises with non-independent accounting systems” for 1992-1997, and “below designated size” industrial enterprises from 1998 regardless of the fact that the threshold used to distinguish “below designated size” industrial enterprises is above 5,000,000 yuan since 1998 or 20,000,000 yuan since 2011. The fact that we do not need to estimate data for these two parts makes our data more accurate.

Fourth, RIOTs are published every five years. Therefore, during 1992-2014, we have five benchmarks, i.e., 1992, 1997, 2002, 2007, and 2012. In each benchmark, RIOTs report detailed industry classification, and the number of all industries is over 100. The comparison between the numbers of sectors in RIOTs and official statistics is shown in Tables 4.5 and 4.6. Due to several times of amendments regarding official standard industry classification, in order to reconcile different versions of industry classification and keep industry classification consistent over time, it seems that the only choice we have at present with the available data is to regroup some sectors together. The detailed industry classification of RIOTs makes this kind of sector regrouping more precise.

| Table 4.5 The Number of Sectors in RIOT Benchmarks |
|-----------|-----------|-----------|-----------|-----------|-----------|
| Industry  | 84        | 84        | 81        | 89        | 93        |
| Service   | 28        | 34        | 34        | 46        | 37        |

Notes: The numbers of industry and service are based on 119 sectors of RIOTs in 1992, 124 sectors in 1997, 122 sectors in 2002, 144 sectors in 2007, and 139 sectors in 2012. Some regions may report more or fewer sectors; e.g., Henan reports 114 sectors, and Shanghai reports 125 sectors in 1992; Inner Mongolia reports 118 sectors in 1997; Gansu reports 123 sectors, and Shanghai reports 131 sectors in 2002; Beijing reports 135 sectors in 2007, etc. As a result, the numbers for industry and services are slightly different.
Source: Author’s collection from NBS.

| Table 4.6 The Number of Sectors in Official Statistics |
|-----------|-----------|-----------|-----------|-----------|
| Industry  | 40        | 40        | 39        | 41        |
| Service   | 10        | 11        | 15        | 15        |

Note: The output data of service sectors reported in official yearbooks are from the perspective of a category that is at a higher level than that of industry, which is based on two-digit industry codes. Thus, it is the number of categories for services.
Source: Author’s collection from NBS.

According to above two tables, we can find that in official statistics, there are 40 industrial sectors at the two-digit level in GB/T4754-1984, 40 sectors in GB/T4754-1992, 39
sectors in GB/T4754-2002, and 41 sectors in GB/T4754-2011. On the other hand, the classification of industrial sectors in RIOTs is more detailed; the number of industrial sectors is more than twice that of official statistics.

Fifth, the classification for service sectors is more detailed in RIOTs. With the rapid development of the modern Chinese economy, service sectors have become a more and more important part of the whole economy, and its share has exceeded that of industry to become the largest component of the Chinese economy since 2001. Thus, in order to investigate the tendency of Chinese economic growth, it is important to measure the role of service sectors. With the detailed classification of service sectors in RIOTs, we can precisely trace the growth path of individual service sectors. As shown in Table 4.5, the classification of service sectors is more detailed in RIOTs than that in official statistics.

The first step to construct regional output data is to regroup detailed sectors into our standard 37 sectors.\(^30\) For several regions, we do not have the detailed RIOTs, and the officials publish the reduced RIOTs instead; for example, this occurs for 33 sectors in 1992, 40 sectors in 1997, and 42 sectors in 2002, 2007, and 2012.\(^31\) In this case, we use data from the China Industry Economy Statistical Yearbook (CIESY) to split broad industrial sectors in the reduced RIOTs. Regarding service sectors, we assume that sector structures are the same as in the adjacent detailed RIOTs and use those sector shares to split broad service sectors in the reduced RIOTs. Consequently, we construct 37 sectors for five benchmark years.

After the first step, we calculate four kinds of ratios: labor compensation-value added ratio (LC-VA ratio), value added-gross output ratio (VA-GO ratio), VA share of each industrial sector in the total industry, and VA share of each service sector in the total services at the five benchmark years. For middle years between two adjacent benchmarks, we interpolate industrial structure by linear projection. The key assumption behind this is that every sector develops along a linear trend. This assumption is valid when there is no major industrial structure change or external shock between two adjacent benchmark years. For last two years, that is, 2013 and 2014, we assume that industrial structure is the same as it was in 2012.

By completing above two steps, we obtain time series of industrial structure during 1992-2014 for four panels in each region, that is, LC-VA ratio, VA-GO ratio, VA share of each industrial sector in the total industry, and VA share of each service sector in the total services.

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\(^30\) See Table A1 in Appendix for the classification of 37 sectors which matches with CIP classification.

\(^31\) The detailed RIOT means the total number of sectors is over 100.
Next, we take gross value added of three broad industries as control totals from regional accounts, that is, primary industry, secondary industry (including industry and construction), and tertiary industry. By multiplying time series of VA shares, we can first obtain time series of VA for both industrial and service sectors. Moreover, with the VA of primary industry and construction from regional accounts, we get nominal VA for each sector. By further using LC-VA ratio and VA-GO ratio, we obtain time series of LC and GO.

Thus, we obtain time series of VA, LC, and GO for every region, and capital compensation is derived as the residual of VA minus LC; intermediate input is derived as the residual of GO minus VA. For national totals, we use data from the CIP database project, which at present covers 37 sectors in total that exhaust all sectors of the economy at this level of sectoral classification over time period of 1981-2010, and the extensions to 2016 are for internal use only.

In order to insert regions into the whole accounting framework and keep accounting identity consistent between the national total and the summation of all regions, we integrate regional accounts with the national account by redistributing the discrepancy between the national account and the summation of all regional accounts according to sector structure of newly constructed regional accounts.

### 4.4 Construction of Sector-level PPIs by Region

Analyzing and evaluating the performance of a regional (national) economy is the main objective of regional (national) accounts that provide comprehensive data used in macroeconomic empirical analysis. The decompositions of annual value change into two parts, i.e., price changes and volume changes, are important aspects of the compilation of regional (national) accounts from the point of view of economic policy (Eurostat Manual, 2008). Data at constant prices have to be derived from current price data combined with appropriate price indicators because they cannot be directly observed. The ideal way of producing volume estimates of macroeconomic aggregates is to work at a highly detailed level, deflating each component by a strictly appropriate price index (SNA 2008, paragraph 15.96). Therefore, the prerequisite to obtain items at constant prices is to construct sectoral-level PPIs by region.

The national PPIs by sector are from the work of Wu and Ito (2015). With the limitations of official regional data availability, two approaches are mainly adopted to construct PPIs for different sectors in each region. One is for agriculture and industrial sectors in which official PPIs are used. The other is for service sectors, which is the most difficult part because the
officials do not report any related PPI information. The data of relevant components of regional CPI and other price information are employed to construct PPIs for most service sectors. The approaches and data used to construct regional PPIs are summarized in Table 4.7, which are similar to the way used to construct national PPIs.

<table>
<thead>
<tr>
<th>Sector by CIP Code</th>
<th>Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture (1)</td>
<td>Aggregate PPI for all agricultural products, assumed to move with national total before 2004</td>
</tr>
<tr>
<td>Mining (2-5)</td>
<td>Sector-specific PPIs, not adjusted</td>
</tr>
<tr>
<td>Manufacturing (6-24)</td>
<td>Sector-specific PPIs, geometric average of sub-sectors for each standard sector</td>
</tr>
<tr>
<td>Utilities (25)</td>
<td>Aggregate, geometric average of sub-sectors</td>
</tr>
<tr>
<td>Construction (26)</td>
<td>Investment price index of construction and installation</td>
</tr>
<tr>
<td>Wholesale and retail (27)</td>
<td>Implicit value added deflator</td>
</tr>
<tr>
<td>Hotels and catering (28)</td>
<td>Regional CPI for 1991-1993; price index of “dining out” (a component of CPI) for 1993 onwards</td>
</tr>
<tr>
<td>Transportation and storage (29)</td>
<td>Transportation expense for 1991-2000; transportation component of CPI, excluding the price of equipment (vehicles) for 2000 onwards</td>
</tr>
<tr>
<td>Post and telecommunication (30)</td>
<td>Postage for 1991-2000; communication services for 2000 onwards</td>
</tr>
<tr>
<td>Financial services (31)</td>
<td>Geometric average of transportation and storage (29), post and telecommunication (30), real estate (32), and other services (37)</td>
</tr>
<tr>
<td>Real estate services (32)</td>
<td>Relation between PPI and national CPI is applied at regional level</td>
</tr>
<tr>
<td>Leasing, business services (33)</td>
<td>As financial services (31)</td>
</tr>
<tr>
<td>Public management (34)</td>
<td>Regional CPI; adjusted to nominal wage index of urban staff from 2002 onwards</td>
</tr>
<tr>
<td>Education (35)</td>
<td>Tuition and childcare charges before 2000; adjusted to nominal wage index of urban staff from 2002 onwards</td>
</tr>
<tr>
<td>Healthcare, social welfare (36)</td>
<td>Medical care service; adjusted to nominal wage index of urban staff from 2002 onwards</td>
</tr>
<tr>
<td>Other services (37)</td>
<td>Geometric average of cosmetic beauty fees, culture and entertainment expense, repair and other service fees before 2000; geometric average of culture and entertainment expense, tourism from 2001 onwards</td>
</tr>
</tbody>
</table>

Source: Constructed by author based on official PPIs and regional CPIs. See also Table A1 for the standard sector classification.

Generally, the data of official producer prices are mainly used to construct PPIs for non-service sectors. For industrial sectors, the official statistics of some regions do not report PPIs at detailed sectoral level in several years; instead, they report another two types of PPIs: one is grouped by production and living materials, and the other is grouped by department of industry; see Table 4.8 for detailed categories of these two standards.
In the process of constructing PPIs for industrial sectors by region, we encounter several difficulties. First, the officials of some regions report PPIs at detailed sectoral level only for a few recent years, for example starting from 2005, and they also report time series of PPIs based on two standards in Table 4.8. The priority of adopting these two standards is first type II (because it contains more detailed industrial sectors compared to type I) and then type I, which are used as corresponding aggregate PPIs for some relevant detailed industrial sectors by assuming that price changes of detailed industrial sectors move with those of corresponding aggregate PPIs. For example, the PPI of “Chemical Industry” in type II is used as aggregate PPI for three detailed industrial sectors, that is, “Manufacturing of Chemical Raw Materials and Chemical Products”, “Manufacturing of Medicines”, and “Manufacturing of Chemical Fibers”. In addition, the PPI of “Machine Manufacturing Industry” in type II is used as the aggregate PPI for six detailed industrial sectors, that is, “Manufacturing of General Machinery”, “Manufacturing of Special Equipment”, “Manufacturing of Transportation Equipment”, “Manufacturing of Electrical Machinery and Equipment”, “Manufacturing of Computers, Communication Equipment, and Other Electronic Equipment”, and “Manufacturing of Measuring Instruments and Meters”, and so on.

Second, the officials of some regions do not report PPIs at detailed sectoral level at all; they only report time series of PPIs based on above two standards. In this case, the principle to construct PPIs for detailed industrial sectors is similar to that in the first case. We simply use aggregate PPIs based on type II as PPIs of relevant detailed industrial sectors. For example, the PPI of “Machine Manufacturing Industry” is used as PPIs for six detailed industrial sectors mentioned above.

<table>
<thead>
<tr>
<th>Type I: Grouped by production and living materials</th>
<th>Type II: Grouped by department of industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Materials</td>
<td>Metallurgical Industry</td>
</tr>
<tr>
<td>Mining and Quarrying Industry</td>
<td>Power Industry</td>
</tr>
<tr>
<td>Raw Materials Industry</td>
<td>Coal Industry</td>
</tr>
<tr>
<td>Processing Industry</td>
<td>Petroleum Industry</td>
</tr>
<tr>
<td>Living Materials</td>
<td>Chemical Industry</td>
</tr>
<tr>
<td>Food</td>
<td>Machine Manufacturing Industry</td>
</tr>
<tr>
<td>Clothing</td>
<td>Building Materials Industry</td>
</tr>
<tr>
<td>Articles for Daily Use</td>
<td>Timber Industry</td>
</tr>
<tr>
<td>Durable Consumer Goods</td>
<td>Food Industry</td>
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<td></td>
<td>Textile Industry</td>
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<td></td>
<td>Tailoring Industry</td>
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<td></td>
<td>Leather Industry</td>
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<td></td>
<td>Paper-Making Industry</td>
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<tr>
<td></td>
<td>Cultural, Educational, and Art Supplies Industry</td>
</tr>
<tr>
<td></td>
<td>Others</td>
</tr>
</tbody>
</table>

Source: Author’s collection.
Third, the regional officials only report PPIs based on the classification of type I in Table 4.8. Similarly, we use aggregate PPIs based on type I as PPIs of relevant detailed industrial sectors. For example, the PPI of “Mining and Quarrying Industry” is used as PPIs of five detailed industrial sectors, that is, “Mining and Washing of Coal”, “Extraction of Petroleum and Natural Gas”, “Mining and Processing of Ferrous Metal Ores”, “Mining and Processing of Non-ferrous Metals”, and “Mining and Processing of Nonmetal Ores”. The PPI of “Food” is used as PPIs of four detailed industrial sectors, that is, “Processing of Food from Agricultural Products”, “Manufacturing of Food”, “Manufacturing of Wines, Beverage, and Refined Tea”, and “Manufacturing of Cigarettes and Tobacco”, and so on.

Fourth, some regions are missing PPIs data for the first few years of the 1990s, or for the last few years. In this case, we first assume that price changes of regional aggregate PPIs move with that of the national aggregate PPI, and then assume that the trend of detailed industrial sectors to regional aggregate PPIs reported in regional official statistics continues for the years without PPIs for detailed industrial sectors.

By overcoming difficulties in above four cases, we obtain PPIs for industrial sectors with the classification reported in regional official statistics. We then derive PPIs for our standard industrial sectors by taking the geometric average of PPIs of corresponding sub-sectors.

As can be seen in Table 4.7, in most cases, we use relevant components of regional CPI to construct PPIs for service sectors.\textsuperscript{32} Specifically, the price index of a component of regional CPI, dining out, is used as the proxy PPI for hotels and catering services (standard sector 28) from 1994. For transportation and storage (29), we use price of transportation expenses for 1991-2000 and transportation components of CPI from 2001 that include four ingredients, that is, fuels and parts, fees for vehicle use and maintenance, in-city traffic fare, and intercity traffic fare. We use the price index of postage for the period of 1991-2000 and communication services for the period of 2001-2014 for post and telecommunications (30). It is difficult to appropriately construct PPIs for both financial services (31) and leasing and business services (33). For these two sectors, we take a geometric average of price indices of transportation and storage (29), post and telecommunication (30), real estate services (32) and other services (37). For education (35), price changes of tuition and childcare charges are used before 2000, and from 2002, we change it to the nominal wage index of urban staff, which is also used for public management (34) and healthcare and social welfare (36) during this period. For healthcare and

\textsuperscript{32} The present work is preliminary and welcomes suggestions for improvement.
social welfare (36), the price index of medical care service is adopted. For the last service sector, other services (37), we take the geometric average of price changes of cosmetic beauty fees, culture and entertainment expenses, repairs, and other service fees before 2000, and of culture and entertainment expenses and tourism from 2001.

For those service sectors that cannot be related to concrete components of regional CPI, we directly use regional CPI as a proxy for their PPIs. Such sectors include hotel and catering services (28) for 1991-1993 and public management (34) for 1991-2001.

In addition, for some service sectors whose PPIs cannot be constructed by using components of regional CPI, i.e., construction (26), wholesale and retail (27), and real estate services (32), we rely on other information to construct their PPIs. For construction (26), we use the IPI of construction and installation. For wholesale and retail (27), the implicit value added deflator is adopted. For real estate services (32), Wu and Ito (2015) first calculate service margin of per square meter housing based on housing statistics reported in the chapter of “Real Estate” of the China Statistical Yearbooks; next, they construct service margin index that is used as the PPI of real estate services (32) starting from 1993. For the time period before 1993, they assume that the PPI follows the housing component of the national CPI. It is difficult, however, to repeat this procedure to construct PPI for real estate services at regional level. Therefore, we apply the relation between PPI of national real estate services and the national CPI to regions.

4.5 Double Deflation

Researchers have mainly focused on growth rates of volume measures of macroeconomics, although both volume and price measures are important in national accounts. In order to measure macroeconomic indicators, especially GDP, at constant prices, most current studies adopt single deflation, in which the volume measure of gross value added is estimated by deflating the current value of gross value added based on a price index. The price index of gross value of output is usually adopted in single deflation. Given that only one price index is used, the key assumption is that price changes of gross value of output and gross value of intermediate inputs are the same, which is not reasonable. At present, along with the increasing depth of industry specialization, the linkage between industries has become closer via input and output connection; that is, the output of an industry is often used as intermediate

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33 Before 2014, the chapter “Real Estate” was included in the chapter “Investment in Fixed Assets”.

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inputs in other industries. The production activity of an industry tends to use a variety of products from other industries as intermediate inputs. Simply assuming that price changes of gross output and intermediate inputs used are the same biases the measurement of an industry’s real value added. Furthermore, since gross output of an industry is the market value of goods and services produced in it, the output deflator is usually valued at basic prices.\(^{34}\) According to the definition of intermediate inputs, intermediate inputs of an industry are goods and services (including energy, raw materials, semi-finished goods, and services purchased from all sources) that are used in the production process to produce other goods or services rather than for final consumption (see website of Bureau of Economic Analysis\(^ {35}\)). The trade and transportation margins paid by the consuming sectors to obtain intermediate inputs are captured in prices of intermediate inputs, which should be reflected in intermediate deflators. Therefore, the intermediate deflator is usually measured at purchasers’ prices. It is inappropriate to replace intermediate deflators with the output deflator, which is often done in single deflation.

The double deflation method is theoretically sound to obtain items at constant prices (SNA, 2008; OECD Manual, 2001; Eurostat Manual, 2008) in which the volume measure of gross value added is obtained as difference between the volume measure of gross value of output, which is derived by deflating the current value of gross output with an appropriate output deflator, and the volume measure of gross value of intermediate inputs, which is derived by deflating the current value of intermediate inputs with appropriate intermediate deflators.

In this study, we adopt the standard double deflation approach to obtain real value added. It is preferred to conduct double deflation approach at a highly detailed industry level, deflating each component by an appropriate price index. Thus, we first construct time series of sectoral structure of intermediate inputs by interpolating and extrapolating RIOTs at benchmark years, and then estimate the values of transaction parts of intermediate inputs by employing the control totals of intermediate inputs constructed in Section 4.3. Further, with the sector-specific PPIs by region constructed in Section 4.4, we can conduct the double deflation approach for each region over the period 1992-2014.

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\(^{34}\) The Chinese official statistics only report various indicators valued at producers’ prices.

\(^{35}\) [https://www.bea.gov/help/faq/185](https://www.bea.gov/help/faq/185)
Chapter 5: Measuring Capital Input by Sector and Region

As an integral part of the standard productivity analysis, the solid measurement of capital input is essential, and it constitutes the actual input in the production process. A large developing country, in particular, the rapid economic growth of China during the past nearly four decades, has been widely considered to be investment-driven growth. In order to precisely characterize the development path of the Chinese economy, the prerequisite is to conduct a conceptually correct and empirically sound measure of capital input. Compared with SNA principles, however, the Chinese official statistics do not report data of capital stock, nor are the available official statistics qualified for constructing capital stock by following the standard approach.

In this chapter, we first describe problems about measuring capital stock in Chinese regions compared with the SNA principles. Next, with the available regional official data, we illustrate procedures to construct capital stock using the standard PIM. We further measure capital service,\(^\text{36}\) which is delivered from capital stock, and finally, summarize the estimates of capital input growth by industry, region, and for the Chinese economy as a whole. Since few data are available at regional level, especially data concerning asset types, depreciation rate, and IPI, the construction of capital data at regional level is in a large part based on the experience of constructing Chinese capital data at the national level by H. Wu (2015a).

5.1 Problems with Measuring Regional Capital Stock

The difficulty of constructing capital stock is that the Chinese regional official statistics do not publish data of capital stock based on the international standards, and the available official data on fixed assets suffer from improper treatments to aggregation and depreciation, inconsistencies in industry classification, and the lack of information on investment price indices (H. Wu, 2002). In this section, we first describe features of the official statistics about capital data and then note problems of constructing data of capital stock.

5.1.1 The Official Investment Series

The investment flow is the crucial component used in PIM to construct net capital stock. In official Chinese regional statistics, two indicators are related to investment: one is “total

\(^{36}\) Capital service and capital input are used interchangeably because both measure the actual input in production.
investment in fixed assets (TIFA)” (quanshehui guding zichan touzi, in Chinese) and the other is NIFA. Details concerning these two indicators are illustrated below.

The total investment in fixed assets refers to the volume of activities in construction and purchases of fixed assets and related fees, and it is expressed in monetary terms during the reference period. It is a comprehensive indicator that shows size, structure, and growth of the investment in fixed assets, and it provides a basis to observe progress of construction projects and evaluate results of investment. In addition, it can be classified by various criteria. One criterion adopted earlier in regional official statistics is by channels of management, which can be classified into capital construction, technical updates and transformation, real estate development, and others. The second is by type of construction. Construction projects in general can be classified into new construction, expansion, reconstruction and technical transformation, the pure construction of living facilities, moving, restoration, and pure purchasing. However, investment by type of construction is not applied to investment by real estate development units and investment by rural households. The third is by structure, which can be classified into construction and installation, purchase of equipment and instruments, and other expenses (2017 CSY, pages 336-337).

Many researchers directly use the indicator of “investment in fixed assets” as the investment series in PIM to construct net capital stock (e.g., Li et al., 1992; Ho and Jorgenson, 2001; Huang et al., 2002), which is conceptually incorrect. Based on above definition, this indicator refers to the volume of activities in construction and purchase of fixed assets in the current period. Given that a long period of construction is usually required to complete a project and finally to form the standard fixed assets in the view of the SNA principle, the investment in such a project may not form the standard fixed assets in the current period. Furthermore, part of investment is even wasted during the construction process and thus cannot form fixed assets. The measurement of investment series in PIM is overestimated if the “investment in fixed assets” reported in regional official statistics is used directly.

The other indicator related to investment flow reported in regional official statistics is NIFA. According to the official definition, it refers to the value of fixed assets that have been completed construction and purchase and have been delivered to production or owner units, including investments in projects that have been completed and put into operation in the current year and investments in equipment, tools, and appliances that meet the standard of fixed assets and fees that should be apportioned. This indicator demonstrates results of investment in fixed
assets in monetary terms, and it is an important indicator to reflect speed of construction and to calculate the efficiency of investment (2017 CSY, page 338).

According to above definition, NIFA refers to the newly increased value of fixed assets in the current year through investment in the current and previous periods, which is more compatible with the SNA standard of fixed assets compared to TIFA. Such investments are effective because they have finally formed fixed assets and are further used in production process, rather than being wasted during the construction process.

There are still, however, two adjustments to make before the indicator of NIFA is used as an investment in PIM: one is to remove the part of investment used to construct residential buildings that do not produce services in production process, and the other is to add back investment projects that are not covered by the official statistics because such projects do not meet the official standards. Since the 1990s, the cut-off point for projects covered by the official statistics of investment in fixed assets has undergone twice adjustments. Since 1997, the cut-off point has been raised from an investment of 50,000 yuan to 500,000 yuan, except for investment in real estate development, farm household investment, non-farm household investment, and private investment in housing construction in urban areas and industrial and mining areas. Further, since 2011, the cut-off size of projects for investment in fixed assets has been risen from a total planned investment above 500,000 yuan to 5,000,000 yuan (2017 CSY, page 293). Thus, investment in fixed assets that are not covered by official statistics mainly concerns investment projects that are below the official threshold for investment statistics.

5.1.2 The Official Capital Stock Series

There is no concept of capital stock in official Chinese regional statistics. Two series related to capital stock reported in regional official statistics for industrial sectors are OVFA and “net value of fixed assets (NVFA)” (guding zichan jingzhi, in Chinese). According to the official definition, OVFA refers to the total value, in monetary terms, that an enterprise spends on fixed assets through construction, purchase, installation, transformation, expansion, or technical upgrading. Generally, it covers costs of purchase, packing, transportation, and

37 Since 2006, statistics on investments in fixed assets of non-farm households have become project-based. The survey method is changed from a sample survey to the system of a reporting form with complete enumeration. The cut-off point has been raised to 500,000 yuan. Since 2006, statistics on private investment in housing construction in urban areas and industrial and mining areas have also become project-based. The cut-off point has also been raised to 500,000 yuan (2017 CSY, page 293).
installation, etc. NVFA is defined as OVFA minus the accumulated depreciation over years (2010 CSY, pages 570-571). 38

The approach adopted in official statistics to calculate OVFA is to add the value of the investment in fixed assets in the current year to the value of existing stock, which is usually valued at historical or acquisition prices. The current investment in fixed assets consists of investments used in buildings, equipment, and machinery. In addition, the NVFA is the residual of OVFA minus the accumulated value of depreciation. It is difficult to adopt the NVFA for two reasons. First, the NVFA cannot be deflated with a proper deflator because it mixes different types of assets purchased at different prices and in different periods. Second, it also includes the investment in residential buildings, which is difficult to be removed. Therefore, OVFA is adopted to construct investment flows for industrial sectors below.

5.1.3 The Official Deflator and Depreciation Rate

In order to obtain fixed assets at a constant price, it is important to find a proper deflator because all the official data on fixed assets are valued at acquisition prices or historical costs. Officials started to publish the price index of investment in fixed assets in 1993. This price index consists of three components: price indices of construction and installation, the purchase of equipment and instruments, and others. The price index of investment in fixed assets before 1990 is scarce. This is a possible reason why researchers use other price indexes as a proxy; for example, Huang et al. (2002) adopt official retail price index, and Chow (1993), Hu and Khan (1997), and Y. Wu (1999 and 2000) use an implicit GDP deflator. As noted by H. Wu (2000), however, the official statistics tend to underestimate price changes, and real investment is thus overestimated if the GDP deflator is adopted as the IPI.

Another obstacle to construct capital stock for Chinese regions is that officials seldom publish data regarding the depreciation rate. As it is widely known, depreciation rate is a crucial ingredient in PIM approach. If it is high, the net capital stock is low because a large part of the stock is gradually depreciated during the formation process, and vice versa. The published official depreciation rates seem quite low compared to those based on empirical evidence from other countries. For example, the comprehensive depreciation rate for SOE is 4.8% and 5.1% for state-owned industrial enterprises in 1990, which rose from 2.9% and 3.7% in 1952, respectively (1992 CSY, page 28). In Hulten and Wykoff (1981), for the U.S. economy in 1977,

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38 Accumulated depreciation refers to the accumulated figure of fixed assets depreciation in past years that are extracted by enterprises at the end of the reference period (2012 CSY, page 563).
the depreciation rate for equipment was 13.3% and 3.7% for structures. This could be true in the central planning period of China, when the service life of fixed assets was always overestimated. Moreover, instead of the geometric depreciation function, Chinese officials assume that depreciation follows the mode of a straight-line function.

5.1.4 The Official Type of Assets and Industry Classification

As mentioned above, the official statistics regarding investment data are divided into three components, i.e., construction and installation, purchase of equipment and instruments, and other based on the criterion of the structure. “Other” investment refers to expenses that arise during construction or purchase of fixed assets other than those expenses related to construction and installation and purchase of equipment and instruments. Other financial expenses that arise during operation are not included (2017 CSY, page 337).

It is difficult to leave “other” as a single type of assets because it has no proper price index and depreciation rate given it mixes many kinds of expenses. Put simply, in this study, the investment in other is redistributed into structures and equipment based on their ratios. Thus, asset types considered in this study are structure and equipment.

In addition, as noted in Section 4.2, the official industry classification has changed several times. The first step is to keep industry classification consistent over time. For industrial sectors, due to the official statistics focus on “above designated size” industrial sectors, we also need to estimate capital data for “below designated size” industrial sectors.39

5.2 Procedures of Constructing Regional Capital Stock

The net capital stock data are constructed by following the widely adopted PIM approach. In this approach, the net capital stock is the sum of past investments weighted by an age-efficiency profile. With the aging of an asset, its efficiency also gradually declines compared with its newer counterparts. The age-efficiency pattern describes changes in an asset’s productive efficiency as the asset ages. Typically, the age-efficiency profile is expressed relative to the productive efficiency of a new asset. By applying the age-efficiency profile to quantities of past investments, all vintages are expressed in new-equivalent efficiency units.

39 Following H. Wu (2015a), net capital stock data of “below designated size” industrial sectors are constructed by using the capital-labor ratio of labor-intensive industries and their employment data are constructed in Chapter 6. The labor-intensive industries are defined by the mean capital-labor ratio with an arbitrary measure of the standard deviation from the mean. The total capital stock of industrial sectors is derived by summing up capital stock of “above- and below-designated size” industrial sectors.
The computation of productive capital stock via the addition of efficiency-adjusted investments of past periods implies the complete substitutability of past vintages once adjusted for efficiency differences (OECD Manual, 2009).

The PIM method can be expressed by the following equation:

\[ A_t = \varphi_0 I_t + \varphi_1 I_{t-1} + \cdots + \varphi_{t-T} I_T, \quad (0 \leq \varphi \leq 1) \]  

(5.1)

where \( A_t \) stands for net capital stock at time \( t \), \( \varphi_0 = 1 \) and \( v = t - T \) is the date of the oldest surviving vintage, \( T \) is the date of the oldest vintage, and \( t \) denotes the current time. Since one unit of vintage \( v \) capital is treated as the equivalent of only \( \varphi_{t-v} \) units of new capital, the stock \( A_t \) is naturally interpreted as the number of units of new investment needed to equal the productive capacity of past investments \((I_t, I_{t-1}, I_{t-2}, \ldots, I_{t-T})\). In other words, the above equation defines capital stock in efficiency units (Hulten, 1990).

As can be seen in above equation, the efficiency sequence \((\varphi_0, \varphi_1, \ldots, \varphi_T)\) is essential for conducting PIM. It is difficult to directly observe this sequence, so it is often estimated indirectly by assuming that it follows a pattern that depends on an observable useful life \( T \) (Hulten, 1990).

Three typical types of efficiency patterns that have been widely explored are the one-hoss shay pattern, the straight-line pattern, and the geometric pattern. In the one-hoss shay form, the efficiency of an asset remains full during its service life and breaks down completely when its service life is over, which can be expressed as the following equation:

\[ \varphi_0 = \varphi_1 = \cdots = \varphi_{T-1} = 1, \; \varphi_{T+\tau} = 0, \tau = 0,1,2,\ldots \]  

(5.2)

According to above equation, we can see that the estimation of useful life \( T \) of an asset is crucial to characterize its efficiency sequence. Therefore, properly measuring the useful life \( T \) is the key point for estimating the efficiency pattern based on the one-hoss shay pattern.

The straight-line pattern can be expressed as follows:

\[ \varphi_0 = 1, \varphi_1 = 1 - \frac{1}{T}, \varphi_2 = 1 - \frac{2}{T}, \ldots \]  

(5.3)

\[ \varphi_{T-1} = 1 - \frac{T-1}{T}, \varphi_{T+\tau} = 0, \tau = 0,1,2,\ldots \]

Thus, we can obtain:

\[ \varphi_{T-1} - \varphi_\tau = \frac{1}{T}, \tau = 1, 2, \ldots, T - 1 \]  

(5.4)
In the straight-line form, efficiency decays in equal increments every year, following the convention of depreciation approach in accounting that assets should be amortized in equal increments over a useful life. Like the one-hoss shay form, the useful life $T$ also completely determines the efficiency pattern in the straight-line form (Hulten, 1990).

The geometric form is the third widely used pattern, and it can be expressed as follows:

$$\frac{\varphi_{t-1} - \varphi_t}{\varphi_{t-1}} = \delta$$

which implies:

$$\varphi_0 = 1, \varphi_1 = 1 - \delta, \varphi_2 = (1 - \delta)^2, \ldots, \varphi_t = (1 - \delta)^T$$

As can be seen from Equation (5.5), in geometric form, the efficiency decays at a constant rate $\delta$. However, the geometric efficiency pattern has two shortcomings. First, the efficiency of an asset decays substantially in the early years during its service life (Harper, 1982). For example, with a 10% rate of depreciation, more than 50% of an asset’s productivity is lost over seven years. This could be true for certain assets, such as computers. With the rapid development of information and communication technology, the upgrading and updating of electronic products has improved remarkably. Captured by Moore’s Law, the successive generations of semiconductors are faster and better, and the time period required to create a new generation of electronic products is less than two years. As a result, the efficiency of old version electronic products decreases dramatically compared with their newer peers. This rapid decrease in efficiency, however, may not be suitable for other assets, such as structure. Compared with electronic products, the speed of updating structure is slow; even after 10 years, the same structure may still serve the same service function as its newer counterparts. The second deficiency regarding the geometric efficiency pattern is that, although the efficiency of assets becomes low along with the aging of assets, they are never retired, which seems implausible in reality.

Despite above two deficiencies concerning the geometric efficiency pattern, it is still widely adopted in theoretical expositions of capital theory because of its simplicity. This study also employs the geometric efficiency pattern to construct age-efficiency profiles of assets. With the geometric form, the perpetual inventory method, expressed as Equation (5.1), can be rewritten as Equation (5.7). In the following section, we illustrate how to construct each variable used in PIM.

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40 In 1965, Gordo Moore observed that the number of transistors in a dense integrated circuit doubles within approximately 18-24 months, which was later known as Moore’s Law.
\[ A_t = I_t + (1 - \delta)A_{t-1} \]  

\[ (5.7) \]

5.2.1 Annual Investment Flows of Industrial Sectors

Following H. Wu (2015a), the investment flows of “above designated size” industrial sectors in region \( j \) are constructed by the following:

\[ I_{i,j,t} = \frac{(1 - \eta_{i,j,t}) \lambda_{i,j,t}(OVFA_{i,j,t} - OVFA_{i,j,t-1} + S_{i,j,t})}{(1 - \lambda_{i,j,t})} \]  

\[ (5.8) \]

where \( \eta_{i,j,t} \) is the proportion of non-productive assets of sector \( i \) in region \( j \), mainly residential structures; \( \lambda_{i,j,t} \) is the proportion of productive assets not covered by the official industry investment statistics, mainly investment projects that are below the official threshold for investment statistics; and \( S_{i,j,t} \) is scrapings. OVFA is calculated at the end of each accounting period, thus excluding any asset that had already retired before that time point. Therefore, the value of retired assets \( S_{i,j,t} \) should be added back to avoid underestimating annual investment flows. Due to the scant information about scrapings, H. Wu assumes that assets of the same vintage follow a normally distributed retirement function to leave production services, and the retirement function is centered at the end of the standard service lives of assets. At regional level, the data of OVFA are from the CIESY.\(^{41}\) Since there are no data about \( \eta_{i,j,t} \), \( \lambda_{i,j,t} \), and \( S_{i,j,t} \) at regional level, these three ratios at the national level are applied for regions.

5.2.2 Types of Assets of Industrial Sectors

The official statistics publish OVFA data for industrial sectors at historical prices that are in total value without detailed decompositions. We cannot simply remove residential structures from it and also conduct the standard deflation and depreciation procedures without decomposing the total OVFA value. Based on the statistical bulletins available in the NBS Archives, which include industry-level investment statistics, H. Wu decomposes fixed assets of industrial sectors into four components: equipment, residential structures, non-residential structures, and others; he then removes “residential structures” and redistributes “others” into “equipment” and “non-residential structures” (hereafter, structure) based on their shares.

Since there are no data for decompositions of OVFA by industrial sectors at regional level, the share of equipment and structure at the national level has been used for regions. A proper reason to explain why this operation is reasonable is that the share of equipment and

\(^{41}\) The name of this yearbook was changed to the China Industry Statistical Yearbook in 2013.
structure in a certain sector reflects the technology level corresponding to characteristics of this sector and does not change no matter where the sector is located.

5.2.3 Non-industrial Sectors

For non-industrial sectors (agriculture, construction, and all service sectors), official statistics provide no data regarding OVFA. Thus, our procedure for industrial sectors cannot be applied to these sectors. Instead of OVFA, the official statistics report NIFA for non-industrial sectors. As explained above, this is an appropriate indicator to be a proxy of investment flows because it refers to the value of investment projects completed and put into production in the current year. The data regarding NIFA for non-industrial sectors are from the Statistical Yearbook of The Chinese Investment in Fixed Assets. In this yearbook, the total NIFA of each region consists of two layers: urban and rural areas, and the rural area further consists of two layers: farmer households and non-farmer households. In a word, at sectoral level, officials report NIFA at three layers: urban areas, rural farmer households, and rural non-farmer households. By summing up NIFA of these three layers, we can obtain the total NIFA of each region by sector.

Regarding asset types, we use data from the China Statistical Yearbook of The Tertiary Industry and divide investment flows into equipment and structure for all service sectors. For agriculture and construction, the share of equipment and structure is set at 5:5 since there are no systematic data about asset decompositions of these two sectors by region.42

5.2.4 The Initial Capital Stock for Regions

In H. Wu (2015a), the construction of initial capital stock follows the method of King and Levine (1994). That is, in the steady state, growth rate of capital stock and real output is the same, i.e.,

\[ g_t^* = \frac{dA_t}{A_t} = \frac{dY_t}{Y_t} \]  

(5.9)

where \( g_t^* \) is the growth rate at the steady state, and \( A_t \) and \( Y_t \) are capital stock and real GDP at time \( t \), respectively. Following the PIM,43 \( dA_t = I_t - \delta A_t \), then \( \frac{dA_t}{A_t} = \frac{I_t}{A_t} - \delta \), where \( I_t \) and \( \delta \) are gross investment and depreciation rate of capital, respectively. Thus, in the steady state,

---

42 The officials report data about asset decompositions for agriculture and construction in regional statistical yearbooks in terms of TIFA rather than NIFA. The share of equipment and structure in TIFA could be a reference to divide NIFA in future research.

43 See Equation (5.7).
Similarly, the initial capital stock can be calculated as $A_0 = \frac{I_0}{g_0 + \delta}$. At the national level, the national gross fixed capital formation in 1952 can be used for $I_0$; the official and the alternative measures of the average GDP growth for the period 1952-1956 are used for $g_0$; and $\delta$ is assumed to be 2% based on information from the 1951 national asset census (H. Wu, 2015a). For regions, the time period of newly constructed regional capital data starts in 1980, we first take two values of 1980 by sectors from H. Wu’s work to construct the initial capital stock for regions. One is the 1980 value of equipment by sector and the other is the 1980 value of structure by sector, both of which are at the national level. Next, based on the regional distribution from the newly constructed regional capital data, we divide the two national sectoral totals into 31 regions. Thus, we have constructed the initial capital stocks for both equipment and structure by region and by sector.

5.2.5 Sector-specific Depreciation Rates

In H. Wu (2015a), the sector-specific depreciation rates at the national level are constructed by following the methodology in Hulten and Wykoff (1981). That is, $\delta = \frac{R}{T}$, where $R$ and $T$ are declining-balance rates and service lives for equipment and structure of each sector, respectively. For industrial sectors, in order to estimate declining-balance rates ($R$), H. Wu adopts the estimates of declining-balance rates for major industrial equipment and structures from the Bureau of Economic Analysis, which are mainly based on the empirical work of Hulten and Wykoff (1981). In addition, for asset lives of different industries, H. Wu uses various statistical materials from the Ministry of Finance and the State Council and divides the full-time period in 1993, when the Chinese economy began to respond to Xiaoping Deng’s push for deeper and bolder economic reforms. For non-industrial sectors, there are no data for service lives of capital assets, H. Wu assumes that capital stock of each non-industrial sector depreciates at a constant rate that is the same as the geometric average of depreciation rates of industrial sectors over the periods 1980-1992 and 1993-2010, respectively. At regional level, depreciation rates for all sectors at the national level from H. Wu’s work are used.

5.2.6 Sector-specific IPIs

To construct sector-specific IPIs, H. Wu mainly uses four sources of investment price statistics, either directly or indirectly. The first is the implicit price deflator for gross fixed capital formation, which can be derived from the national accounts. The second source is investment prices for equipment and structure at the aggregate level in the official price statistics starting in the 1990s. The third is the six-digit level industry-specific asset price
indices for SOEs based on an asset survey conducted by the Ministry of Finance. The last source is the PPIs of investment goods, which are available from the official price statistics.

For industrial sectors, H. Wu relies on data from the Ministry of Finance to construct sector-specific IPIs for equipment, which is then adjusted by aggregate IPI for equipment. For sector-specific IPIs of structure, he uses the national aggregate price index of investment in structures for the period before 1990, and for the period 1990 onwards, the official IPI of “construction and installation” is adopted.

Officials seldom publish price indices for non-industrial sectors, especially for service sectors; thus, H. Wu assumes that investment price changes for equipment in these sectors are the same as the geometric average of IPIs of industrial sectors. Further, the IPI for structures in non-industrial sectors is the same as that of industrial sectors.

In order to truly capture actual price change of each region, the data of investment price indices mainly come from the chapter of “price index” in regional statistical yearbooks. The steps we adopted to construct IPIs for both equipment and structure at regional level are illustrated as follows.

For the IPI of equipment, we first collect data of aggregate IPI of the “purchase of equipment and instruments” from the chapter of “price index” in regional statistical yearbooks for the period from 1990, and for the period before 1990, we assume that price changes of regional aggregate IPI follow that of national aggregate IPI. Second, for industrial sector-specific IPIs of equipment, we apply the ratio of IPI of every industrial sector to the aggregate IPI at the national level to regions. Third, the IPI of equipment of non-industrial sectors is the same as the geometric average of that of industrial sectors.

For the IPI of structure, given structure cannot be traded across regions, instead of the national aggregate price level, the regional price level significantly influences its price change compared with equipment. In addition, even for different sectors, the same structure serves the same function, which means that the same structure provides the same services for different sectors. Thus, there is only a time series of price index for structure, which implies that the IPI is the same for all sectors. We use data of regional IPI of “construction and installation”, which is also from regional statistical yearbooks for the period starting in 1990; for the period before 1990, we assume that price changes of regional IPI follow that of the national aggregate IPI of structure.
5.3 Measuring Capital Services

Capital stock is seen as the carrier of capital services that constitute the actual input in production process. For the purposes of productivity and production analysis, then, capital services constitute the appropriate measure of capital input. However, measuring price or volume of capital services is difficult because producers usually own capital goods. When the capital good “delivers” services to its owner, no market transaction is recorded. The measurement of these implicit transactions – whose quantities are the services drawn from capital stock during a period and whose prices are the user costs or rental prices of capital – is one of the challenges of capital measurement for productivity analysis (OECD Manual, 2009).

If there are rental markets, observed rentals could provide a first approximation of the user costs of capital for owner-users of the same assets. However, rental markets are far from complete or representative. There is also another reason why market rentals may differ from user costs of capital: for a lessor, the rental does not constitute the net benefit from letting a capital good during one period. The lessor has to cover other costs, such as labor and overhead, associated with the leasing service. These costs have to be reflected in the rental, which therefore constitutes a measure of turnover but not of operating surplus, or benefit, to the lessor. Consequently, even if there were pervasive rental markets, observed rentals would constitute only a first approximation of the user costs for the owners of assets (OECD Manual, 2009).

In order to precisely estimate the user cost of capital services, many components must be taken into account. Following Diewert (1974), the user cost of using an asset should consider three main elements: (1) the cost of financing or the opportunity cost of the financial capital tied up in the purchase of an asset; (2) depreciation, i.e., the value loss due to aging; and (3) revaluation, i.e., the expected price change of the class of assets under consideration. Thus, the user cost of capital can be approximated as:

$$p_{t,s}^K \approx [R + \delta_{t,s} - \pi_{t,s}]p_{t,s}^I$$

(5.10)

where $s$ denotes asset age, and $P_{t,s}^K$ and $P_{t,s}^I$ are the user cost and investment price of an asset with age $s$ at time $t$, respectively. $R$ is the nominal rate of return, $\delta_{t,s} = -\left[\frac{p_{t+1,s}^I}{p_{t,s}^I} - 1\right]$ is the rate of decline in asset price with age $s$, and $\pi_{t,s} = \left[\frac{p_{t+1,s+1}^I}{p_{t,s+1}^I} - 1\right]$ is the inflation rate of asset price between year $t$ and $t + 1$. 


The key point to measure the user cost of capital in above equation is to first determine the nominal rate of return \((R)\), which is calculated as follows:

\[
\sum_k \left[ R_{i,j} + \delta_k - \pi_{k,i,j} \right] p_{k,i,j}^l A_{k,i,j} = p_{i,j}^K R_{i,j} = p_{i,j}^V V_{i,j} - p_{i,j}^L L_{i,j}
\]  

(5.11)

where \(k\), \(i\), and \(j\) denote capital asset type, sector, and region, respectively. Following Equation (5.10), the component \([R_{i,j} + \delta_k - \pi_{k,i,j}] p_{k,i,j}^l\) represents the service price of capital asset \(k\) of sector \(i\) in region \(j\), i.e., \(P_{k,i,j}^K\).

From above equation, we find that the sum of capital services over all asset types of sector \(i\) in region \(j\) is equal to the total capital compensation \((P_{i,j}^K K_{i,j})\) of sector \(i\) in region \(j\), which is the residual of value added \((P_{i,j}^V V_{i,j})\) minus labor compensation \((P_{i,j}^L L_{i,j})\). With the data of VA and LC constructed in Section 4.3, we can determine the only unknown variable, i.e., the nominal rate of return \((R)\), in Equation (5.11), and further, the user costs for both equipment and structure by following Equation (5.10).

Thus far, capital measures have been discussed at the level of individual asset type, and the question arises as to how to aggregate them with a view to obtain an overall measure of capital services. In aggregating, two choices must be made. The first relates to the nature of aggregation weights. More specifically, such weights can be the share of individual assets in total capital income (in which case, the weights reflect user costs), or the weights could be the share of individual assets in the constant or current value of capital stock (in which case, the weights reflect constant or current market prices). The second choice relates to the specific index number formula that is used for aggregation. Production theory is quite clear on the appropriate aggregation procedure to obtain total capital services: it should be based on user cost weights and conducted with a superlative index number. Employing user cost terms for aggregation amounts to give greater weights to assets that depreciate quickly in comparison to weights that would result from a direct aggregation or simple addition of asset-specific stocks. The rationale for placing more weight on rapidly depreciating assets is that investors must collect more rents on a dollar’s worth of short-lived assets to compensate for their higher depreciation costs (Dean and Harper, 2001). The rationale for a superlative index number such as the Törnqvist index derives from its property as an approximation of the general functional forms of the production function (OECD Manual, 2001, paragraphs 115 and 116).

Since capital stock is taken as the carrier of capital services, the amount of capital service is assumed to be proportional to its stock (Jorgenson et al., 2005), which can be expressed as:
\[ K_{k,i,j,t} = Q^K \cdot \frac{(A_{k,i,j,t} + A_{k,i,j,t-1})}{2} = Q^K \cdot Z_{k,i,j,t} \quad (5.12) \]

where \( K_{k,i,j,t} \) is the capital service of asset type \( k \) of sector \( i \) in region \( j \), \( Z_{k,i,j,t} \) is the two-period average of capital stock, and \( Q^K \) is the proportionality factor or the “quality of capital of type \( k \)”, which is time-invariant.

The Tornqvist quantity index of total capital services of sector \( i \) in region \( j \) can be defined as:

\[ \Delta \ln K_{i,j} = \sum_k \bar{v}_{k,i,j} \Delta \ln K_{k,i,j} \quad (5.13) \]

where \( \bar{v}_{k,i,j} = \frac{p^k_{k,i,j}Z_{k,i,j}}{\sum_k p^k_{k,i,j}Z_{k,i,j}} \) and \( \bar{v}_{k,i,j,t} = \frac{v_{k,i,j,t} + v_{k,i,j,t-1}}{2} \).

This shows that growth rate of capital services of sector \( i \) in region \( j \) is the weighted sum of growth rates of capital services of each capital asset type by using the share of capital service of each asset type in the total capital services as weights.

By combining Equations (5.12) and (5.13), we can obtain:

\[ \Delta \ln K_{i,j} = \sum_k \bar{v}_{k,i,j} \Delta \ln (Q^K \cdot Z_{k,i,j}) = \sum_k \bar{v}_{k,i,j} \Delta \ln Z_{k,i,j} \quad (5.14) \]

Given that \( Q^K \) is time-invariant, it can be deleted from above equation. Therefore, the growth rate of total capital service of sector \( i \) in region \( j \) can be calculated as a weighted sum of growth rates of the two-period average capital stocks of all capital asset types with the share of capital service in total capital service as weights for each asset type.

The growth rate of capital service of region \( j \) can be defined as:

\[ \Delta \ln K_j = \sum_i \sum_k \frac{p^k_{k,i,j}Z_{k,i,j}}{\sum_i \sum_k p^k_{k,i,j}Z_{k,i,j}} \Delta \ln Z_{k,i,j} \quad (5.15) \]

where \( K_j \) represents capital service of region \( j \).

The growth rate of capital service of the aggregate economy can be defined as:

\[ \Delta \ln K = \sum_j \sum_i \sum_k \frac{p^k_{k,i,j}Z_{k,i,j}}{\sum_j \sum_i \sum_k p^k_{k,i,j}Z_{k,i,j}} \Delta \ln Z_{k,i,j} \quad (5.16) \]

where \( K \) represents aggregate capital service.
Chapter 6: Measuring Labor Input by Sector and Region

Since economic activity is essentially human activity, it is important to measure the role of the people who participate in such activities. From the view of production, it is first necessary to distinguish difference between labor and population because not all the individuals included in the population are engaged in production. For example, some are too young, some too old, and some may simply choose not to work. According to the 2008 SNA (paragraph 19.17), labor employment consists of those who are actively prepared to make their labor available during any particular reference period to produce goods and services that are included within the production boundary of the SNA. Like capital measurement, the prerequisite to precisely characterize the role of labor in the production process is to take into account the heterogeneity of labor, which is crucial to measure the actual labor input.44

Although labor employment is an important indicator to measure labor input, and it is often adopted in most current studies, it is recommended that hours actually worked are used as the statistical variable to measure labor input, as opposed to simple headcounts of employed persons (OECD Manual, 2001). Due to various problems in the Chinese regional official labor statistics, at the regional level, a proper measure of labor input, especially in terms of hours worked, remains as a major gap. In this chapter, we first describe features of the regional official labor statistics and then note the related problems. Next, with the available regional official data, the main procedures to construct labor data, including employment, hours, and compensation, for regions are illustrated. Furthermore, we measure labor service, which is delivered from hours worked, and finally, summarize estimates of labor input growth by industry, region, and for the Chinese economy as a whole. As with capital measurement at regional level, since few data are available for regions, the construction of labor data at this level is in a large part based on the experience of constructing Chinese labor data at the national level by Wu et al. (2015).

6.1 Features of Regional Official Labor Statistics

Like the regional official capital statistics, the Chinese regional official labor statistics also suffer from problems in concept, coverage, and industry classification. In this section, we

44 Like capital input, labor service and labor input are used interchangeably because both measure the actual input in production.
first describe features of the official statistics about labor part and then highlight problems related to construct labor data.

6.1.1 Quantity of Labor Employment

Concerning the quantity of labor employment, regional official statistics report three indicators, that is, “employed persons” (jiuye renyuan in Chinese), “staff and workers” (zhigong in Chinese), and “employed staff and workers” (zaigang zhigong in Chinese).

According to the official explanations, the term “employed persons” refers to those persons who are engaged in social working and receive remuneration or earn business income, including total staff and workers, re-employed retirees, employers of private enterprises, self-employed workers, employees in private enterprises and the individual economy, employees in township enterprises, employed persons in the rural areas, and other employed persons (including teachers in schools run by the local people, people engaged in religious profession, and servicemen, etc.). This indicator reflects the actual utilization of total labor force during a certain period of time. “Staff and workers” refer to persons who work in and receive payment from units of state ownership, collective ownership, joint ownership, shareholding ownership, foreign ownership, and ownership by entrepreneurs from Hong Kong, Macao, and Taiwan, as well as other types of ownership and their affiliated units. They do not include: (1) persons employed in township enterprises, (2) persons employed in private enterprises, (3) urban self-employed persons, (4) retirees, (5) re-employed retirees, (6) teachers in schools run by the local people, (7) foreigners and persons from Hong Kong, Macao, and Taiwan who work in urban units, and (8) other persons not included by relevant regulations. “Employed staff and workers” refer to persons who work in and receive wages from their working units, as well as persons who have jobs but are temporarily absent from work for reasons of study or on sick, injury, or maternal leave and still receive wages from their working units (2004 CSY, pages 183-184).

Based on above explanations, we find that the scope of “employed persons” covers “staff and workers”, which further covers “employed staff and workers”. Thus, we use “employed persons” to construct the quantity of labor employment later.

6.1.2 Different Sources of Official Statistics

The data concerning employed persons in regions mainly come from two Chinese statistical yearbooks: the CIESY\textsuperscript{45} and the China Labor Statistical Yearbook (CLSY). The

\textsuperscript{45} See footnote 41.
former is published by the Department of Industrial and Transportation Statistics,\textsuperscript{46} and the latter is published by the Department of Population and Employment Statistics. There are some differences between these two yearbooks. First, the CIESY focuses on industrial sectors only, whereas the CLSY covers all sectors of each region and includes non-industrial sectors. The second difference is data coverage. The CIESY covers “above designated size” industrial sectors throughout each region, whereas the CLSY mainly concentrates on sectors in urban areas. Therefore, for industrial sectors, the statistical scope of the CIESY is larger than that of the CLSY. Third, as stated in Section 4.2, the industry classification has been amended in 1994, 2002, and 2011. As a result, the industry classification for industrial sectors in both CIESY and CLSY has been changed corresponding to relevant years. For non-industrial sectors in the CLSY, the industry classification has also been changed in relation to 1994, 2002, and 2011. In this study, since data from the CIESY are consistent with capital measurement for industrial sectors, we use data from the CIESY to construct the quantity of labor employment for industrial sectors and data from the CLSY to construct the quantity of labor employment for non-industrial sectors.

6.1.3 Official Statistics about Wage

In order to measure labor input, in addition to the quantity of labor employment, we also need wage data. For the Chinese national economy, we can obtain wage data from various issues of CSY, namely, the average wage of staff and workers by sectors without more details about cross-classified attributes (see the following text). The regional wage data by sectors are from CLSY. As mentioned above, the data coverage of CLSY mainly focuses on sectors located in urban areas, there are no wage data concerning labor force worked in rural areas.

6.2 Problems in Regional Official Labor Statistics

With the rapid development of the Chinese economy, many policies have been amended and implemented to meet the needs of economic growth and industry structure transformation while maintaining historical consistency. The Chinese regional official labor statistics, however, concerning labor employment and compensation cannot catch up with such changes. Many challenges researchers face in conducting the measurement of labor input with the regional official labor statistics are the followings.

\textsuperscript{46} The name of this department was changed to the “Department of Industrial Statistics” in 2008.
First, as stated earlier, the Chinese standard industrial classification was first formulated in 1984, and it was further amended in 1994, 2002, and 2011. Such changes reflect that the industry classification has shifted from a system that is conducive to administrative planning and control over sectors, especially some strategic sectors, to a new system that is more in accordance with the intrinsic characteristics of sectors. However, the official statistics have not adjusted historical statistics for both labor employment and compensation following these changes. As a result, in order to keep industry classification and data consistent over a long period, researchers must reconcile the historical data with different versions of industry classifications based on their own research purposes and methodologies.

Second, for the national total, some structural breaks have not been covered by the official labor statistics. As Maddison and Wu (2008) have argued, the 1990 break cannot be ignored. As reported in the official statistics, the total number of employment from 1989 to 1990 jumped from 553.3 to 647.5 million, which means that the total employment increases 94.2 million in just one year. There are no explanations or adjustments from the official statistical authorities to account for such a major break. Researchers have to make some adjustments based on their own judgments or simply ignore it.

Third, the regional official labor statistics do not report matching hours worked data that correspond to employment data. From the perspective of production analysis, and ignoring quality differences for the moment, labor input is most appropriately measured as the total number of hours worked. Simple headcounts of employed persons hide changes in average hours worked caused by the evolution of part-time work or the effect of variations in overtime, absence from work, or shifts in normal hours. Therefore, hours worked is the best indicator to measure the quantity of labor input in the production process (OECD Manual, 2001, page 39). Due to data limitations of hours worked, however, many studies adopt the indicator of employed persons to measure labor input in the Chinese economy (e.g., Chen et al., 1988; Hu and Khan, 1997; Perkins and Rawski, 2008).

Another important ingredient to measure labor input for regions is the data regarding compensation that corresponds to the data of employed persons. Conceptually, labor income should reflect the compensation paid to labor from a producer’s point of view, i.e., including supplements to wages and salaries such as employers’ contributions to social security payments (OECD Manual, 2001, page 39). The non-wage portion of labor compensation, however, in particular social contributions payable by employers, is difficult to adequately be included in labor compensation. The only available time series data from Chinese regional official statistics
are annual wage bills and average wage per employee by sector. Other income paid in kind to laborers is difficult to be estimated for two main reasons. First, the limitation of the official statistics that report the formal wage only makes it difficult to estimate such kind of income. Even if it could be imputed based on researchers’ speculations, it might differ significantly from the actual situation. Second, the remuneration in different sectors varies remarkably due to the different development of different sectors. As a result, income paid in kind to laborers also varies across sectors. It is difficult to master all the information of each sector. For example, in the central planning era, industrial sectors, especially large SOEs, undertook many social responsibilities and provided various internal services, such as education, health care, child care, and so on, to their employees. In addition, employees of the state sectors also enjoyed heavily subsidized housing and various welfare payments in kind. There is no easy way to estimate the numbers, costs, and outputs of these payments and thus to allocate them to proper service industries (Wu et al., 2015).

Finally, the total contribution of a laborer to the production process consists of two aspects: one is his/her “raw” labor (or physical presence) and the other is the service from his/her human capital. Thus, it is also important to be aware of the heterogeneity of labor because, for one hour worked by a laborer, the amount of labor input is not necessarily the same for two different laborers. There may be differences in skills, education, health, and professional experience that lead to large differences in the contribution of different types of labor. A differentiation of labor input by the type of skill is particularly desirable if one wants to capture the effects of a changing quality of labor on the growth of output and productivity (OECD Manual, 2001, page 40). Therefore, the quality of labor is an important indicator to measure labor input, and it is usually calculated as the ratio of the user cost-weighted index of hours worked cross-classified by demographic, educational, and industry attributes to the un-weighted quantity index (Dension, 1961; Gollop and Jorgenson, 1980 and 1983). The prerequisite for this requires matching the data of employment with that of compensation. However, the regional official labor statistics seldom report data at the required level of detail and mainly do so at sectoral level only. Researchers widely use census and survey data, which do not provide cross-classified data for all demographic, educational, and industry dimensions. Another deficiency of census and survey data is that they seldom report the compensation data that match the quantity data of employed persons. Moreover, census data are not always compatible with annual regional official labor statistics, which becomes a major challenge for researchers to construct time series of data with the consistent statistical criteria.
6.3 Procedures of Constructing Regional Labor Data

In this section, we introduce how to construct labor data, including employment, hours, and compensation, for regions with the available official regional data. Due to the limitations of labor data at regional level, especially data on hours worked and compensation, the construction of regional labor data heavily relies on the corresponding national data. This section is divided into four parts: Section 6.3.1 introduces the cross-classification of labor input and how to construct control totals of employment for 37 standard sectors. Section 6.3.2 explains the methodology and steps used to construct full-dimensional employment matrices. Section 6.3.3 illustrates how to construct hours worked matrices for regions, and the corresponding compensation data are constructed in Section 6.3.4.

6.3.1 Control Totals of Employment for Standard Sectors

We first focus on constructing control totals of employment for 37 standard sectors. In order to precisely reflect the heterogeneity of different types of labor and match them with the data work at the national level, as listed in Table 6.1, at regional level, we also aim to construct labor employment, hours worked, and compensation matrices cross-classified by four primary dimensions, that is, gender/sex \( (g = 2) \), age \( (a = 7 \text{ groups}) \), education level \( (e = 5 \text{ levels}) \), and sector \( (s = 37) \); these capture the movement of labor quality that is significantly affected by skills and occupations of labor. Therefore, each full-dimensional matrix contains four cross-classified dimensions and, in total, 2,590 cells for each time point over the full period.

Table 6.1 Classification of Human Capital Attributes

<table>
<thead>
<tr>
<th>Gender: ( (g) )</th>
<th>Educational Attainment: ( (e) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Male</td>
<td>1. Illiteracy or semi-illiteracy</td>
</tr>
<tr>
<td>2. Female</td>
<td>2. Primary school</td>
</tr>
<tr>
<td>Age Group: ( (a) )</td>
<td></td>
</tr>
<tr>
<td>1. 15-19</td>
<td>3. Junior high school</td>
</tr>
<tr>
<td>2. 20-24</td>
<td>4. Senior high school</td>
</tr>
<tr>
<td>3. 25-29</td>
<td>5. Tertiary education</td>
</tr>
<tr>
<td>Sector: ( (s) )*</td>
<td></td>
</tr>
<tr>
<td>4. 30-39</td>
<td>1. Agriculture</td>
</tr>
<tr>
<td>5. 40-49</td>
<td>2. Mining and Washing of Coal</td>
</tr>
<tr>
<td>6. 50-54</td>
<td>......</td>
</tr>
<tr>
<td>7. &gt;54</td>
<td>37. Other services</td>
</tr>
</tbody>
</table>

Source: Table 1 in Wu et al. (2015). *See detailed sector classification in Table A1 in Appendix.

Control Totals

We take employment data from regional statistical yearbooks as control totals of each region. From the regional statistical yearbooks, we can obtain the employment data for three broad industries, that is, primary, secondary, and tertiary industries. We take the primary industry as our first standard sector, i.e., agriculture (code 1 in our standard 37 sectors).
Regarding the employment data of construction, which is included in the secondary industry, we use data from regional population census. During the time period of 1990-2014, there are three benchmarks of regional population census, that is, 1990, 2000, and 2010. We first calculate the share of employment of construction in the total secondary industry in these three benchmarks, and then interpolate the time series of employment share for the period 1990-2010. For 2010 onwards, we take the three-year moving average. With the time series of the employment share of construction during the whole period of 1990-2014, we can split the secondary industry reported in regional statistical yearbooks into two industries, i.e., industry and construction. Thus far, we have constructed control totals of employment for four broad industries, that is, primary, industry, construction, and tertiary industries. Next, we concentrate on data construction for individual sectors within two broad industries, i.e., industrial sectors and service sectors.

**Employment for Industrial Sectors**

To construct employment data for detailed industrial sectors, we mainly use data from two sources: one is the CIESY and the other is the regional population census. As stated earlier, the data coverage of CIESY is only for “above designated size” industrial sectors,\(^{47}\) while that of the regional population census should be considered as covering all industrial sectors, which also includes “below designated size” industrial sectors. The data from the CIESY are categorized into our 24 standard industrial sectors (codes 2-25) for the time period of 1990-2014. We employ the following steps to construct employment data for “below designated size” industrial sectors.

First, we collect employment data from three benchmarks of the regional population census, that is, 1990, 2000, and 2010, and also classify the data of industry into 24 industrial sectors. Since the data from the population census cover all industrial sectors, we can derive the data for “below designated size” industrial sectors at these three benchmark years as the residual of employment data from the population census minus that of “above designated size” industrial sectors reported in the CIESY.

Second, and again at three benchmark years, for “below designated size” industrial sectors, we calculate the share of employment of individual industrial sectors in the total “below designated size” industrial sectors, and then interpolate the time series of the

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\(^{47}\) The standards for “above designated size” industrial sectors are changed several times. See Section 4.2.1 for details.
employment share for the period of 1990-2010. For 2010 onwards, we take the three-year moving average. Thus far, we have constructed the time series of the share of employment of individual industrial sectors in the total “below designated size” industrial sectors for the whole time period of 1990-2014.

Third, we derive the control total of employment of “below designated size” industrial sectors as the residual of the control total of industry constructed earlier minus the total of “above designated size” industrial sectors from the CIESY. Further applying the time series of the employment share of “below designated size” industrial sectors constructed in the second step, we can obtain the time series of employment data for “below designated size” industrial sectors.

Finally, the whole employment data of industrial sectors can be obtained by summing up employment data of “above and below designated size” industrial sectors.

**Employment for Service Sectors**

The procedures to construct employment data for service sectors are quite similar to those used to construct employment data for industrial sectors above. To construct employment data for detailed service sectors, we mainly use data from two sources: the CLSY and the regional population census. As stated earlier, the data coverage of the CLSY is only for sectors located in urban areas, and that of the regional population census should be considered as covering all service sectors, which also includes service sectors located in non-urban areas. The data from the CLSY are categorized into our 11 standard service sectors (codes 27-37) for the time period of 1990-2014. We employ the following steps to construct employment data for service sectors located in non-urban areas.

First, we collect employment data from three benchmarks of the regional population census, that is, 1990, 2000, and 2010, and classify the data of service sectors into our 11 standard service sectors. Since the data of the population census cover all service sectors, we can derive the data for those service sectors located in non-urban areas at these three benchmark years as the residual of employment data from population census minus that from the CLSY for service sectors located in urban areas.

Second, and again at three benchmark years, for service sectors located in non-urban areas, we calculate the share of employment of individual service sectors in the total service sectors located in non-urban areas, and then interpolate the time series of the employment share for the period of 1990-2010. For 2010 onwards, we also take the three-year moving average.
Thus, to this point, we have constructed the time series of the share of employment of individual service sectors in the total service sectors located in non-urban areas for the whole time period of 1990-2014.

Third, we derive the control total of employment of service sectors located in non-urban areas as the residual of the control total of tertiary industry constructed earlier minus the total of service sectors located in urban areas from the CLSY. Further applying the time series of the employment share of service sectors located in non-urban areas constructed in the second step, we can obtain the time series of employment data for service sectors located in non-urban areas. The whole employment data of service sectors can finally be derived by summing employment data of service sectors located in both urban and non-urban areas.

Thus, we have constructed the employment data for 37 standard sectors over the whole time period 1990-2014, which are used later as control totals of each sector to construct full-dimensioned employment matrices.

### 6.3.2 Construction of Full-dimensioned Employment Matrices

To construct full-dimensioned employment matrices, we first must look for available employment data cross-classified by other dimensions, such as sector by gender, gender by education, sector by gender and age, and so on. These available cross-classified matrices are called “marginal matrices” because they are not yet fully cross-classified by all designated dimensions listed in Table 6.1. These marginal matrices are mainly from the regional population census. With these available marginal matrices, we construct a full-dimensioned matrix by using the IPF approach. In the following part, we start with an introduction to the IPF approach and then describe marginal matrices used in IPF exercise.

The IPF method is used by Bishop et al. (1975) to estimate full-dimensioned benchmark matrices based on all available or constructed marginal matrices, including the relevant data for benchmarks of the constructed marginal matrices in time series. The IPF approach is designed to integrate marginal matrices that contain incomplete data by generating the maximum likelihood estimate of each element of a matrix, which is also used to fill in missing cells.

The IPF procedure can be illustrated as follows. There is a set of marginal matrices, $J$, for a specific benchmark. We denote the number of elements in set $J$ by using $J$ for simplicity. A matrix $j \in J$, which is collected from the available yearbooks or constructed, contains some of four dimensions (see Table 6.1), and $N_{ij}$ denotes elements in a specific cell $i$ of $j$. The $\Sigma$ is
the summation of all elements in a given marginal matrix. In this estimation, we search for \( \hat{N}_i \) in a full-dimensional matrix such that \( \hat{N}_i \) is the maximum likelihood estimate of the expected value of \( N_i \).

Let \( N_i^{(0)} = 1 \forall i \), and for \( 1 \leq t \leq T \), we run the following loop:

\[
N_{i1}^{(t-j+1)} = \frac{N_{i1}^{(t-j)} N_{i1}}{\sum N_{i1}^{(t-j)}}
\]

\[
N_{ij}^{(t-j+j)} = \frac{N_{ij}^{(t-j+j-1)} N_{ij}}{\sum N_{ij}^{(t-j+j-1)}}
\]

\[
N_{ij}^{(t)} = \frac{N_{ij}^{(t-1)} N_{ij}}{\sum N_{ij}^{(t-1)}}
\]

A full-dimensional matrix has been constructed when the expected value of \( N_i \) has been derived from \( \lim_{T \to \infty} N_i^{(JT)} \). The larger \( T \) is, the higher the probability that the limit of \( N_i^{(JT)} \) converges. As recommended in Wu et al. (2015), \( T \) should be established at 150, although \( N_i^{(JT)} \) finally converges when \( T = 3 \) in their exercise. Following their suggestions, we first establish \( T \) at 150 and also find that \( N_i^{(JT)} \) almost converges when \( T = 3 \) even in the regional case.

Another important point is that the value of the \( j \)th estimate of \( N_i \) in the \( t \)th loop, \( N_{ij}^{(t-j+j)} \), is dependent on the value of the total sum of the \( (j-1) \)th matrix in \( J \), as shown in above loop. Since marginal matrices used in IPF may have different totals if they come from different data sources, the order of these marginal matrices operating in the loop may affect the resulting value of \( \hat{N}_i \). However, this problem is not severe and a solution for it, suggested by Wu et al. (2015), is that when it appears, we can further adjust the resulting value to make it consistent with the constructed control totals. For the regional case in this study, this problem does not exist because all marginal matrices are from the same data source, i.e., the regional population census, and the totals of these marginal matrices are consistent in terms of each dimension.

We first focus on constructing full-dimensional matrices for benchmarks. The full-dimensional employment matrix is defined as 37 standard sectors cross-classified by two
genders, seven age groups, and five education levels. The full-dimensional matrix is constructed by using the IPF approach with available marginal matrices from the regional population census. To construct three benchmarks, that is, 1990, 2000, and 2010, Table 6.2 summarizes the available marginal matrices from the regional population census.

Table 6.2 Data Source and Description of Marginal Employment Matrices

<table>
<thead>
<tr>
<th>Benchmark</th>
<th>Data source</th>
<th>Number of sectors</th>
<th>Marginal matrices</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>4th population census</td>
<td>75/13</td>
<td>( s \times ) e; ( s \times g \times a )</td>
</tr>
<tr>
<td>2000</td>
<td>5th population census</td>
<td>92/16</td>
<td>( s \times g ; s \times g \times a \times e )</td>
</tr>
<tr>
<td>2010</td>
<td>6th population census</td>
<td>95</td>
<td>( s \times g \times e ; s \times g \times a )</td>
</tr>
</tbody>
</table>

Source: As specified in the table.

The sectors in marginal matrices in above table are first classified into 37 standard sectors, and IPF is then operated to construct full-dimensional employment matrices. After completing the construction of the full-dimensional employment matrices for three benchmarks, the following steps are adopted to construct the time series of full-dimensional employment matrices.

First, at three benchmark years, we derive the total employment of each standard sector by summing all its components. In a full-dimensional matrix, every sector is cross-classified by two genders, seven age groups, and five education levels (totally \( 2 \times 7 \times 5 = 70 \) cells). We then calculate the share of employment of each cell in the total employment of a certain sector and interpolate the time series of the employment share for the period of 1990-2010. For 2010 onwards, we also take the three-year moving average. Thus, to this point, we have constructed the time series of the employment share of individual attributes in the total employment of each sector for the whole time period of 1990-2014.

Second, with the control totals of employment data for 37 standard sectors constructed in Section 6.3.1, and by further applying the time series of the employment share of individual attributes in the total employment of each sector constructed in the first step, we can derive the time series of full-dimensional employment matrices for the whole time period of 1990-2014.

6.3.3 Construction of Full-dimensional Hour Matrices

Regarding hours worked, which are seldom reported by the Chinese regional official labor statistics, Table 6.3 summarizes the available data collected from the regional population census.
Table 6.3 Data Source and Description of Marginal Matrices for Hours Worked

<table>
<thead>
<tr>
<th>Benchmark</th>
<th>Data source</th>
<th>Number of sectors</th>
<th>Marginal matrices</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>4th population census</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2000</td>
<td>5th population census</td>
<td>16</td>
<td>$s \times g$</td>
</tr>
<tr>
<td>2010</td>
<td>6th population census</td>
<td>95</td>
<td>$s \times g$</td>
</tr>
</tbody>
</table>

Source: See Table 6.2. In addition, in 2010, another marginal matrix, $g \times a$, is reported for 13 age groups.

As shown in above table, the data regarding hours worked from the regional population census are quite limited, and there are no other data sources from regional official labor statistics. Thus, it is difficult to construct regional hours worked matrices cross-classified by all four dimensions (i.e., sector, gender, age, and education) by only relying on regional official labor statistics.

Another data source used by Wu et al. (2015) to construct hours worked at the national level is the Chinese Household Income Project (CHIP).\footnote{Please check the website \url{http://www.ciidbnu.org/chip/index.asp?lang=EN} for details about CHIP.} The CHIP conducts five waves of household surveys in 1989, 1996, 2003, 2008, and 2014 to track the dynamics of income distribution in China to cover income and expenditure information in 1988, 1995, 2002, 2007, and 2013, respectively. The difficulty for us in using this data is that the industry classification for industrial sectors cannot align with the 24 standard sectors (codes 2-25) of this study. The CHIP divides the overall industry into three broad sectors: the mining sector, the manufacturing sector, and the utility sector, and each broad sector consists of many detailed sub-sectors in terms of different versions of the Chinese Standard Industrial Classification 1984, 1994, 2002, and 2011. When an employee completes the questionnaire, instead of the industry code of the sub-sector with which this employee is affiliated, the CHIP reports the industry code of one of three broad sectors. For example, if an employee works in the sector of “Mining and Washing of Coal”, a sub-sector of the mining sector, the CHIP reports the industry code of the mining sector rather than that of “Mining and Washing of Coal”. Thus, the CHIP data are difficult to be used to construct hours worked matrices for regional industrial sectors. Furthermore, it only reports some marginal matrices that contain the intersection of some of four dimensions, and the overall dimensions in all marginal matrices in one year cannot cover all four dimensions. Due to the lack of certain dimensions, it is impossible to construct the full-dimensioned matrix via the IPF approach.

The work of Wu and Yue (2012) has also been adopted by Wu et al. (2015) to construct hours worked at the national level. However, Wu and Yue (2012) focus on industrial sectors
only and do not cover non-industrial sectors. It is also difficult to apply the national industrial structure of hours worked to all regions, which may bring a severe bias.

Given above various reasons, we use national hours data to construct regional full-dimensional hours worked matrices by assuming that the number of average hours worked of each type of labor at the national level is as same as it in regions. By employing the time series of full-dimensional employment matrices of each region constructed in previous sections, we can construct the time series of the full-dimensional hours worked matrices for each region.

6.3.4 Construction of Corresponding Compensation Matrices

Another crucial ingredient to measure labor input is to construct hour compensation matrices corresponding to hour matrices. Although the detailed employment data cross-classified by all four dimensions are reported in regional population census, officials do not report matching compensation data. The only available compensation data for regions are the data regarding average wage of employees by sectors reported in regional statistical yearbooks. The coverage of average wage, however, focuses on sectors located in urban areas and does not cover those sectors located in non-urban areas. Further, there are two deficiencies in the data of average wage from regional statistical yearbooks. One is that they mainly cover sectors located in urban areas, causing the regional labor input to be overestimated if directly taking these data as the average wage by sectors for regions. It is accepted that the average wage by sectors in non-urban areas is lower than that in urban areas, the overall average wage by sectors at regional level is lower when sectors located in non-urban areas are included. Second, the data of average wage are reported at sectoral level and are not further cross-classified by other dimensions, which is inconsistent with hour matrices.

Due to the limited data about compensation at regional level, before more information is available, we have to rely on the national data to construct hour compensation matrices for regions. Based on the work of Wu et al. (2015), the time series of full-dimensional three matrices, that is, employment, hour, and compensation, align with each other at the national level. The steps adopted to construct time series of full-dimensional hour compensation matrices for regions are illustrated below.

First, we estimate average wage of 37 standard sectors at the national level, which involves two steps. One is to derive the total wage of each attribute by the product of employment and per capita compensation of each attribute, and then aggregate to 37 standard sectors. The second step is to aggregate the full-dimensional employment matrices to 37
standard sectors to obtain the total employment of each standard sector. The average wage of
37 standard sectors is calculated as the total wage of each standard sector divided by its
employment.

Second, we calculate the ratio of per hour compensation of each attribute to the average wage of its corresponding standard sector at the national level, which is applied to regions.

Third, we estimate the average wage of 37 standard sectors at regional level. In Section 4.3, we have constructed the total labor compensation data for 37 standard sectors for the time period of 1992-2014 based on regional input and output framework. In Section 6.3.2, we have constructed the employment data for 37 standard sectors of each region for the time period of 1990-2014. With these two types of data in hand, we derive the average wage of 37 standard sectors of each region as the total labor compensation of each standard sector divided by its employment.

Fourth, with the time series of the ratio of per hour compensation of each attribute to the average wage of its corresponding standard sector at the national level constructed in the second step, and the average wage of each standard sector at regional level constructed in the third step, we derive the per hour compensation for each attribute of each region for the time period of 1992-2014 by assuming the relation of per hour compensation of each attribute to the average rate of its corresponding standard sector at the national level is as same as it in regions.

6.4 Measuring Labor Services

So far, labor measures have been discussed at the level of individual attributes, and the question arises as to how to aggregate them with a view to obtain an overall measure of labor services. Theoretically, a firm stipulates that, under certain conditions (the firm is a price-taker in labor market and aims at minimizing its total costs), labor of a certain type is hired to the point where the cost of an additional laborer is equal to the additional revenue generated by using this labor. This equality implies that, for a measure of total labor input, the individual laborer inputs of different quality can be weighted with the respective relative wage rate, or more specifically, with the share that each type of labor occupies in total labor compensation (OECD Manual, 2001, paragraph 92).

This study adopts the standard approach to measure labor input, that is, measuring labor input in terms of hours worked rather than labor employment. Since hours worked are seen as
the carrier of labor services, the amount of labor service is assumed to be proportional to hours worked, which can be expressed as:

\[ L_{i,l,i,j,t} = Q^l_i \cdot \left( \frac{N_{i,l,i,j,t} + N_{i,l,i,j,t-1}}{2} \right) = Q^l_i \cdot H_{i,l,i,j,t} \]  
(6.1)

where \( L_{i,l,i,j,t} \) is the labor service of type \( l \) of sector \( i \) in region \( j \); \( N_{i,l,i,j,t} \) is the natural hours worked of type \( l \) of sector \( i \) in region \( j \); \( H_{i,l,i,j,t} \) is the two-period average of natural hours worked, and \( Q^l_i \) is the proportionality factor or the “quality of labor of type \( l \)”, which is time-invariant.

The Tornqvist quantity index of total labor service of sector \( i \) in region \( j \) is defined as:

\[ \Delta \ln L_{i,j} = \sum_l \sigma_{i,l,j} \Delta \ln L_{i,l,i,j} \]  
(6.2)

where \( \sigma_{i,l,j} = \frac{P^L_{i,l,j} H_{i,l,i,j}}{\sum_l P^L_{i,l,j} H_{i,l,i,j}} \), \( \bar{v}_{i,l,i,j,t} = \frac{v_{i,l,i,j,t} + v_{i,l,i,j,t-1}}{2} \), and \( P^L_{i,l,j} \) is labor input price, i.e., per hour compensation, of type \( l \) of sector \( i \) in region \( j \).

This shows that the growth rate of labor service of sector \( i \) in region \( j \) is the weighted sum of growth rates of labor services of all attributes by using the share of labor service of each attribute in the total labor services as weights.

By combining Equations (6.1) and (6.2), we can obtain:

\[ \Delta \ln L_{i,j} = \sum_l \sigma_{i,l,j} \Delta \ln (Q^l_i \cdot H_{i,l,i,j}) = \sum_l \sigma_{i,l,j} \Delta \ln H_{i,l,i,j} \]  
(6.3)

Since \( Q^l_i \) is time-invariant, it can be deleted from above equation. Therefore, the growth rate of total labor service of sector \( i \) in region \( j \) can be calculated as a weighted sum of growth rates of the two-period average hours worked of all attributes with the share of labor service in the total labor service as weights for each attribute.

The growth rate of labor service of region \( j \) can be defined as:

\[ \Delta \ln L_j = \sum_l \sum_i \frac{P^L_{i,l,j} H_{i,l,i,j}}{\sum_l P^L_{i,l,j} H_{i,l,i,j}} \Delta \ln H_{i,l,i,j} \]  
(6.4)

where \( L_j \) represents labor service of region \( j \).
The growth rate of labor service of aggregate economy can be defined as:

$$\Delta \ln L = \sum_j \sum_i \sum_t \frac{p_{L,i,j}H_{i,j}}{\sum_t \sum_i p_{L,i,j}H_{i,j}} \Delta \ln H_{i,j}$$

(6.5)

where $L$ represents aggregate labor service.
Chapter 7: Empirical Results

This chapter presents the main results of this study, which follows methodology illustrated in Chapter 3. Section 7.1 first briefly describes the whole dataset, exploring changes in the industry structure of each region and that in the regional distribution of each industry at the national level over time. Section 7.2 shows the results of value added growth contribution of individual industries to each region and that of each region to the national industry. Section 7.3 shows the results of growth accounting of labor productivity for each region and industry. Section 7.4 introduces the results of aggregate value added and TFP growth and their industry growth origins as well as further regional origins of each national industry. Section 7.5 presents the results of the reallocations of capital and labor inputs and further explores their growth sources from industry and regional perspectives, respectively.

7.1 Descriptive Results

This section first briefly introduces history background about regional economic development in China. Then, in order to obtain a brief glimpse of the whole dataset, this section shows two kinds of descriptive results: changes in the industry structure of each region over time and changes in the regional distribution of each industry at the national level over time.

The development evolution of China’s regional economy has mainly undergone through three stages: (1) 1949-1978: the stage of focusing on development of inland areas and pursuing balanced development across regions. Prior to the founding of the People’s Republic of China in 1949, most areas of China were in a backward traditional agricultural society. Industry accounted for less than 10% of the national economy, of which more than 70% were in coastal areas. After the founding of the People’s Republic of China, in order to improve the situation of imbalanced regional development caused by the extremely uneven industrial distribution, the central government formulated a policy that aims to achieve balanced industrial development and to promote the balanced regional development by placing the focus of industrial construction on inland areas while making use of the industrial foundation in coastal areas. Starting from the First Five-Year Plan (1953-1957), the central government established a strategic guideline for the Chinese industrialization by giving the priority to development of heavy industries. Most of industrial construction projects were deployed in large and medium cities with good development foundations, a majority of which was located in the northeast, central and western areas. Thanks to the heritage from Japan’s construction and the assistance from the Soviet Union, the northeast region achieved significant development in the heavy
industry in the early days of the founding of the People’s Republic of China. At the same time, industrial construction projects have also expanded to the central and western regions, making the latter regions also achieve rapid industrial development.

Starting in 1964, in response to changes in the international situation, the government had proceeded to divide the country into three categories to meet the needs of national defense, namely the first-line, the second-line, and the third-line regions, according to the importance of defense strategic position of each region. Among them, the focus of economic construction and industrial layout is on the third-line areas. The goal of “three-line construction” is to establish a relatively complete industrial system in the southwest and northwest regions. This is a large-scale east-to-west industrial migration process in the Chinese economic history, which not only directly drives the development of basic industries in the central and western regions, but also gradually rationalizes the industrial structure of both regions. Consequently, it plays a vital role in changing the industrial layout and promoting regional socio-economic development in the central and western regions.

(2) 1978-1990: the stage of implementing the strategy of uneven regional development that prioritizes the development of eastern coastal areas and then other areas. After the policy of economic reform and opening-up implemented in 1978, China’s opening to the outside world has taken the lead in starting from the eastern coastal areas. The government concentrated a large amount of resources to promote economic development in eastern coastal areas. In order to achieve this target, the central government established several Special Economic Zones starting in 1979, Coastal Open Cities starting in 1984, and Coastal Economic Open Areas starting in 1985, all of which located in eastern coastal areas, to facilitate economic growth in these regions. In the Seventh Five-Year Plan (1986-1990), the government, for the first time, explicitly proposed the division of the Chinese economy into three major regions, that is, the eastern, central and western regions, and highlighted the priority of economic development in eastern coastal areas. In 1988, Xiaoping Deng for the first time summarized the development relationship between the coast and the inland as the idea of “two overall situations”: the coastal areas should accelerate their opening up to the outside world and develop first; after the coastal development reaches a certain stage, it should devote more power to support the development of inland areas. The regional strategy of unbalanced development to the coastal zone has fully utilized comparative advantages of the coastal areas so that the economic growth rate of the coastal areas has maintained a leading level in the country, and the overall level of the national economy has also been greatly improved.
(3) 1991-present: the stage of implementing the strategy of regional coordinated development. Along with the continuous advancement of economic reform and opening-up, the eastern coastal areas have benefited from the regional unbalanced development strategy and achieved rapid development, which also promoted the economic development of the central and western regions to a certain extent. Although the regional development gap between the east and the west has been narrowed compared with it was before the reform and opening-up, the problem of uneven development across regions is still quite prominent. In order to promote the rational division and coordinated development across regional economies, the government, for the first time, proposed a strategic idea of coordinated regional development in a government report in March 1991. In October 1992, the central government further put forward the guiding ideology of “giving full play to advantages of each region, accelerating regional economic development, and promoting the rationalization of the national economic layout.” During the Eighth Five-Year Plan (1991-1995), the government adjusted the regional development strategy to “correctly handle the relationships between regional advantages and national overall planning, coastal and inland, developed regions and less-developed regions to promote regional economy to move toward coordinated development”.

With the adjustment of the regional strategic deployment, while continuing to promote the development of the eastern region, the central government has also vigorously implemented the strategy of developing the western region starting in 1999, the strategy of revitalizing the old industrial base in the northwest area starting in 2003, the strategy of promoting the rise of the central regions starting in 2004, the strategy of encouraging the eastern region to take the lead in development starting in 2006, and the strategy of the main function areas starting in 2007 to facilitate regional coordinated development. Up to this point, the overall strategy for China’s regional coordinated development has basically formed and entered a new stage of full implementation. Since 2012, the central government has adopted a series of major innovative measures, such as implementing three major strategies of “one belt and one road” construction, the coordinated development of Beijing, Tianjin, and Hebei, and the development of the Yangtze River Economic Belt, to continuously enhance the synergy of regional development and to actively expand a new room for regional development to promote China’s regional coordinated development in a more comprehensive, more inclusive, and more open circumstance (Chen and Yang, 2019; Shi, 2019).
Figure 7.1 shows changes in value added shares of individual industries in several regions over time. The first observation is that industry structures across regions are different. For example, the share of Agriculture in Shanghai is low, while it is high in Hainan, Inner Mongolia, Henan, and so on. In contrast, the share of service sectors in Shanghai is higher than that in above regions. In addition, the industry development tendency across regions is also different. For example, the share of Agriculture in each region declines significantly over 1992-2014, dropping from 0.32 to 0.11 in Inner Mongolia, 0.27 to 0.13 in Henan, and 0.35 to 0.16 in Guizhou. On the other hand, the shares of service sectors clearly increase over the whole time period. For example, the share of Wholesale in Shanghai increases from 0.06 to 0.17 over 1992-2014, and the share of Business Services in Beijing increases from 0.05 to 0.19 (see Figure A1 in Appendix). This indicates that the regional industry structure gradually transforms from agriculture to services, which aligns with the regularity of economic development.

The second observation is that industry structure may reflect the initial endowments and comparative advantage of each region. For example, Agriculture is still a dominant industry in Hainan, Inner Mongolia, Henan, and Guizhou, although its share declines in these regions over 1992-2014. Coal Mining is dominant in Shanxi, Petroleum and Gas is an important industry in Heilongjiang, Tobacco is an important industry in Yunnan, and so on. Furthermore, manufacturing industries are mainly concentrated in Tianjin, Liaoning, Guangdong, Zhejiang, and Jiangsu (see Figure A1 in Appendix).

Figure 7.2 shows changes in value added shares of individual regions in several industries at the national level over time. The results shown in Figure 7.2 echo those in Figure 7.1. For example, Shanxi has a large share of Coal Mining, Heilongjiang has a large share of Petroleum and Gas, Guangdong and Jiangsu have a large share in Electronic Equipment, and so on.

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49 See Figure A1 in Appendix for all regions.
50 See Figure A2 in Appendix for all industries.
Figure 7.1 Changes in Value Added Shares of Individual Industries in Regions

Notes: (1) The total regional value added equals one. (2) The order of regions is ranked by the nominal value added per hour worked of 1992, which is also used for the following figures. Shanghai is the highest, Guizhou is the lowest, Hainan is at the 25th percentile, Inner Mongolia is at the 50th percentile, and Henan is at the 75th percentile.

Source: Author’s calculation.
Figure 7.2 Changes in Value Added Shares of Individual Regions in Industries

Note: The total industry value added equals one.
Source: Author’s calculation.
7.2 Value Added Growth Contribution

This section first shows the value added growth contribution of individual industries to each region, and then shows that of regions to each industry at the national level over time. China entered the WTO at the end of 2001, gradually integrating into the international market. Chinese enterprises had to compete with international enterprises to pursue profit, forcing the former to constantly improve technology and production efficiency. In addition, the Global Financial Crisis in 2008 had major negative impacts on the global economy, including the Chinese economy. The Chinese central government implemented the so-called 4-trillion yuan stimulus package, which was further accompanied by 18-trillion yuan projects financed by local governments, to stimulate the Chinese economy to remove shocks from the crisis, which had an important impact on Chinese economic growth and resource allocation. 51 Thus, we divide the whole period of 1992-2014 into three sub-periods, that is, 1992-2001, 2001-2007, and 2007-2014, to reflect effects of these shocks.

Figure 7.3 shows the average value added growth contribution of individual industries to several regions in three sub-periods. 52 We find that value added growth is obviously heterogeneous among industries and regions. First, taking the regional economy as a whole, regions in the eastern coastal area, such as Shanghai, Zhejiang, Fujian, Jiangsu, and Guangdong, have achieved relatively higher value added growth rates compared to those located in central and western areas. Meanwhile, each region has its own growth characteristics. For example, Hainan, Inner Mongolia, and Guizhou have achieved rapid growth in service sectors, while Shanghai and Henan have achieved rapid growth in both manufacturing and service sectors. Second, industry growth performance not only differs within a region – for example, service sectors have in general achieved rapid growth in each region over time – but also differs across regions; for example, the value added growth contribution of Agriculture declines in Hainan and Inner Mongolia but increases in Henan and Guizhou in 2007-2014 compared with 2001-2007. The value added growth contribution of Business Services in Shanghai is higher than that in Hainan, Inner Mongolia, Henan and so on. Finally, the value added growth rates of most regions peak in 2001-2007 and then decline in 2007-2014.

Figure 7.4 shows the average value added growth contribution of each region to several industries at the national level in three sub-periods. 53 First, the growth rates of value added

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51 Reallocation terms are discussed in Section 7.5.
52 See Figure A3 in Appendix for all regions.
53 See Figure A4 in Appendix for all industries.
across industries are heterogeneous. For example, Chemical Materials, Fabricated Metal Products, and Electronic Equipment achieve high growth rates, whereas the growth rates of Coal Mining, Transportation and Storage, and Finance are relatively slow, and those of Petroleum and Gas and Petroleum Processing are even negative over the whole time period. Second, the regional growth performance within an industry is also heterogeneous. For example, the growth rates of Jiangsu and Shandong are higher than those of other regions in Chemical Materials, and the growth rates of Guangdong and Jiangsu are higher than those of other regions in Electronic Equipment. Finally, the value added growth rates of most industries also peak in 2001-2007 and then decline in 2007-2014.

Figure 7.3 Value Added Growth Contribution of Industries to Regions (%)
Figure 7.4 Value Added Growth Contribution of Regions to Industries (%)

Note: Growth rates of industry value added equal the summation of growth rates of all regions. Source: Author’s calculation.
7.3 Growth Accounting of Labor Productivity

In this section, we examine growth sources of labor productivity of each region (and each industry at the national level). Following Jorgenson et al. (2005), we decompose labor productivity growth into three components: capital-labor ratio, labor quality, and TFP. Figure 7.5 first shows the results of decomposition of labor productivity growth of regions.

According to above figure, differences in capital-labor ratio, labor quality, and TFP all contribute to differences in labor productivity growth across regions over time. Regardless of whether the whole time period or three sub-periods are considered, differences in capital-labor ratio make the largest contribution to differences in labor productivity growth across a majority of regions, followed by differences in labor quality. On the other hand, TFP growth has a negative contribution to labor productivity growth in most regions. The regions where TFP growth makes a positive contribution in the whole time period include Shanghai, Guangdong, Hainan, Zhejiang, and so on.

Comparing growth performances of labor productivity over three sub-periods, we find that the accession to the WTO facilitates labor productivity in most regions to achieve faster growth in 2001-2007 compared to 1992-2001. Further, increases in labor productivity growth in a majority of regions are mostly contributed by TFP growth, such as in Shanghai, Beijing,
and Guangdong, followed by contributions from capital-labor ratio growth, such as in Jiangsu, Shandong, and Inner Mongolia. Labor quality growth makes the dominant contribution to increases in labor productivity growth in Qinghai, Sichuan, and Guizhou. On the other hand, decreases in labor productivity growth in some regions in 2001-2007 compared to 1992-2001 are almost due to decreases in TFP growth, such as in Xinjiang, Fujian, and Hebei.

Although the ambitious stimulus package implemented by the central government in 2009 to remove shocks of the Global Financial Crisis makes the capital-labor ratio increase in most regions in 2007-2014 compared to 2001-2007, TFP declines significantly in a majority of regions during the final sub-period. The increases in labor productivity growth in a majority of regions in 2007-2014 compared to 2001-2007 are mostly contributed by capital-labor ratio growth, such as in Liaoning, Guangdong, and Heilongjiang, followed by contributions from TFP growth, such as in Hainan, Fujian, and Jiangsu. Although labor quality achieves faster growth in all regions in 2007-2014 compared to 2001-2007, it only makes the dominant contribution to increase in labor productivity growth in Xinjiang. On the other hand, decreases in labor productivity growth in some regions in 2007-2014 compared to 2001-2007 are almost due to decreases in TFP growth, such as in Beijing, Tianjin, and Jilin, whereas decreases in capital-labor ratio account for decreases in labor productivity growth in Shanghai and Chongqing.

Figure 7.6 Decomposition of Labor Productivity Growth of Industries (%)

Source: Author’s calculation.
Figure 7.6 shows the results of decomposition of labor productivity growth of industries at the national level. Compared with Figure 7.5, we find not only that differences in capital-labor ratio, labor quality, and TFP contribute diversely to differences in labor productivity growth across industries, but also that differences in labor productivity growth across industries are obviously more diverse than those across regions. During the whole period, labor productivity growth rate of Electronic Equipment is the highest, whereas that of Healthcare is the lowest. The growth sources of labor productivity across industries are different; specifically, capital-labor ratio growth makes the dominant contribution to labor productivity growth of a majority of industries, such as Agriculture, Coal Mining, Metal Mining, and so on, whereas TFP growth makes the crucial contribution to labor productivity growth of Chemical Materials, Rubber and Plastics, Fabricated Metal Products, and Electronic Equipment, and labor quality growth only makes the dominant contribution to labor productivity growth of Public Management. On the other hand, decreases in labor productivity growth of some industries, such as Petroleum and Gas, Petroleum Processing, and so on, are completely due to dramatic decreases in TFP growth.

Considering the labor productivity growth in three sub-periods, we find that TFP growth contributes to over half of industries that achieve positive labor productivity growth in 1992-2001, and the capital-labor ratio growth accounts for the rest. In 2001-2007, TFP growth contributes to nearly half of industries that achieve positive labor productivity growth, and capital-labor ratio growth accounts for the other half. In 2007-2014, capital-labor ratio growth primarily contributes to positive labor productivity growth of a majority of industries, followed by the contribution from TFP growth, and labor quality contributes to labor productivity growth of Education. In addition, despite labor quality grows in nearly all industries except for Electrical Equipment and Electronic Equipment in 1992-2001, declines in several industries in 2001-2007, and increases in all industries except Business Services in 2007-2014, its contribution to labor productivity growth of industries in each sub-period is quite small. On the other hand, decreases in TFP growth completely account for industries whose labor productivity growth rates are negative regardless of whether the whole period or three sub-periods are considered.

Comparing growth performances of labor productivity over three sub-periods, we find that labor productivity of over half of industries, especially service sectors, achieves faster growth in 2001-2007 compared to 1992-2001, and increases in TFP growth account for the relatively faster growth in labor productivity of nearly all industries in 2001-2007, such as
Instruments, Hotel and Catering, and so on, whereas capital-labor ratio growth contributes to labor productivity growth in Agriculture and Other Services. In contrast, decreases in labor productivity growth of a majority of industrial sectors in 2001-2007 relative to 1992-2001, such as in Coal Mining, Metal Mining, Petroleum Processing, and so on, are mostly due to decreases in TFP growth.

The relatively faster growth in labor productivity of a majority of industries in 2007-2014 compared to 2001-2007 largely benefits from capital-labor ratio growth, such as in Petroleum and Gas, Nonmetal Mining, and so on, whereas that of the rest industries benefits from TFP growth, such as in Coal Mining, Paper and Printing, Rubber and Plastics, and so on. On the other hand, decreases in labor productivity growth of industries in 2007-2014 compared to 2001-2007 are all due to declines in TFP growth except for Tobacco, which is due to the decline in capital-labor ratio growth.

7.4 Growth Sources of Aggregate Value Added and Productivity

In this section, we examine growth sources of the Chinese economy as a whole. We first show the results of aggregate value added growth and sources, then those of aggregate TFP growth and sources. The empirical results shown in this section are calculated by following the growth accounting methodology in Chapter 3 from the industry perspective.54

7.4.1 Aggregate Value Added Growth and Sources

Table 7.1 presents the annual growth rate of national value added over the period 1992-2014, which is derived using the standard double deflation by considering the role of intermediate inputs. The annual growth rate of aggregate value added is 8.73% over the whole period, which reaches 7.54% during 1992-2001, peaks in the WTO period (2001-2007), and slightly declines to 9.10% in 2007-2014 due to the shock from the 2008 Global Financial Crisis and the tremendous downturn tendency of the Chinese economy starting in 2012.

Regarding individual industries, Figure 7.7 ranks industries by their average growth over the whole period and shows that a majority of industries falls between 0.10% and 0.41%. The four fastest-growing industries are Wholesale, Chemical Materials, Electronic Equipment, and Finance, with annual value added growth over 0.45%. On the other hand, the bottom four industries with the slowest growth rates are Petroleum and Gas, Petroleum Processing, Healthcare, and Education, whose annual growth rates of value added are negative in 1992-

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54 The results from the regional perspective are available from the author upon request.
2014. The common characteristics of these four industries are that they are dominated by SOEs or directly controlled by the central government. Other industries that are vulnerable to governmental interventions are Coal Mining, Metal Mining, Nonmetal Mining, and Tobacco, all of which show relatively slow value added growth rates. This may indicate that the governmental interventions are not conducive to the growth of industry value added for two reasons: one is that there are no strong incentives for these industries to improve their production efficiency (which is seen in the following TFP analysis) to minimize costs because they receive a large amount of subsidies or financial grants from the government. The other is that they are overly protected by the government, causing the lack of competition with other types of enterprises, such as private enterprises and foreign investment enterprises.

Another observation is that the average annual growth rate of value added of the service industry as a whole is higher than that of the whole industry over the entire time period, which is 0.28% versus 0.20% annually. The service sectors have achieved rapid growth along with the continuous Chinese economic reforms, especially after China entered the WTO in 2001. During the WTO period, the average annual growth rate of the whole service is nearly twice as large as that of the whole industry (0.41% versus 0.21% annually). More importantly, even in the last sub-period, due to influences of the 2008 Global Financial Crisis and the aftermath of the stimulus policies implemented before, the value added growth rate of industry decreases, while that of the service industry maintains high growth, with 0.18% versus 0.36% on average annually. This suggests that the industry structure of the Chinese economy has gradually transformed from industry to service sectors, and the latter could be an important growth potential of the Chinese economy in the future.

We next examine how growth in these industries changes over three sub-periods.\(^5\)\(^5\) China entered the WTO at the end of 2001, and since then, the Chinese market has gradually integrated with the international market, and more and more foreign companies have entered the Chinese market. Due to external shocks from foreign companies, more than half of industrial sectors (14 out of 24) shows slower growth in the WTO period compared to their growth performances in previous sub-period. In contrast, nearly all of service sectors (except for Public Management) achieves higher growth in the WTO period compared to their growth performances in 1992-2001. During the last sub-period, 2007-2014, 11 industrial sectors and

\(^{55}\) In order to save space, we do not show the results table, which can be derived from Table 7.1.
8 service sectors show slower value added growth rates compared with their growth performances in 2001-2007.

Table 7.1 Industry Sources of National Value Added Growth (%)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>7.54</td>
<td>10.11</td>
<td>9.10</td>
<td>8.73</td>
</tr>
<tr>
<td>Agriculture</td>
<td>0.49</td>
<td>0.07</td>
<td>0.28</td>
<td>0.31</td>
</tr>
<tr>
<td>Coal Mining</td>
<td>0.12</td>
<td>-0.13</td>
<td>0.10</td>
<td>0.05</td>
</tr>
<tr>
<td>Petroleum and Gas</td>
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<td>-0.15</td>
<td>-0.02</td>
<td>-0.07</td>
</tr>
<tr>
<td>Metal Mining</td>
<td>0.05</td>
<td>-0.02</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td>Nonmetal Mining</td>
<td>0.08</td>
<td>-0.05</td>
<td>0.04</td>
<td>0.03</td>
</tr>
<tr>
<td>Food</td>
<td>0.29</td>
<td>0.52</td>
<td>0.47</td>
<td>0.41</td>
</tr>
<tr>
<td>Tobacco</td>
<td>0.09</td>
<td>0.10</td>
<td>0.11</td>
<td>0.10</td>
</tr>
<tr>
<td>Textile</td>
<td>0.26</td>
<td>0.22</td>
<td>0.10</td>
<td>0.20</td>
</tr>
<tr>
<td>Wearing Apparel</td>
<td>0.19</td>
<td>0.11</td>
<td>0.11</td>
<td>0.14</td>
</tr>
<tr>
<td>Leather and Fur</td>
<td>0.02</td>
<td>0.08</td>
<td>0.06</td>
<td>0.05</td>
</tr>
<tr>
<td>Timbers and Furniture</td>
<td>0.15</td>
<td>0.15</td>
<td>0.08</td>
<td>0.13</td>
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<tr>
<td>Paper and Printing</td>
<td>0.22</td>
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<tr>
<td>Petroleum Processing</td>
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<td>-0.25</td>
<td>-0.21</td>
<td>-0.07</td>
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<tr>
<td>Chemical Materials</td>
<td>0.72</td>
<td>0.57</td>
<td>0.63</td>
<td>0.65</td>
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<tr>
<td>Rubber and Plastics</td>
<td>0.25</td>
<td>0.15</td>
<td>0.18</td>
<td>0.20</td>
</tr>
<tr>
<td>Non-metallic Products</td>
<td>0.42</td>
<td>0.34</td>
<td>0.21</td>
<td>0.33</td>
</tr>
<tr>
<td>Metal Pressing</td>
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<td>0.15</td>
<td>0.46</td>
<td>0.28</td>
</tr>
<tr>
<td>Fabricated Metal Products</td>
<td>0.41</td>
<td>0.17</td>
<td>0.11</td>
<td>0.25</td>
</tr>
<tr>
<td>General Equipment</td>
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<td>0.60</td>
<td>0.11</td>
<td>0.37</td>
</tr>
<tr>
<td>Electrical Equipment</td>
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<td>0.20</td>
<td>0.27</td>
<td>0.25</td>
</tr>
<tr>
<td>Electronic Equipment</td>
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<td>0.78</td>
<td>0.80</td>
<td>0.63</td>
</tr>
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<td>Instruments</td>
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<td>0.05</td>
<td>0.03</td>
</tr>
<tr>
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<td>0.52</td>
<td>0.39</td>
</tr>
<tr>
<td>Other Manufacturing</td>
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<td>0.21</td>
<td>0.08</td>
<td>0.14</td>
</tr>
<tr>
<td>Utility</td>
<td>0.20</td>
<td>0.51</td>
<td>-0.01</td>
<td>0.22</td>
</tr>
<tr>
<td>Construction</td>
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<td>0.56</td>
<td>0.42</td>
<td>0.40</td>
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<td>Wholesale</td>
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<td>Hotel and Catering</td>
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<td>0.31</td>
<td>0.03</td>
<td>0.14</td>
</tr>
<tr>
<td>Transportation and Storage</td>
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<td>0.56</td>
<td>0.36</td>
<td>0.36</td>
</tr>
<tr>
<td>Post</td>
<td>0.12</td>
<td>0.50</td>
<td>0.31</td>
<td>0.28</td>
</tr>
<tr>
<td>Finance</td>
<td>0.06</td>
<td>0.57</td>
<td>0.85</td>
<td>0.45</td>
</tr>
<tr>
<td>Real Estate</td>
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<td>0.52</td>
<td>0.45</td>
<td>0.40</td>
</tr>
<tr>
<td>Business Services</td>
<td>0.09</td>
<td>0.39</td>
<td>0.62</td>
<td>0.34</td>
</tr>
<tr>
<td>Public Management</td>
<td>0.34</td>
<td>0.18</td>
<td>0.01</td>
<td>0.19</td>
</tr>
<tr>
<td>Education</td>
<td>-0.29</td>
<td>0.11</td>
<td>0.13</td>
<td>-0.05</td>
</tr>
<tr>
<td>Healthcare</td>
<td>-0.13</td>
<td>0.05</td>
<td>-0.03</td>
<td>-0.05</td>
</tr>
<tr>
<td>Other Services</td>
<td>0.13</td>
<td>0.26</td>
<td>0.21</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Notes: The contribution of each industry represents the share-weighted growth rate. All figures are annual average percentages. See Table 1A.1 in Appendix for industry classification.

Source: Author’s calculation.
4.2 Aggregate TFP Growth and Sources

Table 7.2 decomposes aggregate value added growth into four components: capital input, hours worked, labor quality, and TFP growth. The annual growth rates of four components over the whole period are 6.06%, 0.37%, 1.68%, and 0.62%, accounting for 69.42%, 4.24%, 19.24%, and 7.10% of aggregate value added growth, respectively. This shows that the Chinese economic growth mode is still heavily reliant on factor inputs, especially capital input. This growth mode is not sustainable in the long run given that the amount of factor inputs is finite, and the marginal revenue by one additional unit of factor input is diminishing.
Given that capital input is the most important contributor to aggregate value added growth, the annual growth trends of both are quite similar. Specifically, benefiting from the southern tour speech in 1992, both achieved rapid growth in the first half of the 1990s and later declined due to shocks from the Asian Financial Crisis in 1997. After China entered the WTO in 2001, the growth rates of aggregate value added and capital input increased. The 2008 Global Financial Crisis caused both to decline slightly in the later periods compared to that in the WTO period. The growth rate of hours worked continued to increase until 2001, when it began to decline in the later periods. The change of labor quality roughly kept increasing over the whole time period, except for 1998-2001. The annual change of TFP, however, was quite volatile over time. We further decompose aggregate TFP growth into three components in Table 7.3 to explore factors that cause fluctuations in TFP growth.

56 After the political turmoil in 1989, the inside of the Chinese central government emerged different opinions on whether to continue reform and opening-up policy. At the beginning of 1992, Xiaoping Deng visited some cities in southern China and made a series of important speeches. The speeches reiterated the necessity and importance of deepening economic reform and accelerating development, which stimulated the second wave of China’s reform and opening-up. The speeches played a key role in promoting China’s economic reforms and social progress in the 1990s. This is later known as “southern tour speech”.

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Table 7.2 Decomposition of National Value Added Growth (%)

<table>
<thead>
<tr>
<th>Year</th>
<th>V</th>
<th>K</th>
<th>H</th>
<th>LQ</th>
<th>TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>5.14</td>
<td>6.19</td>
<td>0.58</td>
<td>1.81</td>
<td>-3.44</td>
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<tr>
<td>1993</td>
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<td>6.88</td>
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<td>1994</td>
<td>9.26</td>
<td>8.63</td>
<td>0.59</td>
<td>1.89</td>
<td>-1.85</td>
</tr>
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<td>1995</td>
<td>10.89</td>
<td>4.30</td>
<td>0.73</td>
<td>1.41</td>
<td>4.46</td>
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<tr>
<td>1996</td>
<td>6.01</td>
<td>3.15</td>
<td>0.92</td>
<td>1.45</td>
<td>0.50</td>
</tr>
<tr>
<td>1997</td>
<td>5.63</td>
<td>2.24</td>
<td>0.93</td>
<td>1.05</td>
<td>1.41</td>
</tr>
<tr>
<td>1998</td>
<td>5.68</td>
<td>4.17</td>
<td>0.96</td>
<td>0.38</td>
<td>0.17</td>
</tr>
<tr>
<td>1999</td>
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<td>4.10</td>
<td>0.90</td>
<td>0.41</td>
<td>0.78</td>
</tr>
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<td>2000</td>
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<td>1.15</td>
<td>0.00</td>
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</tr>
<tr>
<td>2001</td>
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<td>5.95</td>
<td>1.01</td>
<td>0.54</td>
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<tr>
<td>2002</td>
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<tr>
<td>2003</td>
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<td>9.03</td>
<td>0.82</td>
<td>1.32</td>
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<td>7.65</td>
<td>0.80</td>
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</tr>
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<td>2005</td>
<td>9.34</td>
<td>7.72</td>
<td>-0.00</td>
<td>1.84</td>
<td>-0.22</td>
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<tr>
<td>2006</td>
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<tr>
<td>2007</td>
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<td>7.67</td>
<td>0.08</td>
<td>2.60</td>
<td>0.82</td>
</tr>
<tr>
<td>2008</td>
<td>6.44</td>
<td>5.95</td>
<td>0.09</td>
<td>2.83</td>
<td>-2.43</td>
</tr>
<tr>
<td>2009</td>
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<td>6.74</td>
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<td>-2.97</td>
</tr>
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<td>2011</td>
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<td>6.03</td>
<td>0.02</td>
<td>1.26</td>
<td>4.21</td>
</tr>
<tr>
<td>2012</td>
<td>7.40</td>
<td>5.37</td>
<td>0.19</td>
<td>2.18</td>
<td>-0.34</td>
</tr>
<tr>
<td>2013</td>
<td>7.98</td>
<td>6.88</td>
<td>0.16</td>
<td>1.81</td>
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<td>2014</td>
<td>7.54</td>
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<td>2001-2007</td>
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<td>2007-2014</td>
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<td>0.73</td>
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<tr>
<td>1992-2014</td>
<td>8.73</td>
<td>6.06</td>
<td>0.37</td>
<td>1.68</td>
<td>0.62</td>
</tr>
</tbody>
</table>

Notes: (1) H and LQ stand for hours worked and labor quality, respectively. (2) The contributions of each component to aggregate value added growth represent the share-weighted growth rate. All figures are annual average percentages.

Source: Author’s calculation.

Table 7.3 decomposes aggregate TFP growth into three components: the Domar-weighted TFP growth, the reallocation of capital, and the reallocation of labor. The volatility of aggregate TFP growth over time is mainly dominated by the Domar-weighted TFP growth because the change trends of reallocations of capital input and labor input are relatively stable over time. The growth rate of aggregate TFP is 0.62% on average during the whole time period, with -0.80% from Domar-weighted TFP growth, -0.37% from the reallocation of capital input, and 1.80% from the reallocation of labor input. We first focus on the Domar-weighted TFP growth and leave the reallocations of capital and labor for the next section. Table 7.4 presents industry contributions to national Domar-weighted TFP growth, and Figure 7.8 ranks industry contribution over the time period 1992-2014.

Table 7.3 shows that the positive aggregate TFP growth is wholly benefited from the reallocation of labor input because the Domar-weighted TFP growth as well as the reallocation of capital input are negative during the whole time period and three sub-periods, except that
the Domar-weighted TFP achieves positive growth in 2001-2007. According to Table 7.4, the first observation is that a majority of industries (21 out of 37) achieves negative TFP growth. The two fastest TFP growing industries are Electronic Equipment and Chemical Materials, with TFP growth above 0.30%. The sector with the slowest TFP growth is Real Estate. Second, those sectors that are vulnerable to governmental interventions, such as Coal Mining, Petroleum and Gas, Tobacco, Petroleum Processing, Utility, Finance, Public Management, Education, and Healthcare, experience negative TFP growth, which may indicate that the governmental interventions are not helpful in improving production efficiency or the technology level. Third, the TFP growth performance of industrial sectors is better than that of service sectors, while most service sectors experience negative TFP growth in both the whole time period and each sub-period. This shows that although the value added growth of service sectors performs well, its TFP growth is not optimal. The main contributors to Chinese overall TFP growth are industrial sectors. In 2015, the Chinese government issued a strategic plan, i.e., “Made in China 2025”, to boost innovations in Chinese manufacturing to further promote TFP growth in manufacturing.

From Table 7.4, we find that TFP growth in nearly all service sectors is negative during the entire time period, especially in Real Estate. An important reason for this phenomenon may be rooted in PPIs of service sectors. Compared to studies that adopt official implicit GDP deflators as PPIs of service sectors, this study uses regional CPI and its relevant components to construct PPIs of service sectors. Compared to official GDP deflators, our alternatives show faster increases in price indexes. As a result, the growth of real output in service sectors slows down, and other things being equal, TFP growth also slows down. Another important reason for negative TFP growth in Real Estate is attributed to the excessive increases in factor inputs. Since China implemented the reform of the housing system in 1998, the development of the real estate industry has become very active, and its proportion in the national economy has kept increasing. In China, farmers only have the right to use the contracted land, without ownership that belongs to governments. They cannot sell the contracted land privately. Developers need to buy land from the governments who first expropriate land from farmers. The fierce competition of bidding land via the auction system among developers causes land

57 The objective of this plan is to promote China to basically achieve industrialization and become a powerful manufacturing country by 2025 via the further development of ten high-tech fields, such as information technology industry, aerospace equipment, new materials, and so on.
58 See Table 4.7 in Chapter 4 for construction of PPIs of each sector.
59 See Figure A5 in Appendix for comparisons between our alternative PPIs and official ones of service sectors.
price to increase. The governments can get huge revenue to make up for fiscal revenue by selling land to developers, which causes the so-called “land finance” phenomenon. Therefore, in order to obtain high revenue and to stimulate regional economic growth, local governments have intrinsic incentives to sell a lot of land to developers who further invest a large amount of capital and labor to develop land. Thus, due to slow increase in output while fast increase in inputs, the TFP residual of real estate industry shows significantly negative growth.

We also examine how industry TFP growth changes over three sub-periods. The 1992 southern tour speech inspired the initiatives of market agents, and most industrial sectors achieved positive TFP growth. However, due to the suppression of service sectors, most of which experienced negative TFP growth except for Public Management, the national TFP growth rate was -0.94% on average during 1992-2001. In the WTO period, the obvious improvement of TFP growth of service sectors compared with that in previous sub-period facilitated the national TFP increase to 0.67%. The 2008 Global Financial Crisis and the side-effects of previously implemented stimulus package caused TFP growth in a majority of industries (24 out of 37) to slow down in 2007-2014 compared to 2001-2007. Consequently, the national TFP growth declined dramatically in the last sub-period, and it was -1.88% on average.

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60 We do not show the results table, which can be derived from Table 7.4.
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<th>3. Reallocation of L</th>
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Notes: The contributions of three components to aggregate TFP growth represent the share-weighted growth rate. All figures are annual average percentages. Source: Author’s calculation.
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</table>

Notes: The contribution of each industry to aggregate Domar-weighted TFP growth represents the share-weighted growth rate. All figures are annual average percentages.
Source: Author’s calculation.
Figure 7.9 shows regional origins of the Domar-weighted TFP growth of several national industries, i.e., how much each region contributes to the Domar-weighted TFP growth of each national industry.\(^{61}\) This figure provides a comprehensive picture of industry TFP growth from the regional perspective, which can trace regional origins of industry TFP growth. For example, TFP growth of Petroleum and Gas is mainly from Heilongjiang and Shandong, although both show negative growth, and that of Electronic Equipment is mainly from Guangdong and Jiangsu. Meanwhile, we can determine in which industries each region performs efficiently. For example, Guangdong achieves rapid TFP growth in Electronic Equipment but low growth in General Equipment and Transportation and Storage. Jiangsu achieves rapid TFP growth in Chemical Materials and Electronic Equipment but low growth in Petroleum Processing and Finance.

\(^{61}\) See Figure A6 in Appendix for all industries.
Figure 7.9 TFP Growth Contribution of Regions to Industries (%)

Note: TFP growth rates of each industry equal the summation of TFP growth rates of all regions. Source: Author’s calculation.
Combining Figures 7.4 and 7.9, we find that some regions achieve relatively high (or low) growth contributions to both value added and the Domar-weighted TFP growth of national sectors. For example, Zhejiang, Jiangsu, and Shandong make important contributions to value added and Domar-weighted TFP growth of Chemical Materials. In contrast, Heilongjiang and Shandong make significantly negative contributions to value added and Domar-weighted TFP growth of Petroleum and Gas. Another observation is that, although the contributions of certain regions to the value added growth rate of certain national sectors are relatively high, their contributions to the Domar-weighted TFP growth are relatively low, and vice versa. For example, the contributions of Jiangsu and Shandong to value added growth of Transportation and Storage are high, but their TFP growth contributions are low or even negative. The contribution of Beijing to value added growth of Wholesale is relatively low, but its TFP growth contribution is high. The contribution of each region to value added and Domar-weighted TFP growth of each national sector may reflect its corresponding initial endowments and comparative advantages.

Furthermore, sectors that are prone to government interventions even at regional level tend to achieve relatively slow or even negative TFP growth. For example, Inner Mongolia, Shaanxi, Henan, and Anhui achieve rapid value added growth in Coal Mining, while the corresponding TFP growth in these regions is negative except for slight positive growth in Anhui. Although all regions achieve positive value added growth in Tobacco over the whole period, many regions show negative TFP growth, and this is also true for Petroleum Processing, Finance, and Public Management. It may indicate that governmental interventions are not helpful to achieve high TFP growth. On the contrary, industries that are less prone to government interventions could achieve rapid value added growth and TFP growth simultaneously, for example, in Timbers and Furniture, Paper and Printing, Chemical Materials, and so on.

### 7.5 Reallocations of Capital and Labor

The reallocations of capital and labor are non-negligible in China, and, according to Table 7.3, both move in opposite directions. As shown in Equations (3.55) and (3.77), we decompose aggregate reallocations of capital and labor into industry effect and region effect from industry and regional perspectives, respectively. Figure 7.10 depicts change trends of the reallocations of capital and labor inputs as well as their components over the period 1992-2014 from the industry perspective, while Figure 7.11 depicts the results from the regional
From the point of view of industry, the green line in the left panel of Figure 7.10 shows that the reallocation of capital input continuously deteriorates over the whole period, with a sharp acceleration in the decline during the WTO period. Since the government-enhanced excessive capital investment is still an important contributor to Chinese economic growth, which is also confirmed by the results in Table 7.2, capital input, mostly controlled by the government, is much more vulnerable to governmental interventions, and much of it tends to flow into state-owned enterprises and state-controlled sectors although the utilization efficiency is relatively low in those sectors. Thus, capital is heavily affected by administrative planning rather than market mechanisms, and it grows relatively slowly in industries with high capital service prices, causing the reallocation of capital input to be negative in the whole period. In the WTO period, the Chinese domestic market gradually opened to foreign companies. In order to dampen the external shocks to domestic enterprises, the government supported a large number of export-oriented enterprises through subsidies. The government subsidies had cost distortion effects, which inhibited the internal motivation of enterprises to participate in international competition by upgrading their own technological levels. As a result, the domestic enterprises were caught in a low-cost, low-profit competition model, which led to extensive growth of enterprises and an ineffective usage of subsidized funds (Yu and Yu, 2018). Therefore, the reallocation of capital input declined sharply during this period.

On the other hand, the green line in the right panel shows that the reallocation of labor input constantly improves over the whole period and grows relatively quickly starting in the late WTO period. Since the policy of economic reform and opening up implemented in 1978, the government has gradually relaxed restrictions on labor mobility, especially the relaxation of the household registration system. The labor market is much less controlled than the capital market, and labor forces can move relatively freely across sectors, which may indicate that labor mobility is more inclined to follow the market mechanisms. As a result, labor grows relatively rapidly in industries with high labor service prices, causing the reallocation of labor input to be positive in the whole period. In particular, starting from the WTO period, the inexpensive labor cost has attracted a large amount of foreign direct investment, making China known as the “World Factory”, and the treatment of labor force has been greatly improved, making the labor reallocation grow relatively quickly since the late WTO period.
From the point of view of region, the red dashed-lines in both panels show that the reallocations of both capital and labor inputs slightly increase during the study period, which may indicate that allowing factors of production to flow across regions is conducive to factor allocations. The TFP growth and, further, the overall economic growth would be boosted by considering China as a united market and allowing the factors of production to flow freely across sectors and regions.

The significant reallocations of capital and labor inputs have important impacts on aggregate TFP growth. According to the results in Table 7.3, the source of aggregate TFP growth is dominated by the labor reallocation in each sub-period. In the whole time period, the reallocations of capital and labor inputs are -0.37% and 1.80%, respectively, and the net reallocation is 1.43% on average during 1992-2014, completely accounting for aggregate TFP growth. Benefiting from the labor reallocation, the growth rate of aggregate TFP is 0.62% on average during the whole time period, and it continues to increase over each sub-period.

Figure 7.10 Change Trends of Reallocations, 1992=100 (industry perspective)

Source: Author’s calculation based on Equation (3.55).
In order to explore industry origins of the reallocations of capital and labor inputs, as shown in Equation (3.61), Figure 7.12 first shows the industry level reallocation of capital input, 
\[
\left( \frac{\sigma_i}{\beta_i} \varphi_i^K - \bar{w}_i^K \bar{a}_i^K \right) (\Delta \ln K_i - \Delta \ln K_i),
\]
and two components of this value, 
\[
\left( \frac{\sigma_i}{\beta_i} \varphi_i^K - \bar{w}_i^K \bar{a}_i^K \right)
\]
and 
\[
(\Delta \ln K_i - \Delta \ln K_i)
\]
for three sub-periods. The growth rates of capital input of most industries were lower than the national average growth of capital input in 1992-2001 and 2001-2007, while those of many industries increased in 2007-2014. On the other hand, service prices of capital input in a majority of industries were higher than the national average capital service price, whereas the capital service prices in Utility, Transportation and Storage, Real Estate, Public Management, and Education were obviously lower than the national average service price. Therefore, industries with high (or low) capital input growth and high (or low) capital service prices, such as Coal Mining, Utility, Business Services, and Other Services, contributed to the improvement of capital allocation. Further, industries with high (or low) capital input growth and low (or high) capital service prices, such as Tobacco, Wholesale, Finance, Real Estate, and Public Management, were responsible for the negative reallocation of capital input. Moreover, the aggregate capital reallocation was significantly deteriorated in 2001-2007 and partially improved in 2007-2014.

Figure 7.13 shows the industry level reallocation of labor input, 
\[
\left( \frac{\sigma_i}{\beta_i} \varphi_i^L - \bar{w}_i^L \bar{a}_i^L \right) (\Delta \ln L_i - \Delta \ln L_i),
\]
and two components of this value, 
\[
\left( \frac{\sigma_i}{\beta_i} \varphi_i^L - \bar{w}_i^L \bar{a}_i^L \right)
\]
and 
\[
(\Delta \ln L_i - \Delta \ln L_i)
\]
for three sub-periods. In many industries, especially service sectors, growth rates of labor input were higher than the national average growth of labor input in each period,
particularly in 2001-2007. In addition, service prices of labor input in nearly all industries were higher than the national average service price, whereas in Agriculture, Public Management, Education, Healthcare, and Other Services, they were lower than the national average service price. Therefore, industries with high (or low) labor input growth and high (or low) labor service prices, such as Agriculture, Finance, Real Estate, and Business Services, contributed to the improvement of labor allocation. Further, industries with high (or low) labor input growth and low (or high) labor service prices, such as Public Management, Education, Healthcare, and Other Services, were responsible for the negative reallocation of labor input. Moreover, the labor reallocation was improved in 2001-2007 and deteriorated in 2007-2014.

In order to explore regional origins of the reallocations of capital and labor inputs, as shown in Equation (3.83), Figure 7.14 shows the regional level reallocation of capital input, \( \left( \frac{\omega_j}{\sigma_j} \bar{v}_j^K - \bar{w}_j^K \bar{u}_j^K \right) (\Delta ln K_j - \Delta ln K_j) \), and two components of this value, \( \left( \frac{\omega_j}{\sigma_j} \bar{v}_j^K - \bar{w}_j^K \bar{u}_j^K \right) \) and \( (\Delta ln K_j - \Delta ln K_j) \) for three sub-periods. The growth rates of capital input of nearly half of regions were higher than the national average growth of capital input in 1992-2001 and 2001-2007, and that of many regions further increased in 2007-2014. On the other hand, service prices of capital input in a majority of regions were lower than the national average capital service price, whereas in Guangdong, Zhejiang, Fujian, Jiangsu, and Shandong, they were obviously higher than the national average service price. Therefore, regions with high (or low) capital input growth and high (or low) capital service prices, such as Shanghai, Liaoning, Jiangsu, and Shandong, contributed to the improvement of capital allocation, while regions with high (or low) capital input growth and low (or high) capital service prices, such as Guangdong, Inner Mongolia, and Chongqing, were responsible for the negative reallocation of capital input. Moreover, the aggregate capital reallocation was positive in 1992-2001 and 2001-2007 while turned to be negative in 2007-2014.

Figure 7.15 shows the regional level reallocation of labor input, \( \left( \frac{\omega_j}{\sigma_j} \bar{v}_j^l - \bar{w}_j^l \bar{u}_j^l \right) (\Delta ln L_j - \Delta ln L_j) \), and two components of this value, \( \left( \frac{\omega_j}{\sigma_j} \bar{v}_j^l - \bar{w}_j^l \bar{u}_j^l \right) \) and \( (\Delta ln L_j - \Delta ln L_j) \) for three sub-periods. Although growth rates of labor input in many regions were lower than the national average growth of labor input in 1992-2001, many regions increased in both 2001-2007 and 2007-2014. The service prices of labor input in nearly half of regions, especially in Shanghai, Beijing, Tianjin, Liaoning, and Guangdong, were higher than the national average service price, whereas in Shandong, Jiangxi, Henan, Yunnan, and so on, they were lower than
the national average service price. Therefore, regions with high (or low) labor input growth and high (or low) labor service prices, such as Beijing, Guangdong, and Inner Mongolia, contributed to the improvement of labor allocation. Furthermore, regions with high (or low) labor input growth and low (or high) labor service prices, such as Liaoning, Yunnan, Chongqing, and Anhui, were responsible for the negative reallocation of labor input. Moreover, the aggregate labor reallocation was deteriorated in 2001-2007 and obviously improved in 2007-2014.
Figure 7.12 Industry-level Reallocation of Capital Input

Source: Author’s calculation.
Figure 7.13 Industry-level Reallocation of Labor Input

Source: Author’s calculation.
Figure 7.14 Region-level Reallocation of Capital Input

Source: Author’s calculation.
Figure 7.15 Region-level Reallocation of Labor Input

Source: Author’s calculation.
Chapter 8: Conclusions

This study adds a regional dimension to the whole analytical framework for the following reasons: first, although China has achieved rapid economic growth at national level, there exists wide economic disparity across regions, suggesting that the overall economic development pattern is characterized by growth performance at regional level and driven by the performance of a limited number of local economies within the nation. Second, competition among growth-motivated local governments has, in a large part, accounted for the spectacular economic growth of China during the past four decades (Li and Zhou, 2005; Zhou, 2007; C. Xu, 2011). In order to get promoted, local governors spare no efforts to stimulate regional economic growth because the latter is used as an important indicator for the central government to assess the management ability of local governors. To achieve rapid local economic growth to exceed their peers, local governors have strong incentives to adopt administrative planning or direct interventions to instruct factor inputs to flow into industries or sectors that play a key role in local economies. Given the different geography and industry structures across Chinese regions, industry policies adopted by local officials are different, which creates different influences on industries among regions. Third, compared to factor allocation under the market mechanism, such local governmental interventions have important impacts on the allocation of capital and labor inputs, may cause factor inputs to flow into industries where efficiency is low, which results in a misallocation effect and finally a negative effect on productivity growth. Thus, it is worth adding region to the analytical framework, which is not only beneficial to trace regional origins of aggregate economy and TFP growth in China, but also to provide a better understanding of the growth mode of the Chinese economy.

By extending studies that account for China’s growth and productivity performance at industry level (e.g., H. Wu, 2015b and 2016a), this study follows the Jorgensonian type of growth accounting approach to account for the Chinese economy and TFP growth by further adding a regional dimension. The objective of this study is to account for China’s growth and productivity performance from both region and industry perspectives because the regional distribution of each industry has an important impact on its growth and productivity performance. By adding regional dimension to the whole analytical framework, we can not only explore growth contributions of individual regions to each industry and further to aggregate economy, but also investigate resource reallocation effects across regions and industries simultaneously on aggregate TFP growth.
The APPF approach is adopted to measure TFP growth because it relaxes some stringent assumptions that underlie the widely used APF approach in current studies. The APF approach needs relatively restrictive assumptions, that is, the value added function is identical across all industries and each specific type of capital and labor receives the same service price in all industries. However, in China, where is still in a transitional phase, the intrinsic characteristics and technology levels of each industry determine its corresponding value added production function, which is difficult to be identical across industries. In addition, the assumption that factor inputs receive the same price in all industries overlooks resource reallocations caused by different factor prices across industries in practice. In fact, different technical levels of different industries, as well as the institutional deficiencies and even governmental interventions, are bound to cause different factor prices across industries. Furthermore, the APF approach is based on a net-output (usually value added) production function, which is a function of capital input and labor input while ignores intermediate input. Many studies, however, have recognized the important role of intermediate input in economic growth (e.g., Hulten, 1978; Jorgenson et al., 2005). The aggregate estimates of capital and labor derived by totaling capital and labor inputs across industries are likely to result in the aggregation bias associated with internal shifts in the composition of factor inputs. Consequently, the violation of the underlying assumptions leads to biases in the TFP calculation based on the APF approach.

The APPF approach is still based on the neoclassical growth theory, which needs some necessary assumptions, such as constant returns to scale, and perfect market (Jorgenson and Griliches, 1967; Jorgenson et al., 2005). This approach was proposed by Jorgenson (1966), generalized by Jorgenson and Griliches (1967), developed by Jorgenson et al. (1987), and often used in studies (e.g., Jorgenson et al., 2005; H. Wu, 2015b and 2016a) due to its several advantages. First, it relaxes the above stated two essential assumptions underlying the APF approach. In this case, the growth rate of total output is calculated as a weighted average of growth rates of various individual outputs, and weights are defined by the relative shares of the value of individual outputs in the value of total output. Similarly, the growth rate of total input is calculated as a weighted average of growth rates of various individual inputs, and weights are defined by the relative shares of the value of individual inputs in the value of total input. Second, it is based on a gross output production function, which takes intermediate inputs into account and considers the input-output relationship among industries via intermediate inputs. Finally, by further incorporating Domar weights, this approach can not only trace industry and
region origins of the aggregate economy and overall TFP growth, but also investigate resource reallocation effects across regions and industries on aggregate TFP growth.

According to Jorgenson and Griliches (1967), the proper measurements of output and input data are critical for reliable TFP results, otherwise, it causes a severe mismeasurement of TFP residual. In order to meet the data requirement for conducting productivity analysis at regional level by following the APPF approach, we are the first to follow KLEMS principles to extend the CIP database to regions to construct regional KLEMS dataset, which covers all regions in China’s mainland, and each region consists of relatively detailed sectors, 37 sectors in total. The main procedures to construct the regional KLEMS dataset are illustrated as follows.

As for output data, we first construct time series of labor compensation-value added ratio (LC-VA ratio), value added-gross output ratio (VA-GO ratio), VA share of each industrial sector in the total industry, and VA share of each service sector in the total services by interpolating and extrapolating ratios and shares at benchmark years using regional input-output tables. Then, we take gross value added of three broad industries from regional yearbooks as control totals, that is, primary industry, secondary industry (including industry and construction), and tertiary industry. By multiplying time series of VA shares, we can first obtain time series of VA for both industrial and service sectors. With the VA of primary industry and construction from regional accounts, we get nominal VA for each sector. By further using the LC-VA ratio and VA-GO ratio, we obtain time series of LC and GO. Capital compensation is derived as the residual of VA minus LC, and intermediate input is derived as the residual of GO minus VA. For national totals, we use data from the CIP database based on the work of Wu and Ito (2015). In order to insert regions into the whole accounting framework and keep the accounting identity consistent between the national total and the summation of all regions, we integrate regional accounts with the national account by redistributing the discrepancy between the national account and the summation of all regional accounts into regions using the industry structure of newly constructed regional accounts. This balance approach is also used for capital stock, persons employed, and hours worked later.

In order to conduct the standard double deflation to derive real value added, we construct price deflators for each sector in regions by following the same principles that are used to construct national price deflators. Generally speaking, the regional official PPIs are used for agriculture and industrial sectors. The investment price index of construction and installation is used as PPI of construction sector. The data of relevant components of regional CPI and other price information are employed to construct PPIs for service sectors.
As for capital data, following H. Wu (2015a), we adopt the PIM approach to construct net capital stock of each region. The core variables in the PIM approach are constructed as follows: (1) For industrial sectors in each region, we use the two-period difference of original value of fixed assets as investment flow, add back scrapings and further make two adjustments: one is to remove investment in residential structures, and the other is to add back productive assets not covered by the regional official industry investment statistics. We use newly increased fixed assets as the investment flow for non-industrial sectors. (2) Concerning asset types, we apply the shares of equipment and structure in the total investment of national industrial sectors to regional industrial sectors, and use data from the China Statistical Yearbook of The Tertiary Industry to divide investment flows into equipment and structure for all service sectors. For agriculture and construction, the share of equipment and structure is set at 5:5 because there are no systematic data information about asset decompositions for these two sectors by region. (3) The national depreciation rates of each asset in every sector are applied for regions because no such data are reported in regional official statistics. (4) For the initial capital stock of each region, given that the regional capital data start in 1980, we take the values of equipment and structure by sector in 1980 from the national data and divide these two values into 31 regions by using the regional distribution from the newly constructed regional capital data. (5) We employ the ratio of IPI of equipment of every industrial sector to the aggregate IPI at the national level to construct IPIs of equipment of industrial sectors in each region. The IPI of equipment of non-industrial sectors is the same as the geometric average of that of industrial sectors. We adopt regional IPI of “construction and installation” as the IPI of structure in each region.

As for labor data, following Wu et al. (2015), we first use employment data from regional statistical yearbooks and the population census to construct sectoral employment control totals for each region, and then use various marginal employment matrices to construct full-dimensioned employment matrices (which is cross-classified by two genders, seven age groups, and five educational levels in each industry) for benchmark years by following the IPF approach. Using the sectoral employment control totals and the time series of sector structure of employment by interpolating and extrapolating full-dimensioned employment matrices at benchmark years, we construct time series of full-dimensioned employment matrices for each region. The corresponding hours worked and compensation data of each region are constructed by assuming that the number of average hours worked of each type of labor at the national level is the same as it is in regions, and the ratio of the hourly compensation of each type of
labor to the average wage of its corresponding standard sector at the national level is as same as it is in regions, respectively. Up to this point, we have tied production theory, methodology, and data measurement firmly together for China’s growth and productivity analysis from a regional perspective.

The first observation from the data is that structural change is continuously evolving over time. The data show that there is a pervasive phenomenon that the share of agriculture in each regional economy declines, while that of industries and services increases over time. This follows the general economic development pattern, that is, along with the advancement of technology and the development of society and economy, labor force in agricultural sector shifts to non-agricultural sectors, which promotes the regional industry structure to gradually transform from agriculture to industries and services. Many studies find that such structural change is beneficial to industry structure upgrade and further to economic development (Xu and Zhang, 2016; Cheng et al., 2018; Li et al., 2018; Hao, 2016; Cai, 2017). The regional distributions of each industry at the national level are heterogeneous, which may reflect the initial endowment and comparative advantage of each region. In addition, the value added growth contributions of individual industries to each region and that of each region to the national industry are disparate across industries and regions.

The growth sources of labor productivity across regions and that across industries, respectively, are different. By decomposing labor productivity growth into capital-labor ratio, labor quality, and TFP growth, we find that differences in these three components all contribute to differences in labor productivity growth across regions over time. Differences in the capital-labor ratio make the largest contribution to differences in labor productivity growth across a majority of regions, followed by differences in labor quality, whereas TFP growth has a negative contribution to labor productivity growth in most regions. From the point of view of industry for the whole economy, differences in capital-labor ratio, labor quality, and TFP contribute diversely to differences in labor productivity growth across industries, and differences in labor productivity growth across industries obviously differ from those across regions. Moreover, the growth sources of labor productivity across industries are different. Specifically, the capital-labor ratio growth makes the dominant contribution to labor productivity growth in a majority of industries, such as Agriculture, Coal Mining, Metal Mining, and so on, whereas TFP growth makes the crucial contribution to labor productivity growth of Chemical Materials, Rubber and Plastics, Fabricated Metal Products, and Electronic Equipment, and labor quality growth only makes the dominant contribution to labor
productivity growth of Public Management. On the other hand, decreases in labor productivity growth of some industries, such as Petroleum and Gas, Petroleum Processing, and so on, are completely due to dramatic decreases in TFP growth.

The growth mode of the Chinese economy is input-driven. By decomposing the growth of aggregate value added into capital input, hours worked, labor quality, and TFP growth, the result shows that capital input growth makes the dominant contribution to the growth of aggregate value added, followed by growth in labor quality, TFP, and hours worked. This indicates that the Chinese economic growth mode is still heavily reliant on factor inputs, especially capital input. Such growth mode is not sustainable in the long run given that the amount of factor inputs is finite, and the marginal revenue by one additional unit of factor inputs is diminishing. As for individual industries, industry and services achieve relatively rapid growth in terms of value added, both together make a dominant contribution to the overall economic growth. Moreover, the average annual growth rate of value added of services as a whole is relatively higher than that of industrial sectors, even in the last sub-period. This suggests that the industry structure of the Chinese economy has gradually transformed from agriculture to industry and services, which is conducive to economic growth.

The growth rate of productivity of the Chinese economy is low. The growth rate of aggregate Domar-weighted TFP in the Chinese economy is negative during the entire time period, which is mainly depressed by service sectors in which TFP growth is negative except for Wholesale, and Post. TFP growth in the industry as a whole makes positive contribution to the aggregate Domar-weighted TFP growth. This suggests that although the average annual growth rate of value added of the service industry as a whole exceeds that of the whole industry, its TFP growth is lower than the latter. Furthermore, TFP growth exhibits obvious heterogeneity across industries. The ICT sector, i.e., Electronic Equipment, achieves the fastest TFP growth, which is similar to the finding in Jorgenson et al. (2005). On the contrary, TFP growth in Real Estate is the slowest, which is caused by low growth in real output and rapid growth in factor inputs.

The contributions of individual regions to both value added and productivity growth of each national industry are heterogeneous across regions. The initial endowments are different across regions, and the industry structure and production efficiency are also heterogeneous among regions, which contributes to the disparate economic development across regions and in turn has an important effect on the contribution of each region to both the value added and productivity growth of each national industry. For example, Heilongjiang and Shandong make
a dominant contribution to value added and TFP growth of Petroleum and Gas. Guangdong and Jiangsu make a significant contribution to value added and TFP growth of Electronic Equipment. Due to the uneven economic development and different industry structures across regions, the contributions of each region to aggregate value added and TFP growth are obviously different.

Resource reallocations have remarkable impacts on productivity growth in China. Both reallocation effects of capital and labor inputs on aggregate TFP growth are significant in China. Since capital is heavily affected by administrative planning rather than market mechanisms, it grows relatively slowly in industries with high capital service prices, causing the reallocation of capital to be negative in the whole period. In contrast, the positive labor reallocation mainly benefits from the relaxation of various restrictions on labor mobility, especially the relaxation of the household registration system. The labor market is much less controlled than the capital market, and labor forces can move relatively freely across sectors, which may indicate that labor mobility is more inclined to follow the market mechanisms. As a result, labor grows relatively rapidly in industries with high labor service prices, resulting in the reallocation of labor to be positive in the whole period. Furthermore, both the reallocations of capital and labor have been improved by adding regions to the framework, which may indicate that eliminating barriers to prevent factors of production from flowing across regions is conducive to factor allocations. The TFP growth and, further, the overall economic growth would be boosted by considering China to be a united market and allowing the factors of production to flow freely across sectors and regions. Finally, the significant reallocations of capital and labor inputs have important impacts on aggregate TFP growth. The labor reallocation is the most important source of aggregate TFP growth. The net reallocation of capital and labor inputs is 1.43% on average during 1992-2014, which completely accounts for all aggregate TFP growth.

By exploring the origins of the reallocations of capital and labor inputs, we find that their growth sources are quite disparate from the point of view of industry and regional perspectives, respectively. Generally speaking, industries/regions with high (or low) capital input growth and high (or low) capital service prices contribute to the improvement of capital allocation, and industries/regions with high (or low) capital input growth and low (or high) capital service prices are responsible for the negative reallocation of capital input. This is also the case for labor reallocation. This may indicate that allowing market mechanisms to play a decisive role in allocating factor inputs is helpful to improve efficiency and further TFP growth in China.
In a word, this study has shown that the Chinese economic growth is still heavily reliant on factor inputs, especially capital input. However, the reallocation of capital is negative during the entire time period. This implies that although capital input, mainly subject to administrative planning, can stimulate rapid economic growth, it is not conducive to TFP growth because it cannot follow the market mechanism to flow from industries where the service price or user cost is low into industries where the service price is high. On the contrary, the reallocation of labor is positive, and makes a dominant contribution to aggregate TFP growth during the entire time period. This is benefited from relaxations on labor mobility so that labor force can follow the market mechanism to flow from industries where the service price is low into industries where the service price is high. Furthermore, by taking regional effect into account, this study shows that even if factor inputs are confined in industries where their service prices are low, they still can follow the market mechanism to flow into regions where the service price is high. As a result, both reallocations of capital and labor are improved by considering the regional dimension. Therefore, China still needs to improve technology to gradually transform the input-driven growth mode to a productivity-driven one. Meanwhile, China not only needs to reduce governmental interventions on market activities and to eliminate barriers that prevent factor inputs from freely flowing across regions and industries, but also to let the market play a decisive role in allocating factor inputs, all of which are not only beneficial to productivity improvement, but also to facilitate the Chinese economy to achieve rapid growth in the long run.

It is better to understand the results in this study by comparing it with studies that are based on industry level without considering a regional dimension (e.g., H. Wu, 2015b and 2016a). This study provides a new perspective to understand the growth mode of Chinese economy, that is, a regional perspective, because the contributions of individual regions to both value added and productivity growth of each national industry are heterogeneous across regions. Due to local governments heavily intervene in market activities to pursue rapid local economic growth under the strong pressure to compete with their peers, one can argue that such competition among growth-motivated local governments may solve the growth problem but not efficiency problem because the governmental interventions on factor allocation, compared to factor allocation under the market mechanism, may cause factor inputs to flow into industries where efficiency is low, which results in a misallocation effect and finally a negative effect on productivity growth. The results of this study demonstrate that the whole Chinese economy has achieved rapid economic growth (i.e., 8.73% per annum), which is mainly contributed from
capital and labor inputs, but low productivity growth (i.e., 0.62% per annum) over 1992-2014. The annual growth rate of TFP is obviously lower than that in the existing studies (see Tables 2.1 and 2.2), and more specifically, the growth rate of Domar-weighted TFP by aggregating TFP growth across industries and regions is negative. As for the factor allocation, due to capital is much controlled by administrative planning, although its flow across regions can to some extent make up for its misallocation at industry level, the total capital reallocation is still negative over 1992-2014. On the other hand, thanks to the relaxation of regulations on labor mobility, labor market is much less controlled than capital market, labor force can flow into industries where its user cost is higher. Moreover, they can further flow to regions where they find a better position with a higher compensation. Both of which remarkably contribute to labor reallocation, which further has a significant effect on aggregate TFP growth. Thus, this study states that it is helpful to form a comprehensive understanding of the Chinese growth mode by taking the roles of regional economies and governments into account.

Some attentions should be given to the limitations of this study. The analytical framework of measurements of aggregate output and TFP growth in this study is based on the neoclassical growth theory, which needs some necessary assumptions, such as constant returns to scale, and perfect market (Jorgenson and Griliches, 1967; Jorgenson et al., 2005). It is readily understandable that the errors of measurement arise if these conditions are not fulfilled. Suppose that there are increasing returns to scale, the direct deflation of value added understates the growth of a true index of value added. The double deflation can avoid such bias at a cost of gross output production function needs to be separable. However, some researchers (e.g., Denny and May, 1978) find that the assumption of separability of gross output production function cannot be met in reality. Moreover, under the conditions of imperfect competition and supplier exploitation, the relative market price of intermediate inputs is taken as its marginal product, the true contribution of intermediate inputs is underestimated and thus gross output is overestimated. How this biases the net output index is in part dependent upon the way of the elasticity of output with respect to intermediate inputs varies over time.

As pointed out by David (1966), the concept of net output, being abstract and theoretical in nature, requires that some theoretical conditions must be satisfied if it is to be quantified in a well-defined and accurate manner. It turns out that the simplest theoretical conditions whose fulfillment would be sufficient for precise unambiguous measurements, i.e., perfect competition, and constant returns to scale, are themselves frequently assumed by economists in the course of analysis of both micro- and macro-economic production relationships.
The reliable measurement of productivity growth is also dependent on the availability of and quality of data. Due to limited availability of regional data reported in official statistical yearbooks, we construct regional productivity accounts based on assumptions to some extent. For example, given that official statistics do not report PPIs for service sectors, the PPIs of service sectors are constructed by using regional CPI and its relevant components. Compared to official GDP deflators, which are often used in the existing studies, our alternatives show faster increases in price indexes. As a result, the growth of real output in service sectors has a downward tendency compared to studies that adopt GDP deflators as the PPIs of service sectors. On the other hand, TFP growth is calculated as a residual of output growth not explained by growth of capital input, labor input, and intermediate input. The proper measurement of quality changes of factor inputs is crucial for precise TFP residual. We construct cross-classified labor data in details, which is conducive to measure changes in human capital across regions. For capital data, we only have two types of capital assets, which may understate quality changes of capital input because many studies find that the ICT equipment has played a critical role in economic growth in past two decades (e.g., Jorgenson et al., 2005). Consequently, the corresponding present results may overestimate TFP growth in China.

It is worth noting that in many regards the analysis here only represents the starting point to account for China’s growth and productivity performance from both region and industry perspectives. Much work remains to be done, for example, regrouping regions and industries to provide a growth story of the Chinese economy from a regional perspective, adding ICT assets in capital data, and extracting the portion of state-owned enterprises to characterize impacts of governmental interventions on market activities. These issues are left for future research.
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### Appendix

**Table A1 CIP Industry Classification and Codes**

<table>
<thead>
<tr>
<th>CIP Code</th>
<th>Industry Description</th>
<th>Short Names</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Agriculture, Forestry, Animal Husbandry and Fishery</td>
<td>Agriculture</td>
</tr>
<tr>
<td>2</td>
<td>Mining and Washing of Coal</td>
<td>Coal Mining</td>
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<tr>
<td>3</td>
<td>Extraction of Petroleum and Natural Gas</td>
<td>Petroleum and Gas</td>
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<tr>
<td>4</td>
<td>Mining of Metal Ores</td>
<td>Metal Mining</td>
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<tr>
<td>5</td>
<td>Mining of Nonmetallic Ores and Other Ores</td>
<td>Nonmetal Mining</td>
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<tr>
<td>6</td>
<td>Manufacturing of Foods</td>
<td>Food</td>
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<tr>
<td>7</td>
<td>Manufacturing of Cigarettes and Tobacco</td>
<td>Tobacco</td>
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<tr>
<td>8</td>
<td>Manufacturing of Textile</td>
<td>Textile</td>
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<tr>
<td>9</td>
<td>Manufacturing of Textile Wearing Apparel and Ornament</td>
<td>Wearing Apparel</td>
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<tr>
<td>10</td>
<td>Manufacturing of Leather, Fur, Feather and Their Products, and Footwear</td>
<td>Leather and Fur</td>
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<tr>
<td>11</td>
<td>Processing of Timbers, Furniture</td>
<td>Timbers and Furniture</td>
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<tr>
<td>12</td>
<td>Manufacturing of Paper, Printing</td>
<td>Paper and Printing</td>
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<tr>
<td>13</td>
<td>Processing of Petroleum, Coking</td>
<td>Petroleum Processing</td>
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<tr>
<td>14</td>
<td>Manufacturing of Chemical Raw Materials and Chemical Products</td>
<td>Chemical Materials</td>
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<tr>
<td>15</td>
<td>Manufacturing of Rubber and Plastics Products</td>
<td>Rubber and Plastics</td>
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<td>16</td>
<td>Manufacturing of Non-metallic Mineral Products</td>
<td>Non-metallic Products</td>
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<td>17</td>
<td>Manufacturing and Pressing of Metals</td>
<td>Metal Pressing</td>
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<tr>
<td>18</td>
<td>Manufacturing of Fabricated Metal Products</td>
<td>Fabricated Metal Products</td>
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<tr>
<td>19</td>
<td>Manufacturing of General and Special Equipment</td>
<td>General Equipment</td>
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<td>20</td>
<td>Manufacturing of Electrical Machinery and Equipment</td>
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<td>21</td>
<td>Manufacturing of Computers, Communication Equipment and Other Electronic Equipment</td>
<td>Electronic Equipment</td>
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<td>22</td>
<td>Manufacturing of Instrumentation, and Culture, Office Machinery</td>
<td>Instruments</td>
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<tr>
<td>23</td>
<td>Manufacturing of Transportation Equipment</td>
<td>Transportation Equipment</td>
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<tr>
<td>24</td>
<td>Other Manufacturing</td>
<td>Other Manufacturing</td>
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<td>25</td>
<td>Production and Distribution of Electricity, Heating Power, Gas and Water</td>
<td>Utility</td>
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<tr>
<td>26</td>
<td>Construction</td>
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<td>27</td>
<td>Wholesale and Retail Trades</td>
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<td>Transportation and Storage</td>
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<td>30</td>
<td>Post and Telecommunication</td>
<td>Post</td>
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<td>Finance</td>
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<td>Real Estate</td>
<td>Real Estate</td>
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<tr>
<td>33</td>
<td>Leasing, Technical, Science and Business Services</td>
<td>Business Services</td>
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<td>34</td>
<td>Public Management and Social Organizations</td>
<td>Public Management</td>
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<td>35</td>
<td>Education</td>
<td>Education</td>
</tr>
<tr>
<td>36</td>
<td>Health and Social Welfare Services</td>
<td>Healthcare</td>
</tr>
<tr>
<td>37</td>
<td>Other Services</td>
<td>Other Services</td>
</tr>
</tbody>
</table>

Source: From CIP database with modification.
Figure A1 Changes in Value Added Shares of Individual Industries in Regions

Notes: (1) The total value added of a region equals one. (2) The order of regions is ranked by nominal value added per hour worked of 1992.
Source: Author’s calculation.
Figure A1 (Continued)
Figure A1 (Continued)
Figure A1 (Continued)
Figure A2 Changes in Value Added Shares of Individual Regions in Industries

Note: The total value added of an industry equals one.
Source: Author’s calculation.
Figure A2 (Continued)
Figure A2 (Continued)
Figure A2 (Continued)
Figure A3 Value Added Growth Contribution of Industries to Regions (%)
Figure A3 (Continued)
Figure A3 (Continued)
Figure A3 (Continued)
Figure A4 Value Added Growth Contribution of Regions to Industries (%)

Source: Author’s calculation.
Figure A4 (Continued)
Figure A4 (Continued)
Figure A4 (Continued)
Figure A5 Comparisons between Alternative PPIs and Official Ones of Service Sectors, 1990=100

Note: The alternative PPIs are a geometric average of PPIs of individual service sectors in each region. The official PPIs are implicit value added deflators.
Source: Author’s calculation.
Figure A6 TFP Growth Contribution of Regions to Industries (%)

Source: Author’s calculation.
Figure A6 (Continued)
Figure A6 (Continued)
Figure A6 (Continued)