Labor Inputs and Productivity in Chinese Industries: 2000–2018

Menggen Chen, Yuanyuan Hou*

Under the framework of growth accounting, this paper introduces four heterogeneity characteristics of labor, namely, educational level, age, gender and industry, constructs a cross classification matrix of employment, labor compensation and working hours, and calculates the labor input (volume) of the whole country and of 19 industries during 2000–2018. Then it decomposes the volume into quantity and quality parts to analyze the total amount of labor input and the performance of industry labor input. The results are as follows. First, during the research period, the annual growth rate of labor input was 2.5%, and 78.8% of that came from the growth of labor input quality. The growth of labor input was mainly resulted from the improvement of educational level and the optimization of industrial structure. Second, in 2018, the proportions of labor input of the primary, secondary and tertiary sectors were 13.76%, 31.06% and 55.18% respectively, and the transfer speed of labor input to the secondary and tertiary sectors was higher than that of the quantity structure; the labor input volume in the new economy and related industries in the tertiary sector has been greatly increased. Third, the index method-based labor productivity (ILP) of some producer service and consumer service industries was relatively low, and the growth of total industry output mainly attributed to the increase of labor input and the expansion of industrial scale. The improvement of labor input quality has become the key to the growth of labor input in China, and the improvement of educational level is the core power to improve the labor input quality.

Keywords: labor input volume, labor input quality, labor productivity, total employment, working hours

1. Introduction

Since the implementation of reform and opening up policy in 1978, China's economy has grown rapidly. Especially during 1978–2010, the annually growth rate reached 10.02%, which is a growth miracle in the human development history. The unique volume and structure characteristics of population during this period (i.e. demographic

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dividend) provide necessary condition for the high growth of China's economy. Since 2011, the share of working-age population (from the age of 15 to 65) showed a decreasing trend and the growth rate of total population and labor force slowed down. Correspondently, China's economic growth rate declined from 10.6% in 2010 to 6.0% in 2019, which signals that both the total population and economy in China entered into the new normal. According to a research by United Nation,[1] the total population in China would reach the peak in 2030 and the old-age dependency ratio (ODR) would keep increase continuously. There is no doubt that population growth rate would slowed down and the population is facing aging trend. Labor quality and its matched industries may become the core momentum of how labor factor promoting economic growth.

This paper constructs a measurement framework of labor input and labor productivity at the level of industry and total volume, and analyzes the industrial labor input in China from 2000 to 2018 and its impact on labor productivity and economic growth. The contribution of this paper is as follows. First, the labor input is calculated under the framework of national economic accounting, that is, taking the output of the production method and structure in the accounting of the gross domestic product (GDP) as total value control, this paper conducts corresponding data of total employment and industrial structure and establishes the multi-dimensional cross classification matrix of labor characteristics at the industrial level. Second, the matching cross classification matrix of working hours and labor compensation is constructed with the available data including the census and 1% population sampling survey, the national and industrial level statistics, the data of average weekly working hours from the urban employment survey and the Chinese General Social Survey (CGSS). Third, in view of less attention paid to the service industry in the previous related literature, this paper investigates the labor input of 19 industry categories, and focuses on the development and change of labor input and labor productivity in the service industry. Fourth, this paper constructs and calculates three labor productivity with total employment, working hours and index method-based labor input as the labor input indicators respectively, namely, the traditional labor productivity (NLP), the labor productivity per unit time (ALP) and the the index method-based labor productivity (ILP), to compare their differences and application values; it investigates the influence of the change of national and industrial labor input on the labor productivity and economic growth with the latest data.

2. Literature Review

2.1. Index Method-Based Labor Input

The concept of labor input quality and measurement of labor input are first proposed

[1] UNDESA. (2019). World Population Prospects: 2019 Revision. https://population.un.org/wpp/Publications/.

by Denison (1961). Denison realized the heterogeneity of labor force, decomposed the increase of labor input into increasing of working hour and labor productivity, and proposed the index method-based theory to measure the labor input growth rate at the aggregated level. Afterwards, a series of research from Jorgenson and Griliches (1967), Chinloy (1980), Gollop and Jorgenson (1983) and Jorgenson *et al*. (1987), established the index method-based labor input measurement method. By bringing in the concept of index theory and labor input quality and taking the value share of labor input as weights, this method transforms labor input into labor input volume by weighting the heterogeneous labor working hours.

Based on the productivity measurement of traditional growth accounting and development of new-classical economic growth theory,[1] Jorgenson and Griliches (1967) combined investment theory, index theory, national economy accounting system and micro production theory to construct growth accounting framework with consideration of labor and capital heterogeneity. This accounting framework is used to measure output, input (capital and labor) and total factor productivity (TFP). This study proposed the Divisia index method-based measurement of labor input, which defines labor input as the weighted sum of labor working hours of different labor inputs according to the classification of gender and years of schooling. Gollop and Jorgenson (1983) applied the trans-logarithmic function to measure the growth rate of labor input at the industrial level. Jorgenson *et al*. (1987) systematically discussed the theory of TFP measurement at the industrial level and data generation process of input indicators, which laid the foundation of the current research of productivity and economic growth using growth accounting framework.

The measurement theory of index method-based labor input takes full consideration of labor input quality, which is widely recognized by government statistical institutions and scholars from all over the world (Wu *et al*., 2015). For instance, the Bureau of Labor Statistics in the US adopts the measurement in TFP estimation and regards it as the official measurement. "Measuring Productivity OECD Manual" released by OECD introduced this growth accounting framework and introduced in detail the measurement process of input indicators such as labor inputs and five measurement method of productivity (OECD, 2001). In the process of TFP measurement at the aggregated and industrial level, Jorgenson *et al*. (2005) estimated the labor input of the US from 1977 to 2000 and decomposed the labor input quality. One important achievement of the application of the growth accounting framework is the world KLEMS initiative and the construction of its database (mainly the EU KLEMS database), which includes the measurement of labor input.

There are relatively fewer domestic literature on the impact of structural characteristics on labor input. Young (2003) estimated the total volume of labor input and labor input

[1] The method before growth accounting framework was named as traditional growth accounting method by Jorgenson (1980). In traditional growth accounting method, capital and labor were regarded as homogenous, which neglected the quality differences of capital and labor and their impact on growth rate.

in non-agricultural industries from 1978 to 1998 from three dimensions of gender, age and educational level. By introducing industrial dimension, Yue and Ren (2008) reached the result that the growth rate of labor input in China from 1982 to 2000 was 3.23% and the growth rate of total employment was 1.8%. Holz (2005) compared the data in census in 1982, 1990 and 2000 with those in 1% population sampling survey in 1987 and 1995 and those in 1‰ population sampling survey, and constructed the "age×educational level" cross classification data at the aggregated level. By combining output and capital data, Holz (2006) further estimated labor productivity and TFP at three different levels of aggregation, three sectors and detailed industries. Moreover, Wu and Yue (2003, 2012) constructed the matrix of employee and labor compensation from 1949 to 2009 and estimated the change of labor input and quality for 24 industries. It is worth noting that Wu *et al*. (2015) analyzed the caliber, scope and classification characteristics of Chinese statistical data and estimated the labor input of the whole economy and 37 industries from 1980 to 2010, by using the cross classification matrix of labor characteristics of gender, age, educational level and industry, estimated by the iterative proportional method. This study is the one with the relatively detailed description of statistical data process by far and is also the source of Chinese data for world KLEMS database.

2.2. Labor Input and Labor Productivity

Theoretically, labor productivity is the ratio of labor production (that are created by labor force over a period of time) to labor input. During the calculation process, the labor production is usually presented by outputs at constant price, while labor inputs have many different numerical indicators. This results in different labor productivity with different contents. Chinese literature on labor productivity usually takes the number of employee as the labor input to calculate the traditional labor productivity (i.e. NLP) or takes total working hours as labor input to calculate the labor productivity per unit time (i.e. ALP). These researches mainly focus on the impact on economic growth of factors of population characteristics, such as educational level, market allocation of labor force, aging, and factors of non-population characteristics, such as industrial structural transformation and environmental regulation.

As for the researches on labor productivity, the impact of population characteristics of labor force cannot be neglected. When analyzing and estimating the output and labor productivity in the US by using the production possibility frontier (PPF), Jorgenson *et al*. (2002) defined the labor productivity as the ratio of output to total working hours and decomposed the changes of ALP into the contribution of three factors, which were labor input quality, capital deepening and TFP. Among them, labor input quality was the measurement result of index method-based labor input, which realized the effective separation of labor input quality and other impact factors. "Measuring Productivity OECD Manual" defines ILP as the ratio of outputs to labor input volume, which can effectively eliminate the effect of labor input quality and make ILP mainly represent the combined effect of changes in capital inputs, technique, organization and efficiency. This method has the advantage on data acquisition and measurement, since it does not need the calculation of other factors when estimating the ILP at industrial level.

Limited by the data availability, researches on estimation and application of index method-based labor input in China are relatively rare, especially at the industrial level. Even in the relatively comprehensive research (Wu *et al*., 2015), the cross classification matrix of labor characteristics was numerically simplified and the classification of services was incomplete, where leasing and business service industry (L), scientific research and technology service industry (M) and culture, sports and recreation service industry (R) were not included.

3. The Measurement Framework of Index Method-Based Labor Input and Labor Productivity Model

3.1. Index Method-Based Labor Input and Quality Decomposition Model

3.1.1. Labor Input Measurement

Referring to Christensen *et al*. (1973) and Wu *et al*. (2015), we define the labor input function with a trans-logarithmic formation, that is, at time t, we have

$$\ln L_t^i = \alpha_0^i + \sum_{l=1}^{n} \alpha_i^i \ln H_{lt}^i + 1/2 \sum_{l=1}^{n} \sum_{j=1}^{n} \beta_{lj}^i \ln H_{lt}^i \ln H_{jt}^i \tag{1}$$

where, α_0^i, α_l^i and β_{lj}^i $(l, j = 1, 2, \dots n)$ are non-time-varying parameters and $\beta_{lj}^i = \beta_{jl}^i$. When the function is linear and homogeneous, these parameters satisfy the conditions: $\sum_{l=1}^{n} \alpha_l^i = 1, \sum_{j=1}^{n} \beta_{lj}^i = 0$. Then, the value share of labor of type l in industry i can be obtained as:

$$v_{lt}^i = \alpha_l^i + \sum_{j=1}^{n} b_{lj}^i \ln H_{jt}^i \tag{2}$$

At the same time, we have $v_{lt}^i = w_{lt}^i H_{lt}^i / \sum_{j=1}^{n} w_{lt}^i H_{lt}^i$. Then, the growth rate of labor input in industry i can be expressed as:

$$\frac{\partial \ln L_t^i}{\partial t} = \sum_{l=1}^{n} v_{lt}^i \frac{\partial \ln H_{lt}^i}{\partial t} \tag{3}$$

According to Chinloy (1980) and Jorgensen *et al*. (1987), for labor input in trans-logarithmic function form, the Törnqvist index method-based growth rate can be expressed as:

$$\Delta \ln L_t^i = \sum_{l=1}^{n} \bar{v}_{lt}^i \Delta \ln H_{lt}^i \tag{4}$$

where $\bar{v}_{lt}^i = (v_{l,t-1}^i + v_{lt}^i)/2$ and $\sum_{l=1}^{n} \bar{v}_{lt}^i = 1$. As a result, the growth rate of labor input can be viewed as a convex combination of the growth rate of working hours of different labor type, where the weights are labor income share (Wu *et al*., 2015). According to Jorgenson *et al*. (2005) and $p_t^{Li} L_t^i = \sum_{l=1}^{n} w_{lt}^i H_{lt}^i$, when the labor input price $p_{t_0}^{Li}$ at time t_0 is set as 0, then the labor input volume at time t_0 is

$$L_{t_0}^i = \sum_{l=1}^{n} w_{lt_0}^i H_{lt_0}^i \tag{5}$$

Along with the growth rate of labor input in equation (4), one can obtain the labor input volume at time t_0 as well as the price index:

$$L_t^i = \begin{cases} L_{t_0}^i \prod_{m=t_0+1}^{t} (1 + \Delta \ln L_m^i) & t > t_0 \\ L_{t_0}^i & t = t_0 \\ \dfrac{L_{t_0}^i}{\prod_{m=t}^{t_0} (1 + \Delta \ln L_m^i)} & t < t_0 \end{cases} \tag{6}$$

$$p_t^{Li} = \frac{\sum_{l=1}^{n} w_{lt}^i H_{lt}^i}{L_t^i} \tag{7}$$

3.1.2. Labor Input Quality and Its Decomposition

Define the total working hour of the labor force in industry i (H_t^i) as the simple sum of working hours of different labor type, $H_t^i = \sum_{l=1}^{n} H_{lt}^i$. Then the labor input quality can be expressed as $Q_t^i = L_t^i / H_t^i$, and the growth rate of labor input quality is[1]

[1] The total working hour (H_t^i) can be decomposed into number of employee and working hour per person, that is, $H_t^i = N_t^i \times T_t^i$. Then the growth rate of labor input can be expressed as $\Delta \ln L_t^i = \Delta \ln Q_t^i + \Delta \ln N_t^i + \Delta \ln T_t^i$.

$$\Delta \ln Q_t^i = \Delta \ln L_t^i - \Delta \ln H_t^i \tag{8}$$

To decompose the growth rate of labor input quality, we first need to construct the partial index of labor input. At the industrial level, we investigate the cross classification of three characteristics of labor force: educational level (*e*), age (*a*) and gender (*g*). Denote H_{eag}^i as the total working hour of labor type *l* in industry *i* (similarly, the subscript *l* in previous part can be replaced with *eag*) and denote v_{eag}^i as the value share of each heterogeneous labor type.

The basic idea behind the decomposition of growth rate of labor input quality is as follows. First, select one labor characteristic (for instance, *e*) and then add up the total working hours and value shares of other labor characteristics (for instance, *a* and *g*). We arrive at H_e^i and v_e^i with only one characteristic dimension. Then, the corresponding growth rate of labor input can be obtained as $\Delta \ln L_{et}^i = \sum_e \bar{v}_{et}^i \Delta \ln H_{et}^i$. In a similar way, if working hours and value share of only one characteristic are aggregated, one can get the second-order index as well as the seven partial index of labor input $(\Delta \ln L_e^i, \Delta \ln L_a^i, \Delta \ln L_g^i, \Delta \ln L_{ea}^i, \Delta \ln L_{eg}^i, \Delta \ln L_{ag}^i, \Delta \ln L_{eag}^i)$. Therefore, the corresponding contribution of first-order (for instance, *e*), second-order (for instance, *ea*) and third-order can be expressed as:

$$\Delta \ln Q_{et}^i = \Delta \ln L_{et}^i - \Delta \ln H_t^i \tag{9}$$

$$\Delta \ln Q_{eat}^i = \Delta \ln L_{eat}^i - \Delta \ln Q_{et}^i - \Delta \ln Q_{at}^i - \Delta \ln H_t^i \tag{10}$$

$$\Delta \ln Q_{eagt}^i = \Delta \ln L_{eagt}^i - \Delta \ln Q_{et}^i - \Delta \ln Q_{at}^i - \Delta \ln Q_{gt}^i - \Delta \ln Q_{eat}^i - \Delta \ln Q_{egt}^i - \Delta \ln Q_{agt}^i - \Delta \ln H_t^i \tag{11}$$

Then, the growth rate of labor input quality in each industry can be decomposed into the contribution of seven factors, which are $\Delta \ln Q_e^i, \Delta \ln Q_a^i, \Delta \ln Q_g^i, \Delta \ln Q_{ea}^i, \Delta \ln Q_{eg}^i$, $\Delta \ln Q_{ag}^i$ and $\Delta \ln Q_{eag}^i$. Among then, the first three are the main effects and the rest are interaction effects. If we take industry *i* as a characteristic at the aggregated level, then the labor input at the aggregated level can be constructed and its quality can be decomposed, which reflects the influence of industrial characteristics on the labor inputs at the aggregated level.

3.2. The Construction and Comparison of Measurement Model of Labor Productivity

3.2.1. Industrial Labor Productivity

"Measuring Productivity OECD Manual" defines labor productivity on the basis of labor input volume, that is, index method-based labor productivity (ILP). At the industrial level, define ILP^i as the ratio of output and labor input ($ILP_t^i = Y_t^i / L_t^i$), then its growth rate is obtained as:

$$\Delta\ln ILP_t^i = \Delta\ln Y_t^i - \Delta\ln L_t^i \tag{12}$$

where $\Delta\ln Y_t^i$ is the growth rate of industrial output at constant price. To decompose industrial total working hour, denote $H_t^i = T_t^i \times N_t^i$, where, T_t^i is working hour per labor input and N_t^i is the number of employee. Then, $\Delta\ln H_t^i = \Delta\ln T_t^i + \Delta\ln N_t^i$. Suppose the growth rate of traditional industrial labor productivity ($NLP_t^i = Y_t^i / N_t^i$) is $\Delta\ln NLP_t^i = \Delta\ln Y_t^i - \Delta\ln N_t^i$, then the growth rate of labor productivity per unit time ($ALP_t^i = Y_t^i / H_t^i$) is expressed as $\Delta\ln ALP_t^i = \Delta\ln Y_t^i - \Delta\ln H_t^i$. With equation (8) and (12), we can derive the relationship among NLP^i, ALP^i and ILP^i:

$$\Delta\ln NLP_t^i = \Delta\ln ALP_t^i + \Delta\ln T_t^i = \Delta\ln ILP_t^i + \Delta\ln T_t^i + \Delta\ln Q_t^i \tag{13}$$

where $\Delta\ln ALP_t^i = \Delta\ln ILP_t^i + \Delta\ln Q_t^i$. The above equation reveals that inherent numerical relationship among labor productivity based on number of employee (*NLP*), labor productivity based on working hours (*ALP*) and labor productivity based on index method (*ILP*). It is obvious that $\Delta\ln ILP_t^i$ effectively separates labor input quality ($\Delta\ln Q_t^i$) and working hour per person ($\Delta\ln T_t^i$) form the traditional labor productivity ($\Delta\ln NLP_t^i$), which makes the $\Delta\ln ILP_t^i$ only reveal the impact of capital inputs and technical changes (other than the labor characteristics) of each industry on economic growth. $\Delta\ln ALP_t^i$ effectively separates the impact of working hour per person and only reveals the impact of non-labor-characteristics ($\Delta\ln ILP_t^i$) and labor input quality ($\Delta\ln Q_t^i$).

3.2.2. Aggregated Labor Productivity

Jorgenson *et al*. (2005) pointed out that, when constructing the labor input indicator at the aggregated level, one can regard industry as a characteristic to revel the impact of industrial factors. However, the method cannot define the aggregated production function well. This paper calculates the aggregated labor productivity based on the method of adding up industrial labor productivity (ILP^i) proposed in "Measuring Productivity OECD Manual". At the aggregated level, the growth rate of output is expressed as the weighted sum of each industrial growth rate of output at constant price:

$$\Delta\ln Y_t = \textstyle\sum_i v_{it}^Y \Delta\ln Y_{it} \tag{14}$$

where $v_{it}^Y = p_{it}^Y Y_{it} / \sum_i p_{it}^Y Y_{it}$ represents the value share of industrial output in total output. p_{it}^Y and Y_{it} are the output price and output at constant price at time *t*. Similarly, growth rate of aggregated labor input can be expressed as the weighted sum of growth rate of industrial labor input:

$$\Delta \ln L_t = \sum_i v_{it} \Delta \ln L_{it} \tag{15}$$

where $v_{it} = p^L_{it} L_{it} / \sum_i p^L_{it} L_{it}$ represents the value share of industry i in total labor force. p^L_{it} and L_{it} are the labor input price and volume of industry i at time t. Meanwhile, $p^L_{it} L_{it} = w_{it} H_{it} = \sum_l w^i_{it} H^i_{it}$, where w_{it} is the hourly wage of labor in industry i and total labor income in industry i is $w_{it}H_{it}$. Then, the growth rate of index method-based labor productivity at the aggregated level can be expressed as:

$$\begin{aligned} \Delta \ln ILP_t &= \Delta \ln Y_t - \Delta lnL_t = \sum_i v^Y_{it} \Delta \ln Y_{it} - \sum_i v_{it} \Delta \ln L_{it} \\ &= \sum_i v^Y_{it} \Delta \ln ILP^i_t + \sum_i (v^Y_{it} - v_{it}) \Delta \ln L_{it} \\ &= ILPIE + RE \end{aligned} \tag{16}$$

The above equation decomposes the ILP at the aggregated level into the aggregated effect of ILP^i of each industry ($ILPIE$) and redistribution effect (RE). Among them, $ILPIE = \sum_i v^i_{it} \Delta \ln ILP^i_t$ is the weighted average of labor productivity of each industry with the value share of output as weights. The redistribution effect $RE = \sum_i (v^Y_{it} - v_{it}) \Delta \ln L_{it}$ shows that when industry i's value share of output is higher than that of labor input, that is, $(v^Y_{it} - v_{it}) > 0$, then the redistribution effect of labor transferring to this industry is positive. This means that when the resources go to industries with higher productivity, then the redistribution of labor input would increase the ILP at the aggregated level. According to equation (6) and (14), the traditional labor productivity at the aggregated level ($NLP_t = Y_t / N_t$) can be decomposed into the impacts of ILP, working hours per person and labor input quality. Denote the total working hours at the aggregated level as $H_t = T_t \times N_t$, then

$$\begin{aligned} \Delta \ln NLP_t &= \Delta \ln Y_t - \Delta \ln N_t = \Delta \ln ILP_t + \Delta \ln L_t - \Delta \ln N_t \\ &= \Delta \ln ILP_t + (\Delta \ln L_t - \Delta \ln N_t - \Delta \ln T_t) + \Delta \ln T_t \\ &= \Delta \ln ILP_t + \Delta \ln Q_t + \Delta \ln T_t \end{aligned} \tag{17}$$

where $\Delta \ln Q_t = \Delta \ln L_t - \Delta \ln N_t - \Delta \ln T_t$ represents the impact of labor input quality at the aggregated level. $\Delta \ln T_t$ is the impact of working hour per person. Similarly, for ALP_t ($= Y_t / H_t$), we have $\Delta \ln ALP_t = \Delta \ln ILP_t + \Delta \ln Q_t$.

4. Result Analysis of Labor Input and Structural Decomposition

4.1. The Construction of Cross Classification Matrix of Labor Characteristics and Data Specification

The difficulty of measuring index method-based labor input is the construction of cross classification matrix of labor characteristics, including number of employee (N_{ieag}), working hours (H_{ieag}), and labor compensation (W_{ieag}). This paper classifies labor force according to the three population characteristics, namely educational level (e), age (a), and gender (g), and makes the N_e, N_a and Ng satisfy the marginal structure of aggregated labor force documented in *Chinese population and employment statistical yearbook*. At the same time, we make sure that the total numbers are consistent with national economy accounting framework, with number of employees and labor income at both aggregated and industrial level as controls. As shown in Table1, the labor characteristics are classified into two genders, 7 levels of educational level, 11 age groups and 19 industries (GB/T4754 2017), which classified into 2926 units. Based on this, labor inputs and quality decomposition are estimated, which are used to capture the impact of labor heterogeneity on labor inputs.

Table 1. The Classification Structure of Labor Characteristics

Gender	Educational level	Age	Industrial classification			
Male	1 Never went to school	16~19	Primary sector	A Farming, forestry, animal husbandry and fishery	Consumer Services	H Hotel and restaurants
Female	2 Primary school	20~24	Secondary sector	B Mining		K Real estate
	3 Middle school	25~29		C Manufacturing		O Resident services, repairand other services
	4 High school	30~34		D Production and supply industry of electricity,heat, gas and water		
	5 Junior college	35~39				R Culture, sports and recreation service industry
	6 Bachelor degree	40~44		E Construction	Other Services	N Water, environment, and Public facilities management industry
	7 Postgraduate and above	45~49	Producer services	F Wholesale and retail		
		50~54		G Transportation, storage and post		P Education
		55~59		I Transmission of information, software, and information technology services Industry		Q Health and social work
		60~64		J Finance		S Public administration, social security and social organizations (including international organizations)
		65 and above		L Leasing and business service industry		
				M Scientific Research and technology service industry		

4.2. Aggregated Labor Input and Structural Decomposition

Labor income is the total value received by labor inputs, which can be decomposed into labor input (volume) and labor input price index, or decomposed into total working hours (number of employee and working hour per person) and hourly income per person. Table 2 lists the labor input and each kind of basic indicators at the aggregated level. The main changes and relationships of each indicator are as follows.

First, during the sample period, the labor input in China showed a growth trend with some fluctuations. Influenced by the global financial crisis in 2008, the working hour per person showed an U-shape from 2005 to 2010, where the working hour per person in 2008 was the lowest with 44.76 hours per week. This resulted in the short-term decline and increase in labor input and total working hours in the corresponding years. The differences in working hour per person in each year led to larger fluctuations in annually growth rate of total working hours than that of total number of employee, which implies that using number of employees as labor input quantity would bring some errors. Furthermore, since the growth rate of number of employees in China declined continuously and first showed negative in 2018, using number of employees to measure labor input would create a false impression that the labor input in China has reached the peak.

Second, the annually growth rate of total labor income was 12.07%, which kept relatively high over the sample period. Among them, the annually growth rate of labor input price index, which reflects the impact of non-population-characteristics on labor input price, was 9.63% and became the main reason for the high growth rate of labor compensation. In contrast, the hourly compensation per person without getting rid of the influence of labor input quality increased from 3.15 to 25.12, with the annually growth rate as 11.54%. On the one hand, the rapid growth rate of hourly compensation per person represents the significant increase in labor cost. On the other hand, the difference between the growth rate of hourly compensation per person and that of labor input price index is due to the labor compensation increase brought by the increase in labor input quality.

Table 2. Labor Input and Its Basic Indicators

Year	Labor input			Labor compensation	Number of employees	Working hours per person	Hourly compensation per person	Total working hours
	Growth trend	Volume	Price index					
2000	0.675	23865	0.22	5284	72085	46.58	3.15	16788
2001	0.689	24363	0.24	5821	72797	46.35	3.45	16870
2002	0.700	24756	0.26	6527	73280	46.44	3.84	17016
2003	0.719	25452	0.29	7257	73736	46.99	4.19	17323

Year	Labor input			Labor compensation	Number of employees	Working hours per person	Hourly compensation per person	Total working hours
	Growth trend	Volume	Price index					
2004	0.747	26411	0.31	8189	74264	46.95	4.70	17434
2005	0.787	27850	0.34	9422	74647	48.83	5.17	18226
2006	0.792	28010	0.38	10774	74978	47.98	5.99	17989
2007	0.786	27801	0.47	12964	75321	45.85	7.51	17268
2008	0.778	27540	0.55	15255	75564	44.76	9.02	16911
2009	0.793	28055	0.61	17019	75828	44.89	10.00	17021
2010	0.879	31110	0.63	19507	76105	48.01	10.68	18268
2011	0.926	32772	0.70	22840	76420	47.04	12.71	17974
2012	0.939	33222	0.80	26500	76704	47.14	14.66	18078
2013	0.954	33742	0.89	30048	76977	47.42	16.46	18253
2014	0.971	34349	0.95	32540	77253	47.37	17.78	18298
2015	1.000	35380	1.00	35380	77451	46.59	19.61	18041
2016	1.024	36221	1.06	38337	77603	47.32	20.88	18359
2017	1.031	36494	1.16	42327	77640	47.35	23.03	18380
2018	1.047	37037	1.25	46429	77586	47.64	25.12	18480

Note: (1) Unit: Labor input volume: billion yuan (2005 as the base period); Labor compensation: billion yuan; Number of employees: 10 thousand; Working hour per person: hours/week (suppose working weeks are 50 per year); Hourly compensation per person: yuan; Total working hours: 100 million hours. (2) Industry is regarded as a dimensional characteristic when calculating the aggregated labor input with the growth rate of aggregated labor input $\Delta \ln L_t = \sum_{ieag=1}^{2926} \bar{v}_{ieagt} \Delta \ln H_{ieagt}$.

Table 3 displays the decomposition results of annually growth rate of labor input indicators and labor input quality. The growth of labor input can be decomposed into changes in quantity (number of employees, working hour per person) and quality. The annually growth rate of labor input in China was 2.5% from 2001 to 2018, where the annually growth rate of labor input quality was 1.97% and contributed 78.8% of the growth rate of labor input. This shows that the growth of aggregated labor input mainly depends on the increase in labor input quality since the 21 century. Over the same period, annually growth rate of number of employees and working hours per person were 0.41% and 0.12%, respectively. The growth rate based on index method-based labor input is significantly higher than that based on number of employees or total working hours.[1]

[1] The annual growth rate of total working hour equals the sum of the growth rate of number of employee and working hour per person. Here it is 0.53%.

Table 3. Annually Growth Rate of Labor Input and Its Decomposition (Unit: %)

Year	Labor input	Number of employees	Working hours per person	Labor input quality	Decomposition of labor input quality				
					$\Delta\ln Q_i$	$\Delta\ln Q_e$	$\Delta\ln Q_a$	$\Delta\ln Q_g$	Interaction effect
2001–2010	2.74	0.54	0.30	1.89	1.21	1.52	−0.16	0.03	−0.71
2011–2018	2.21	0.24	−0.10	2.07	0.70	2.38	0.07	0.04	−1.12
2001–018	2.50	0.41	0.12	1.97	0.98	1.90	−0.06	0.04	−0.89

Note: (1) China's economy entered the new normal after 2011, which is taken as the break point to divide the sample period. (2) The growth rate of labor input in the table does not consider the net production tax. If the net production tax is considered, the growth rate of labor input from 2001 to 2018 would be 2.81%.

4.3. Labor Input at the Industrial Level and Its Structural Decomposition

4.3.1. The Basic Indicators of Industrial Labor Input

According to Table 4, the shares of labor input volume in three sectors in total labor input were 13.76%, 31.06% and 55.18% in 2018, which showed significantly improvement in labor input structure comparing to those in 2000 (shares were 39.06%, 28.41% and 32.53% for three sectors respectively). Comparing to the total working hours (shares were 22.93%, 29.27% and 47.80% for three sectors respectively) and number of employees (shares were 26.11%, 27.57% and 46.32% for three sectors respectively), the transfer of labor input volume from the primary sector to the secondary and tertiary sectors was more obvious. The industrial structure showed a significant change for labor input quantity (total working hours) during the sample period. Comparing to 2000, industry A, C and F were still the three main industries with the highest labor input quantity, but the share of industry A's working hours in total working hours decreased from 48.61% to 22.93%, while that of industry F increased from 8.77% to 15.98%. The industrial structure change of working hours in the tertiary sector was the most obvious. Among them, the rankings of working hour share of industry L, K and H was the fastest in tertiary sector, whose shares increased from 0.46%, 0.32% and 2.6% in 2000 to 3.62%, 2.06% and 4.69% in 2018, respectively. The working hour share of industry I, M and J also witnessed increase to some extent. This led to the result that the working hour share of producer services and consumer services increased from 15.05% and 4.84% to 28.96% and 10.19%, respectively. The labor input quantity shares of other services (industry N, P, Q and S) in tertiary sector decreased slightly, with 0.57%, 4.66%, 1.39% and 4.44%, respectively, but theirs shares in all industries kept low-speed increase.

Table 4. Industrial Labor Input and Basic Indicators in 2000 and 2018

Industry		Labor input volume		Price index		Labor compensation		Total working time		Working hour per person		Hourly compensation per person	
		2000	2018	2000	2018	2000	2018	2000	2018	2000	2018	2000	2018
Primary sector (A)		10173	5093	0.12	1.26	1239	6406	8161	4238	45.28	41.84	1.52	15.12
Secondary sector		7402	11497	0.28	1.35	2091	15542	3916	5410	48.29	50.58	5.34	28.73
	B	650	556	0.37	1.48	240	821	224	158	46.25	48.85	10.73	51.85
	C	5181	7261	0.27	1.41	1417	10265	2903	3298	48.18	50.82	4.88	31.12
	D	387	416	0.21	1.47	82	613	133	118	43.95	45.70	6.14	51.90
	E	1132	3279	0.31	1.17	352	3844	656	1835	50.57	50.65	5.37	20.95
Tertiary sector		8473	20429	0.23	1.20	1954	24481	4711	8833	47.53	49.15	4.15	27.72
Producer services	F	1284	3196	0.30	1.21	382	3862	1472	2952	51.64	51.88	2.60	13.08
	G	1540	1626	0.20	1.19	301	1940	742	718	48.07	50.55	4.05	27.03
	I	118	927	0.37	1.21	44	1118	38	265	44.93	46.04	11.60	42.25
	J	798	3130	0.20	1.00	162	3125	133	447	42.74	44.81	12.20	69.94
	L	123	1316	0.41	1.49	51	1959	78	669	48.04	47.43	6.51	29.30
	M	169	972	0.29	1.17	49	1136	64	302	43.34	44.99	7.70	37.63
Consumer services	H	489	1079	0.17	0.83	84	893	436	867	52.15	54.10	1.93	10.31
	K	107	757	0.91	1.22	97	923	54	380	43.87	48.45	18.21	24.28
	O	454	1007	0.22	1.30	101	1312	243	479	49.69	50.67	4.17	27.39
	R	158	357	0.25	1.33	39	476	79	157	44.84	47.93	4.94	30.37
Other services	N	212	270	0.10	0.94	22	255	76	93	43.79	47.39	2.83	27.34
	P	1564	2120	0.16	1.19	248	2517	525	574	42.97	44.50	4.72	43.86
	Q	786	1419	0.14	1.24	110	1759	240	326	44.14	46.86	4.60	53.87
	S	1547	2107	0.17	1.52	263	3207	532	605	42.54	44.29	4.94	53.02

Note: (1) Unit: Labor input volume: billion yuan (2005 as the base period); Price index: 2015=1; Labor compensation: billion yuan; Total working hour: 100 million hours; Working hour per person: hours/week (suppose working weeks are 50 per year); Hourly compensation per person: yuan. (2) The calculation of labor input, labor input volume and price index at level of sector and industry are based on equation (6) and (7), which results in differences between the result at the sectoral level and the aggregated labor input at the industrial level.

4.3.2. Industrial Labor Input and Quality Decomposition

As shown in Table 5, labor input in all industries except industry A and B experienced increase trend, though there were large variations among industries. In the tertiary sector, the labor input in producer services grew the fastest and that in consumer services, other services and secondary sector also experienced growth to some extent, while that in the primary sector declined continuously. Among them, the annually growth rate of labor input in industry L, I, K and M surpassed 10%, which were the highest. Due to the industrial structural upgrading in China since 21st century, more labors have been absorbed into industries dominated by information technology and high-tech.

Table 5. Annually Growth Rate of Industrial Labor Input and Quality Decomposition from 2001 to 2018

(Unit: %)

Industry		Labor input	Number of employee	Working hour per person	Labor input quality	Decomposition of labor input quality						
						$\Delta \ln Q_e^i$	$\Delta \ln Q_a^i$	$\Delta \ln Q_g^i$	$\Delta \ln Q_{ea}^i$	$\Delta \ln Q_{eg}^i$	$\Delta \ln Q_{ag}^i$	$\Delta \ln Q_{eag}^i$
Primary sector (A)		−3.63	−3.20	−0.44	0.01	0.40	−0.67	−0.04	0.33	0.00	−0.01	−0.01
Secondary sector		2.56	1.54	0.26	0.77	0.94	0.02	0.18	0.07	−0.03	−0.04	−0.02
	B	−0.60	−2.24	0.30	1.33	1.38	−0.10	−0.00	−0.03	0.10	−0.01	−0.01
	C	1.99	0.41	0.30	1.28	1.08	0.13	0.18	0.03	−0.09	−0.02	−0.03
	D	0.66	−0.88	0.22	1.33	1.38	−0.17	0.07	0.08	−0.02	−0.04	0.04
	E	6.16	5.70	0.01	0.44	0.60	−0.20	0.00	0.06	−0.01	−0.02	0.01
Tertiary sector		5.04	3.31	0.19	1.55	1.64	0.12	−0.03	−0.01	−0.01	−0.03	0.01
Producer services	F	5.23	3.84	0.03	1.37	1.28	0.04	0.12	0.03	−0.06	−0.02	−0.02
	G	0.49	−0.46	0.28	0.67	0.79	−0.10	−0.06	0.04	0.01	−0.02	0.00
	I	12.41	10.63	0.14	1.64	1.54	0.45	0.38	−0.24	−0.49	−0.35	0.34
	J	8.43	6.47	0.26	1.70	1.71	0.24	0.23	−0.18	−0.28	−0.32	0.30
	L	14.27	12.04	−0.07	2.30	1.93	0.27	0.36	−0.08	−0.15	−0.19	0.15
	M	10.46	8.44	0.21	1.81	1.69	0.44	0.80	−0.34	−0.79	−0.75	0.75
Consumer services	H	4.59	3.61	0.20	0.78	0.71	−0.07	0.05	0.10	−0.03	0.03	−0.01
	K	11.80	10.34	0.55	0.91	0.85	0.15	0.07	−0.04	−0.09	−0.14	0.11
	O	4.69	3.66	0.11	0.92	0.94	−0.07	−0.03	0.10	0.01	−0.01	0.00
	R	4.77	3.43	0.37	0.97	0.97	0.23	0.01	−0.14	−0.09	−0.10	0.09
Other services	N	1.48	0.66	0.44	0.38	0.49	−0.53	0.02	0.42	−0.03	−0.06	0.06
	P	1.75	0.30	0.19	1.26	1.40	0.11	0.04	−0.12	−0.16	−0.21	0.19
	Q	3.40	1.39	0.33	1.68	1.70	0.25	0.09	−0.23	−0.14	−0.15	0.14
	S	1.84	0.49	0.22	1.13	1.20	0.00	−0.00	−0.01	−0.05	−0.06	0.04

Note: (1) The labor input quality of three sectors contained the impact of industrial characteristics. In the secondary sector, $\Delta \ln Q_i^2 = -0.33(\%)$. The negative contribution of industrial characteristic lowered down the growth level of labor input quality of the secondary sector, while the sum of other effects was 0.02. In the tertiary sector, $\Delta \ln Q_i^2 = 0.28(\%)$ and the sum of other effects was 0.42. (2) If the net production tax was split into capital and labor, the labor input of industry A~S would be (from up to bottom respectively, unit: %): −3.56, −0.49, 2.06, 0.85, 6.23, 5.29, 0.59, 12.52, 8.61, 14.45, 10.60, 4.62, 11.90, 4.75, 4.89, 1.70, 1.93, 3.60, 2.01. It is obvious that the differences of labor input were smaller when the net production tax was not included, comparing to that with net production tax included. In particular, the impact of net production tax on the labor input differences at the industrial level was very small.

In general, the growth differences among industries are determined by labor input quantity (number of employee and working hour per person) and labor input quality.

Among them, the different growth trend of employee is the main reason for the variation of labor input in different industries. In the sample period, the number of employee in the primary sector declined by 3.2% each year, which was influenced by the transfer of surplus rural labor. In the secondary sector, the number of employee in industry E grew relatively faster, while that in industry B and D experienced decline to some extent. Except industry G, all industries in the tertiary sector witnessed relatively high growth rate of number of employee. Among them, the growth rate of number of employee surpassed 10% for industry L and I, to which the inflow of labor input was relatively faster.

Increase of labor input quality and working hour per person also significantly improved the industrial labor input. Its role was more prominent in industries whose growth rate of number of employee was slow or declined. In the secondary sector, the annually growth rate of labor input in industry B was −0.6%, while the labor input quality and working hour per person increased by 1.33% and 0.3%, respectively. This helped offset the impact of the decline of number of employee. The growth rate of labor input quality and working hour per person in industry C contributed to 64.26% and 14.92% of growth rate of labor input, which surpassed the contribution of the growth rate of number of employee. In the tertiary sector, the increase in labor input quality and working hour per person made the labor input increased by 1.55% and 0.19%, respectively. The improvement of labor input quality on labor input increase was more important for industries whose growth of number of employee were low, for instance for industry Q, P, S and G.

According to the decomposition result, there are some variations of labor input quality in each industry. The educational level of labor input was the main reason for the different growth rate of industrial labor input quality. The growth rate of labor input quality surpassed 1% in secondary sector, producer services and other services (except industry E, G and N) in the tertiary sector. The contribution of educational level increase in these industries also surpassed 1%, whose growth trend was similar to that of labor input quality. The growth rate of labor input quality in other industries were smaller than 1% and the contribution of educational level increase of labor input was also smaller than 1%. Overall, the influence of age and gender structure on labor input quality was generally small.

5. The Comparison Analysis of Labor Productivity

5.1. The Aggregated Labor Productivity

5.1.1. The Decomposition and Comparison of Aggregated Labor Productivity

According to equation (17), the traditional labor productivity (NLP) can be decomposed into two parts: labor productivity per unit time (ALP) and working hour per person (T), or three parts: index method-based labor productivity (IPL), labor input quality (Q) and working hour per person (T) (that is, ALP can be decomposed into two parts of ILP and Q). Comparing to NLP, ALP represents the production level per unit of working time, which eliminates the impact of T. ILP represents the production level per unit of homogeneous labor input, which eliminates the impact of Q and T. ILP effectively separates the influence of population characteristic factors and is only influenced by non-population-characteristic factors, such as capital and technique.

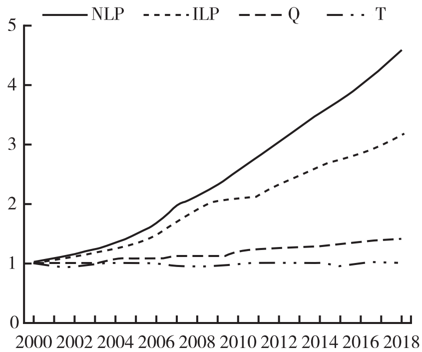
Results show that the annually growth rate of NLP, ALP and ILP were 8.85%, 8.73% and 6.69%, respectively. Among them, the contribution of working hour per person (T) which was split from NLP (that is, $\Delta \ln T = \Delta \ln NLP - \Delta \ln ALP$) was 0.12%. The contribution of working hour per person (T) and labor input quality (Q) that were separated from NLP was 2.15% (where the contribution of Q was 2.03%). Results show that the numerical difference between NLP and ALP was relatively small, therefore, there would be small differences between empirical researches using NLP and those using ALP.[1] however, if the impact of population characteristics (mainly Q) of labor input cannot be eliminated or controlled well, the enlarging growth difference between NLP and ILP would impact the estimation accuracy when NLP was used. Figure 1 (left) shows the growth trend of NLP and the contribution of ILP, Q and T. During the sample period, NLP kept stable and high-speed growth, due to the relatively high-speed growth of ILP. That is, the increase of capital input and technical progress were the crucial factor that promoted per capita living standard (or economic growth).

According to equation (16), the aggregated ILP growth can be further decomposed into the aggregated effect of industrial ILP^i (ILPIE) and redistribution effect of labor input (RE). As shown in Figure 1 (right), the growth of ILP was mainly influenced by ILPIE and the industrial redistribution effect of labor input also promoted the growth rate of ILP. Among them, the annually growth rates of ILPIE and RE were 5.71% and 0.99%, respectively. The aggregated effect of the increase in industrial ILP^i (ILPIE) contributed to the growth of ILP by 85.26%, while the industrial redistribution effect of labor input contributed to 14.74%.

5.1.2. Aggregated Labor Productivity and Economic Growth

As the aggregated level, the growth rate of output (Y) at constant price can be decomposed in three ways. The first way is to decompose Y into the impacts of traditional

[1] Since the impact of total volume and working hour per person were limited, the differences between NLP and ALP were relatively small. Therefore, the rest parts only analyze the growth of NLP and ILP and the relative indicators.



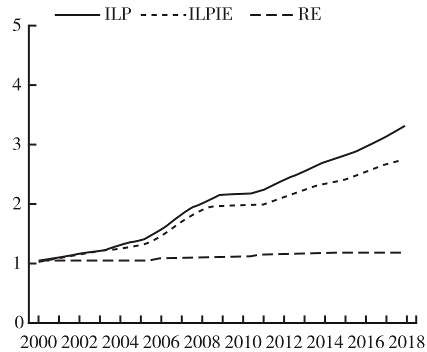


Figure 1. NLP and ILP and Their Driving Factors (2000=1)

labor productivity (NLP) and number of employee (N). The second way is to decompose Y into the impact of index method-based labor productivity (ILP) and labor input (L). The third way is to decompose Y into the impact of the aggregated effect of industrial ILP^i (ILPIE), redistribution effect of labor input (RE), labor input quality (Q), working hour per person (T) and number of employee (N). As shown in Table 6, in the first way of decomposition, the contribution of NLP and N to the annual growth of Y were 95.59% and 4.41%. In the second way of decomposition, the contribution of ILP and L to the growth of Y were 72.28% and 27.72%, respectively. It shows that the contribution of labor force to the economic growth was larger. In the third way of decomposition, the growth of Y was mainly come from the growth of ILPIE and Q, which were higher than RE, N and T obviously. The annually growth rate of Y during 2001 to 2018 was 9.26%, where the contributions of ILPIE and Q were 5.71% and 2.03%, the proportional contribution rate reached 83.59%.

Table 6. The Annually Growth Rate of Total Output and the Decomposition (Unit: %)

Year	$\Delta\ln Y$	Decomposition Ⅰ		Decomposition Ⅱ		Decomposition Ⅲ				
		$\Delta\ln NLP$	$\Delta\ln N$	$\Delta\ln ILP$	$\Delta\ln L$	$ILPIE$	RE	$\Delta\ln Q$	$\Delta\ln T$	$\Delta\ln N$
2001–2010	10.47	9.92	0.54	7.71	2.76	6.81	0.90	1.92	0.30	0.54
2011–2018	7.75	7.51	0.24	5.43	2.32	4.33	1.10	2.18	−0.10	0.24
2001–2018	9.26	8.85	0.41	6.69	2.57	5.71	0.99	2.03	0.12	0.41

Note: The results are calculated according to equation (14) and (17), which results in differences between the growth rate of L and Q reported here and that reported in Table 3. Meanwhile, $\Delta\ln Y_t=\Delta\ln NLP_t+\Delta\ln N_t=\Delta\ln ILP_t+\Delta\ln L_t=ILPIE+RE+\Delta\ln Q_t+\Delta\ln T_t+\Delta\ln N_t$ (that is, $ILPIE$, RE, $\Delta\ln Q$, $\Delta\ln T$ and $\Delta\ln N$).

In different sample period, the annually growth rate of Chinese economy was 10.47% from 2001 to 2010. According to the third decomposition method, the growth contributions of ILPIE and Q were the main driving factors of Chinese economic growth, which promoted economic growth by 6.81% and 1.92%, respectively and the aggregated proportional contribution reached 83.37%. The growth rate of Chinese economy slowed down to 7.75% during 2011 to 2018, where the slow down of the growth rate of ILPIE and N and the negative growth of T were the main reasons. However, the growth rates of Q and RE increased slightly, that is the supported effect of labor input quality and industrial redistribution on economic growth increased. During this period, the growth contributions of ILPIE and Q were still the main driving factors of Chinese economic growth, which promoted economic growth by 4.33% and 2.18%, respectively and the aggregated proportional contribution reached 83.95%. In particular, the contribution of Q increased significantly, comparing to the previous period. At the current stage, the labor input quality would become the crucial momentum among population characteristics that drive sustainable economic growth, when the population is stable, number of employee and working hour per person cannot continuously increase and the impact of labor input quantity on economic growth declines gradually.

5.2. Industrial Labor Productivity

5.2.1. The Comparison and Decomposition of Industrial Labor Productivity

Though comparing the changes of NLP^i, ILP^i and ILP^i of each industry, we analyze the impact of industrial labor working capacity of (Q^i and T^i) and non-population characteristic factors (ILP^i) on of each industry. As shown in Figure 2 (upper part), the growth difference between NLP^i and ILP^i of each industry was due to the effect of Q^i. There were large differences in ILP^i of each industry, where the growth rate of ILP^i for the primary and secondary sector (except industry E) and other services in tertiary industry. Among them, the annually growth rate of ILP^i for industry P, O, D, S and C surpassed 8%. However, the growth rate of ILP^i for producer services (except industry G) and some consumer services (industry H and K) were smaller than the median of industrial growth rate, and the growth rate for some industries (industry L and K) was even negative.

As show in Figure 2 (lower part), when comparing the results of sample period from 2001 to 2010 and that from 2011 to 2018, the growth rate of ILP^i for most industries (except industry L, I, B, A, Q and K) all experienced decline to different extent. Among them, the growth rate of industry J declined the most from 9.2% to −7.43%. This implies that the production productivity did not increase by the same pace as the increase of industrial labor input. Meanwhile, the growth rate of ILP^i for consumer services, industry F, N and D all experienced large decline. This is highly related with the changes of capital reallocation, production technique and market environment after China went into the new normal.

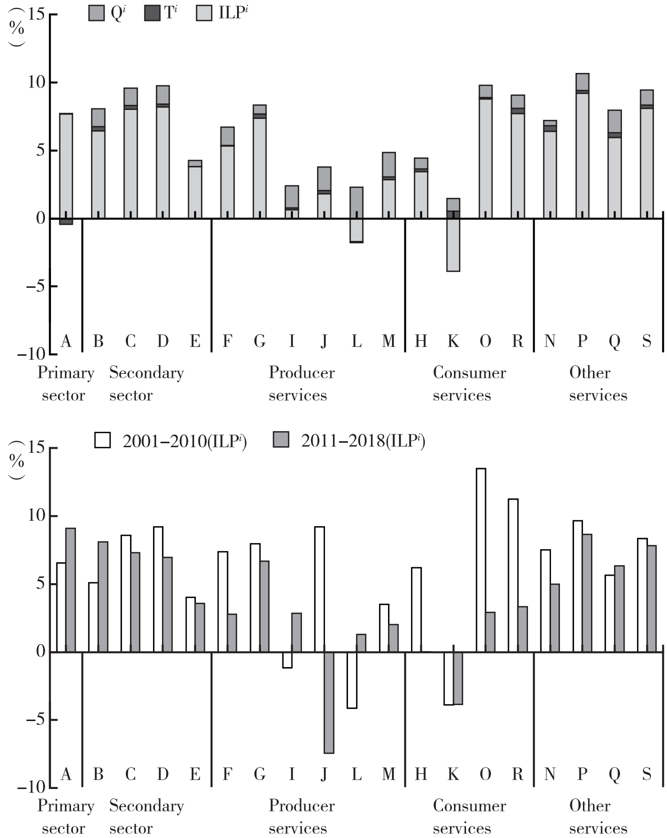


Figure 2. The Annual Growth Rate and Decomposition of ILP^i and the Comparison of Growth Rate of ILP^i of Different Sample Period from 2001 to 2018

5.2.2. Industrial Labor Productivity and Output Growth

As shown in Figure 3 (upper part), there were variations of output growth rate of different industries and the output growth rate of the tertiary sector was higher than that of the primary and secondary sectors. In general, the growth rates of ILP^i and L^i were in different direction, which narrowed the differences of output growth rate among industries. Among them, the annually growth rate of output, ILP, and labor input for the primary sector were 4.05%, 7.68% and −3.63%. Those for the secondary and tertiary sectors were 9.55%, 6.98%, 2.58% and 10.15%, 5.07%, 5.08%, respectively.[1] This indicates that the output growth rate of the tertiary sector

[1] In this section, the growth rates of Y, ILP and L of the secondary and tertiary sectors are calculated according to equation (14), (15) and (16). Therefore, there are some differences between the result of L of the secondary and tertiary sectors and that reported in Table 5 (the differences are due to the impact of industrial characteristics).

was the largest, while the growth rate of ILP for the tertiary sector was the smallest. The increase in labor input was the main reason of the fast output growth rate of the tertiary sector.

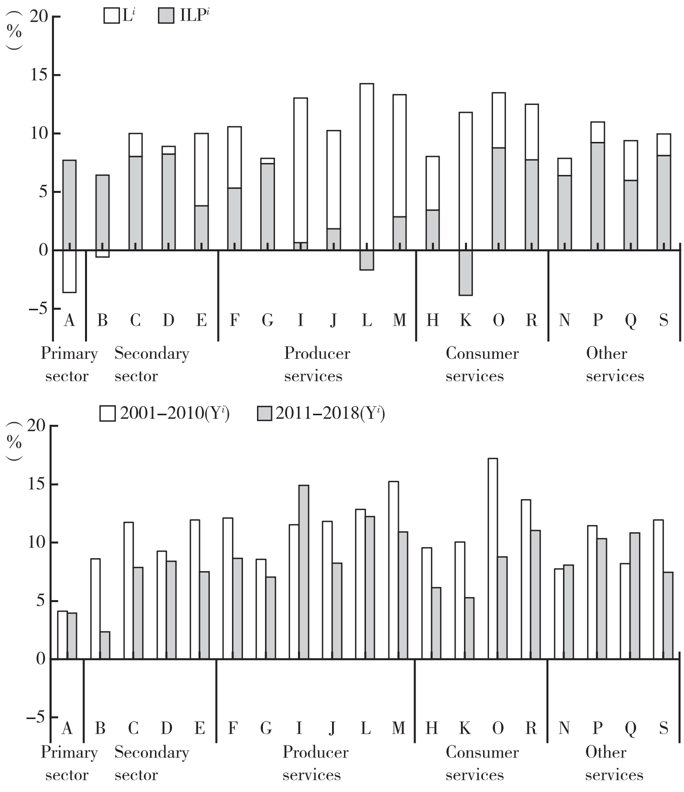


Figure 3. The Annual Output Growth Rate and Decomposition of Each Industry and the Comparison of Growth Rate of Y^i of Different Sample Period from 2001 to 2018

The factors that led to differences of growth rate of Y^i in each industry were as follows. First, the growth rate of Y^i for the primary sector (industry A) was the second lowest and the growth rate of labor input quantity was negative. The transfer of employee from the primary sector to the secondary and tertiary sectors was the major reason for the slowdown of output growth. Second, the growth of Y^i of industry C and D in the secondary sector was mainly drove by the increase of ILP^i. The growth rate of Y^i of industry B was the lowest (5.83%), which was caused by the low growth rate of ILP^i and the negative growth of L^i. In the secondary sector, only industry E had a higher growth rate of L^i than that of ILP^i and the growth of L^i contributed of the output growth rate. Third, the growth of L^i contributed to increasing the output to some extent for the tertiary sector, where the growth rate of L^i was higher than that of ILP^i for producer services (except industry F and G) and some consumer services (industry H and K). In contract, the growth of Y^i was mainly drove by the rapid growth of ILP^i in industry O, R, G and other services.

As shown in Figure 3 (lower part), the growth rate of Y^i experienced decline in each industry after China entered the new normal and the growth rate of L^i and ILP^i for each industry also declined to different extent. When comparing the results for the period of 2001 to 2010 and those for the period of 2011 to 2018, we summarize the following findings. First, the growth rate of Y^i decreased from 4.14% to 3.95%. This was caused by the rapid decrease of the growth rate of L^i (from −2.4% to −5.17%), which offset the increase of growth rate of ILP^i (from 6.54% to 9.11%). Second, the growth rate of output in the secondary sector decreased from 11.3% to 7.37%. The decline of growth rate of ILP^i (except industry B) and L^i (except industry D) made the growth rate of Y^i in each industry experienced decline to different extent. Even though the decrease of number of employee in industry B led to increase in growth rate of ILP^i, the growth rate of Y^i still declined. In contrast, the growth rate decrease of Y^i in industry D was mainly due to the fact that the decrease of growth rate of ILP^i was larger than that of L^i. Third, the overall growth rate of output in the tertiary sector decreased from 11.31% to 8.7%. Except industry I, Q and N, the growth rate of for all industries slowed down.

6. Conclusions and Policy Implications

Based on growth account theory, this paper constructs the measurement framework of labor input with educational level, age, gender and industrial structure as the structural characteristics and investigates the impact of changes in number of employee, working hour per person, and labor characteristic structure on labor input and labor input quality. The influencing factors on labor productivity and output in China at both aggregated and industrial level are analyzed afterwards. Results show that the annually growth rate of the aggregated labor input in China from 2001 to 2018 was 2.5%. Specifically, the annual growth rate of labor input quality was 1.97%, which contributed to 78.8% of the labor input growth. The annual growth rates of number of employee and working hour per person were 0.41% and 0.12%, respectively, which contributed 21.2% of the labor input growth in total. In the investigated period, the annual output growth rate originated from traditional labor productivity (NLP) and index method-based labor productivity (ILP) were 8.85% and 6.69%, respectively, which implied that the impact of ILP (which got rid of the impact of population characteristic factors, such as working hour per person and labor input quality) was obviously smaller than NLP. The growth direction of ILP^i and labor input was different, which narrowed the industrial difference of output growth. Among them, the growth rate of ILP^i for industries in the tertiary sector was relatively smaller, where the output growth was mainly drove by the increase of labor input.

This study has some important policy implications. (1) The improvement of labor input quality has become the key to the growth of labor input in China. Among the influencing factors of labor input quality, the structures of gender and age have little influence and therefore, the most effective way to improve the quality of labor input is to vigorously promote the overall level of education. (2) Measures optimizing the allocation of labor input among industries should be taken to guide the labor force transfer to the industries with higher per capita output level, such as the replacement with intelligent robots and industry digitization for industries with low labor output level, as well as the development of the labor complementary technology. (3) The labor input of some service industries represented by the producer services continues to grow rapidly, while their output and ILP increase slowly. Therefore, the supply side structural reform should be deepened further to optimize the allocation of capital factors and technical level among the industries, so as to improve the overall labor productivity and output level.

References

Chinloy, P. T. (1980). Sources of Quality Change in Labor Input. *American Economic Review*, 70(1), 108−119.

Christensen, L. R., Jorgenson, D. W., & Lau, L. J. (1973). Transcendental Logarithmic Production Frontier. *Review of Economics & Statistics*, 55(1), 28−45.

Denison, E. F. (1961). Measurement of Labor Input: Some Questions of Definition and the Adequacy of Data. *The Conference on Research in Income and Wealth, in Output, Input, and Productivity Measurement*. New Jersey: Princeton University Press, 347−386.

Gai, Q., Zhu, X., & Shi, Q. (2013). Labor Market's Distortion, Structural Change and Labor Productivity in China. *Economic Research Journal (Jingji Yanjiu)*, 48(5), 87−97+111.

Gollop, F. M., & Jorgenson, D. W. (1983). Sectoral Measures of Labor Cost for the United States, 1948−1978. in Triplett, J. E. (eds.), *The Measurement of Labor Cost*. Chicago: University of Chicago Press.

Holz, C. A. (2005). The Quantity and Quality of Labor in China 1978–2000–2025. Working Paper, May 16.

Holz, C. A. (2006). Measuring Chinese Productivity Growth, 1952–2005. Manuscript, July 22.

Jorgensen, D. W., & Griliches, Z. (1967). The Explanation of Productivity Change. *Review of Economic Studies*, 34(3), 249−283.

Jorgenson, D. W. (1990). Productivity and Economic Growth. in Berndt, E. R., &

Triplett, J. E. (eds.), *Fifty Years of Economic Measurement: The Jubilee of the Conference on Research in Income and Wealth.* Chicago: University of Chicago Press.

Jorgenson, D. W., Gollop, F. M., & Fraumeni, B. M. (1987). *Productivity and U.S. Economic Growth*. Harvard: Harvard University Press.

Jorgenson, D. W., Ho, M. S., & Stiroh, K. J. (2002). Projecting Productivity Growth: Lessons from the U.S. Growth Resurgence. Economic Review Third Quarter, Federal Reserve Bank of Atlanta.

Jorgenson, D. W., Ho, M. S., & Stiroh, K. J. (2005). *Information Technology and the American Growth Resurgence*. Cambridge: MIT Press.

OECD. (2001). *Measuring Productivity OECD Manual*. Paris: OECD Publishing.

Wu, H., & Yue, X. (2003). Sources of Quality Change in the Labor Input of Chinese Industry: 1955–2000. The Western Economic Association International Pacific Rim Conference.

Wu, H., & Yue, X. (2012). Accounting for Labor Input in Chinese Industry: 1949–2009. RIETI Discussion Papers Series, 12-E-065, 1−74.

Wu, H., Yue, X., & Zhang, G. (2015). Constructing Annual Employment and Compensation Matrices and Measuring Labor Input in China. RIETI Discussion Papers Series, 15-E-005, 1−41.

Yan, S., Guo, K., & Hang, J. (2018). Final Demand Structure, Structural Transformation and Productivity Growth. *Economic Research Journal (Jingji Yanjiu)*, 12, 83−96.

Young, A. (2003). Gold into Base Metals: Productivity Growth in the People's Republic of China during the Reform Period. *Journal of Political Economy*, 111(6), 1220−1261.

Yue, X., & Ren, R. (2008). Measuring the Labor Input of Chinese Economy: 1982–2000. *Economic Research Journal (Jingji Yanjiu)*, 3, 16−28.