An empirical study on the returns to scale of supply structure in China's economic growth: 1993–2015

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Abstract

Purpose – Constant or decreasing returns and increasing returns to scale are two kinds of mechanism in economic growth. The goal of supply-side structural reform is to promote the establishment of the mechanism with increasing returns to scale. The paper aims to discuss this issue.

Design/methodology/approach – This paper argues that the overall economic structure of the developing economy has been divided into the sector of constant or decreasing returns to scale and the sector of increasing returns to scale due to the dual economic structure. Among them, the supply-side structural reform is mainly to reduce the sector of decreasing returns to scale and increase the sector of increasing returns to scale. Based on the hypothesis of such two-sector economic structure in the supply side of developing economies and on the industrial data, this paper empirically tests the returns to scale of China's supply structure. The result suggests that so far the sector of constant or decreasing returns to scale dominates the supply structure of China's economic growth, which results in the state of decreasing returns to scale in China's overall economy.

Findings – Therefore, to realize the long-term sustained growth and transformation of the development pattern of China's economy, the authors must carry out the supply-side structural reform, vigorously develop the modern industrial sectors characterized by modern knowledge and technology, and promote the development of an innovation-driven economy.

Originality/value – Besides, the authors must accelerate the transformation from traditional industrial sectors to modern industrial sectors, actively promote China's industrial structure toward rationalization and high gradation, as well as build a modern industrial system so as to facilitate the formation of the mechanism of increasing returns to scale and accelerate the transformation of the driving force of China's economic growth.

Keywords China's economic growth, Constant returns to scale, Increasing returns to scale

Paper type Research paper

1. Introduction

Under the new normal, China's economy is faced with the severe task of economic structure transformation, and supply-side structural reform has become the latest direction of macroeconomic operation against the background of the new normal. The essence of the supply-side structural reform is to change the economic structure which originally relied on increasing input growth based on the mechanism of constant returns to scale, to the economic structure which gives priority to improving efficiency with increasing returns to scale. In the supply-side structural reform, it is necessary to give full play to the role of advanced elements such as knowledge and technology, develop an innovative economy and establish a mechanism of increasing returns to scale of economic growth through the supply-side structural reform. As a result, we should investigate whether the established mechanism of China's economic growth is the constant returns to scale or the increasing

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returns to scale through the supply-side structural reform, so as to provide basis for innovative development mode and supply-side structural reform.

The basic point of this paper is that the analysis of China's economic growth and supply-side structural reform cannot simply apply the western economic growth theory, but should start from the supply-side structure of China as a developing country in transition, and specifically study whether its growth belongs to the constant or increasing returns to scale in different industries. The research thought of this paper is as follows: on the basis of sorting out domestic and foreign studies, we attempt to propose two-sector hypothesis on the supply-side structure of developing economy. The present paper sampled data of 18 industrial sectors from 1993 to 2015 so as to test the returns to scale. Then, further panel data are used to investigate the status of returns to scale of the overall economy, and the impact of physical capital, human capital and R&D input on China's overall output from the supply side. Different from existing research works, this paper argues that in the period of China's economic transition, there exists a supply-side structure of two sectors at the present stage: the industrial sector of constant or decreasing returns to scale, and the industrial sector of increasing returns to scale with knowledge and human capital as its main driving force, and with the mechanism of constant and increasing returns to scale working together. The contribution of this paper is to put forward the two-sector hypothesis on the supply side of China's economic growth. Through the historical inductive analysis, we put forward the hypothesis of the nature of returns to scale of China's economic growth and transformation; and through the analyses of data in different industries, it is concluded that most supply-side sectors in China exhibit the nature of decreasing or constant returns, and this nature leads to the low-end locking of China's supply-side structure. So, in the future, the feasible path of the supply-side structural reforms of sustained economic growth is to transform the traditional industrial sector to modern industrial sector and break the low-end locking state of industrial structure. The direction of supply-side structural reform is to shift from an economic structure with constant returns to scale to one with increasing returns to scale.

This paper is divided into six parts besides the introduction. Section 2 is the literature review. Section 3 sets forth the two-sector hypothesis on the supply side of economic growth. Section 4 carries out the preliminary test based on the data in different industries in China from 1993 to 2015. Section 5 gives the explanation for the "deviation" of the difficulty in establishing a mechanism of increasing returns to scale on the supply side of China's economy. And Section 6 is conclusion and policy recommendations.

2. Literature review

Before the emergence of endogenous growth theory, all the models of economic growth are basically premised on constant returns to scale. The Ramsey–Cass–Koopmans model proposed by Ramsey (1928) and developed by Cass (1965) and Koopmans (1963) is assumed on constant returns to scale. One of the premises of the famous neoclassical growth theory represented by Solow (1956) is also the constant returns to scale. Its basic model is constructed as an aggregate production function that represents the constant returns to scale in terms of labor and renewable capital. Similarly, one of the assumptions of the overlapping-generations model proposed by Diamond (1965) is the constant returns to scale too. Jones and Manuelli (1990), based on constant returns to scale, changed the assumption that the elasticity of substitution of capital for labor was less than 1 in the neoclassical production function, and investigated the conditions for sustained economic growth. The Rebelo model developed by Rebelo (1991) studies the sustained economic growth from the perspective of core capital goods on the premise of constant returns to scale.

After the endogenous growth theory came into being, its growth model changed the premise of economic growth research into increasing returns to scale, suggesting that the steady growth of marginal returns of capital and labor was brought by technology and innovation.

Arrow (1962) put forward the ideas of "learning by doing" and "research and development," and believed that investment and production activities themselves can accumulate experience and promote production technologies, which will improve capital efficiency and offset the usual decreasing returns on capital together with the spillover effect of knowledge. In "Increasing returns and long-run growth" published by Romer (1986), it is believed that there is increasing returns to scale in long-run economic growth. The increase of returns to scale comes from the externality of knowledge. Knowledge is a non-competitive product with external effects, which not only makes its own returns increase, but also renders other production factors such as physical capital and labor the characteristics of increasing returns. The endogenous economic growth model developed by Romer (1990) argues that increasing returns to scale come from technological progress, while technological progress comes from the conscious investment of manufacturers. The significance of Romer's model lies in that it integrates knowledge as an independent factor into the growth model and decomposes knowledge into general knowledge and specialized knowledge. General knowledge can generate economies of scale, while specialized knowledge can generate incremental returns of factors. The combination of these two effects not only produces increasing returns for knowledge, technology and human capital themselves, but also increases returns for input factors such as capital and labor. According to the endogenous economic growth theory of Lucas (1988), economic growth is increasing returns to scale, which comes from human capital and its externalities. The externalities of human capital – the average human capital level of the social labor force – play a central role, and these effects can spread from one person to another, thus contributing to the productivity of all factors of production and exhibiting increasing returns to scale in terms of production. It is the increasing returns from the externalities of human capital that makes human capital the "engine of growth." Aghion and Howitt (1992) proposed that technological level can be achieved through purposeful research and development activities, which are part of the investment. Through such activities, technological progress can be improved and decreasing returns to capital scale can be avoided. In general, the mainstream of endogenous growth theory holds that increasing returns are not only universal but also necessary in the process of long-term economic growth. Economists of endogenous growth theory introduce knowledge, human capital and other factors into the growth model, emphasizing that special knowledge and specialized human capital can generate increasing returns and increase the returns to scale of the whole economy. This breaks through the traditional growth theory about the assumption of constant or reducing returns of factors and explains the source and power of sustained economic growth.

Domestic research on China's economic growth is fundamentally based on the assumption of constant returns to scale. In order to avoid the influence of multicollinearity on parameter estimation, the studies on China's economic growth conducted by Shen Kunrong (1999) and Shu Yuan and Xu Xianxiang (2002) were also carried out in accordance with the assumption of constant returns to scale. Zhong Xueyi (1996) developed the concept of total factor productivity and put forward pure factor productivity. He held that technological progress is the only source of total factor productivity growth under the condition of constant returns to scale. In the case of non-constant returns to scale, the growth rate of total factor productivity cannot fully reflect the role of technological progress, and the gains and losses caused by returns to scale to output growth must also be considered, namely the elasticity of scale effect. However, the author did not put forward suggestions on the theoretical evaluation of economic growth under the condition of non-constant returns to scale. Xu Ying and Yang Kaizhong (2007) studied the returns to scale from the basic model of the economic growth pattern, and used the panel data fixed impact model, random impact model and random coefficient model to investigate and verify the characteristics of increasing returns to scale of China's economic growth. The results of empirical studies using the above methods showed that since the 1990s, China's economic growth had walked out of the cost-driven stage and entered the endogenous stage of increasing returns to scale and the stage of economic development driven by economies of scale. And with the development of economy, the extent of increasing returns to scale has been showing a growing trend. However, the sum of the output elasticity in the model has no constraint and thus does not stick to the assumption of decreasing returns on capital. Zhang Yan and Wang Zhiqiang (2010) made an empirical test on the knowledge production function with the theory of returns to scale, so as to judge the economic growth mode of China. Through empirical research, Wang and Hou (2007) argued that under the condition of constant returns to scale, the estimation of contribution share of factors would be biased, that is, the contribution share of capital would be overestimated, while the contribution share of labor would be underestimated. Chen Guangren (2015) started from the concept of production function and variable returns to scale, compared and analyzed different stages of variable returns to scale with charts, explained the economic connotation of variable returns to scale, and finally deduced the evolutionary path of upgrading and transformation of Chinese manufacturing enterprises through the mechanism of continuous increasing returns to scale. Based on the transcendental logarithmic cost function model, Chen Lin and Xia Jun (2016) used micro-data of listed companies to measure the parameters of returns to scale of major service industries and studied the "squeezing" effect of financial expansion on the returns to scale of service industries.

The goal of supply-side structural reform is to realize the transformation from a supply structure with constant returns to scale to that with increasing returns to scale. Therefore, the supply-side structure reform in China's economic growth should start from the reality of the special supply-side structure of China's transition economy, and study the nature of returns to scale of different supply structures in China.

3. The hypothesis of the nature of two-sector growth in the supply structure of developing economies

China's economy has the obvious characteristics of dual economic structure of developing economies, which is prominently manifested by the coexistence of traditional industry and modern industry in the supply-side structure. The characteristics of this supply-side structure make the established mechanism of economic growth in such economies special, which is neither based on the neoclassical mechanism of constant returns to scale, nor on the mechanism of increasing returns to scale of the new growth theory, but on the growth mechanism of coexistence and co-development of the traditional industrial sector with the core feature of constant or decreasing returns to scale, and the modern industrial sector with the core feature of increasing return to scale.

3.1 The assumption of constant or decreasing returns to scale of traditional industrial sectors

In traditional industrial sectors, the economic growth mode is based on the idea of expanding the scale, which drives the input of labor through investment and brings about the growth of output. The economic growth of traditional industrial sectors is achieved on the basis of constant or decreasing returns to scale. The reason for the constant or decreasing returns to scale derives from the proposition that "as long as all necessary inputs can vary in the same proportion, a given set of production conditions will be repeated, and the indivisibility of the production process will limit the exact repetition of such conditions to a certain level of output" (Xu *et al.*, 2007). The constant or decreasing returns to scale in traditional industrial sectors are caused by the constant or decreasing marginal substitution rate of factors in production. As for the traditional industrial sector in a perfect competition market, when there is no technological progress and externality, the allocation of resources cannot be realized through recombination. When the economic growth reaches a steady state, that is, when the ratio of capital to labor becomes stable after reaching an optimal level, the output and consumption per capita will not increase. The linear homogeneous production function can exactly realize the equality of the price of factors and the marginal products of the factors, thus forming the constant returns to scale.

In developing economies, although the returns to scale for traditional industrial sectors are constant, there are decreasing marginal returns of factors, which are mainly caused by the following four reasons: first, due to the low technical level of traditional industrial sectors in developing economies, the economic growth mainly depends on the expansion of scale; and under the condition of quite large economic scales, and perfect competitions, when the scale of economy gets larger, the production specialization level is unlikely to improve, and the opportunity to make profits through the specialization would not exist, resulting in the slower speed of increasing outputs than increasing factors and decreasing marginal returns of production factors. Second, since the economic growth of traditional industrial sectors of developing economies is realized through scale expansion driven by investment, and on the premise of keeping the labor input unchanged, if there is only increase of capital factors, the marginal outputs will be decreasing. The reason for the decrease is that economic growth is carried out in the process of input and output. When the input of capital factors in economic activities increases, the cost of capital uses will also increase because of the scarcity of capital resources. As a result, although output increases, the marginal output decreases gradually. Third, traditional industrial sectors of developing economies mainly used two production factors: capital and labor, and there is a certain proportional relationship between these two factors. When this proportional relationship remains unchanged, the returns to scale will keep constant. Once this proportional relation is not satisfied, the marginal output of larger number of labor factors will be restricted by the smaller number of capital factors, resulting in the decrease of marginal returns of factors. Fourth, there may be technological progress in the growth of traditional industrial sectors in developing economies. But this technological progress is caused by the technological advances with increasing factors, which greatly relies on the accumulation of capitals. This technological progress can only cause the increase of output per capita, but will not cause the change of economic structure, thus forming an unstructured growth. The unstructured economic growth can only lead to decreasing marginal returns. The main feature of decreasing marginal returns in traditional industrial sectors is that when production factors increase in the same proportion, the proportion of output increase is smaller than that of input factors. There are two main reasons for the decreasing marginal returns. First, there is a limitation of availability of production factors. With the gradual expansion of manufacturers' production scale, and due to the limitations of geographical location, raw material supply, labor market and other factors, the factor input required by manufacturers in production may not be satisfied; and even if it is satisfied, it will be of high cost. Second, due to the decline of the management efficiency of large-scale manufacturers, the imperfection of the internal supervision and control mechanisms, information transmission and other factors, it is easy to miss the favorable decision-making opportunity, hence the decline in the production efficiency.

In traditional industrial sectors, except monopolistic sectors, the price is formed by the market competition due to the characteristic of the market that tends to be completely competitive. And every manufacturer is the price follower. Against this market structure background, traditional industrial sectors can only achieve growth by expanding their scale. At the same time, due to the characteristics of decreasing marginal returns of traditional industrial sectors, in order to ensure the constant returns to scale, they can only achieve growth by the expansion of scale.

3.2 The assumption of increasing returns to scale in modern industrial sectors

Knowledge and technological progress are the source of increasing returns to scale. If modern industrial sectors realize an endogenous growth, the economic growth pattern will be formed through the increase in efficiency caused by knowledge innovation and technological progress. Due to the endogenous growth, knowledge innovation can promote technological progress, and technological progress can in turn lead to the improvement of factor allocation efficiency, resulting in the increase of outputs. Therefore, it can be seen that the modern industrial sectors with endogenous growth achieve economic growth through the mechanism of increasing returns to scale.

The source of increasing returns to scale in modern industrial sectors with endogenous growth mainly comes from six aspects. First, modern industrial sectors have the spillover effects of knowledge. Knowledge is a very important special factor in modern industrial sectors, which is different from capital and labor because of its spillover effects. In essence, knowledge factor has some exclusivity in property rights, which causes the spillover effect. And these spillover effects can lead to the incremental effect of labor output and the increasing returns of the whole national economy. Second, modern industrial sectors have a high level of technology, and there is a room for them to form the division of labor and specialization. The division of labor in modern industrial sectors improves the degree of specialization of production. Through specialization, the mechanism of increasing returns to scale is formed so as to improve labor productivity. Third, modern industrial sectors use resources in an intensive way. Modern industrial sectors implement the socialized mass production, and at the same time, focus on using large number machinery equipment of similar performance. Therefore, due to the low probability of the shutting down of machines because of operating failures on the one hand, and the reduction of costs because of unified training of workers of the same type of work on the other, the manufacturers can improve the use efficiency of their machines to form the mechanism of increasing returns to scale. Fourth, the inseparability of factors of production. The inseparability of such factors means that some production factors can exert their maximal production capacity only within a certain limit and scope. Manufacturers with larger production scale can use these production factors more effectively than those with smaller production scale, and create increasing returns to scale through the improvement of production capacity. Fifth, non-competitiveness of market structure. Due to the non-competitiveness of market structure, manufacturers with larger production scale often have stronger bargaining power in raw material procurement, channels of distribution, product transportation and other aspects, so they can purchase raw materials at lower prices, and have stronger ability to establish channels of distribution with lower unit distribution cost. Sixth, the economic growth of modern industrial sectors with endogenous growth is achieved through non-factor incremental technological progress. This technological progress not only causes the increase of output per capita, but also causes the change of economic structure, thus forming the structural economic growth, which in turn leads to the increasing returns to scale.

3.3 The hypothesis of the nature of returns to scale in China's supply structure

China's economy is both a type of developing economy and a type of transition economy. As a developing economy, it has the characteristics of dual economic structure; and as a transition economy, it has the characteristics of institutional changes. The characteristics of dual economic structure of the developing economy combined with the characteristics of institutional changes of the transition economy make the economic growth of China since the reform and opening up a typical transformation growth. This kind of transformation growth exhibits specificities in terms of growth conditions, growth factors and driving forces. It is different from the traditional growth mode before reform and opening up and from the conventional growth mode of developed market economies. Meanwhile, this growth mode has also the special nature of growth. From the perspective of special growth conditions, according to the "Washington Consensus" designed by neoclassical economists, the conditions for economic growth are that property rights are clearly defined and the market price mechanism can play a full role. However, China began to transform its growth under the initial conditions of unclear property rights and basically incomplete market development. Under such special initial conditions, along with the advancement of market-based reform, the reform of property rights system and the gradual release of various industrial policies, China's economy has witnessed the transformation from a single ownership structure to a diversified ownership structure. The diversification of ownership structure promotes the diversification of industrial structure, which in turn leads to the growth pattern of scale expansion. From the perspective of special growth factors, China's economic growth mainly depends on the promotion of one unique factor, namely the transformation of the dual economic structure. In the transformation of the dual economic structure, a large-scale and continuous transfer of labor force from agriculture to industry has facilitated the rapid dual industrialization, namely the joint promotion of rural industrialization and urban industrialization. However, in rural industrialization, the transfer of labor force in China is not from rural areas to urban areas as designed by development economists. But rather, the invention and creation of rural township enterprises promotes the development of a number of labor-intensive industries and promotes the rural industrialization. At the same time, urban industrialization promotes the diversification of industrial structure and expands the scale of sectors by deepening the division of labor, forming a diversified industrial system where tradition and modernity coexist. Even the export-oriented economy dominated by the introduction of foreign capital expands the scales of traditional sectors through learning effects and low labor force advantage. The reason why the dual industrialization formed by the transformation of the dual economic structure promotes economic growth is mainly that the transformation of the dual economic structure realizes the diversification of economic structure and industrial structure through the mechanism of division, and the diversification of economic structure and industrial structure further accelerates scale expansion, hence the promotion of economic growth. From the perspective of special driving forces, China's economic growth is accompanied by the transformation from dual economy to industrialization and modernization. But this kind of economic growth relies on China's abundant energy and resources and cheaper labor supply so as to realize the growth mode of "low-price industrialization." Its basic logic is to realize the expansion of economic scale driven by investment. The economic growth mode driven by long-term investment is combined with China's transformation from a single industrial structure to a diversified industrial structure, creating a growth mode of scale expansion in the traditional industrial system.

Because China's economic growth is achieved under the special growth conditions, factors and driving forces, this type of economic growth is a kind of transformation growth, which is manifested by the growth against the background of economic system transformation and dual economic structure transformation. This special transformation growth leads to the diversification of economic structure and industrial structure. Against the background of diversification of economic and industrial structure, the driving force of investment brings up the growth mode of scale expansion. However, although this kind of special mode of growth solves the diversification of industrial structure, it does not solve the upgrading of industrial structure. As a result, although the content of China's economic growth is reflected in the coexistence of traditional industrial system and modern industrial system, in the whole industrial system, the traditional industry is the leading factor, and the level of industrial system is still low, forming the low-end locking of industrial institutions.

Because traditional and modern industrial sectors are opeated according to different economic growth modes, the mechanism of increasing returns to scale and the mechanism of constant or decreasing returns to scale coexist in the overall industrial structure. The mechanism of constant or decreasing returns to scale plays a dominant role in traditional industrial sectors, while the mechanism of increasing return to scale plays a role in knowledge-based industrial sectors. The overall economic structure is divided into two interrelated industrial sectors, so it corresponds to two types of returns to scale. The Chinese economy is undergoing a structural transformation from large-scale material production to technology design and application, from processing resources to processing information, and from the application of natural resources to the application of knowledge and technology, as the bonus space that underpinned China's economic growth fades away. As this shift takes place, the fundamental mechanism that determines economic behavior needs to shift from constant or decreasing returns to increasing returns to scale. Starting from the reality and specificities of China's transition growth, this paper puts forward the following hypotheses of the nature of returns to scale in China's supply-side structure:

H1. Due to the dual structure characteristics of China's developing economy, the overall economic supply structure is divided into two sectors: the constant or decreasing returns to scale and the increasing returns to scale. In the supply structure, both mechanisms may play a role simultaneously. But the size or proportion of the two mechanisms depends on the actual functions performed by human capital and R&D.

H2. Due to the characteristics of China's transformation growth, China's supply structure is in the process of continuous evolution and traditional industrial system gradually evolves to modern industrial system. In the process of the evolution of supply structure, it is not only necessary to realize structural diversification and scale expansion on the basis of constant returns to scale, but also to realize the upgrading of industrial structure, so as to create conditions for the full play of technological progress with key factors and human capital formed by the mechanism of increasing returns to scale.

4. Preliminary tests based on the data of different industries in China from 1993 to 2015

4.1 The setting of measurement model

The hypothesis of the coexistence of increasing returns to scale and constant returns to scale in China's supply structure needs to be further verified with empirical data in China. We generally use the C-D function to analyze the problem of returns to scale. Lucas (1988) and Romer (1986) added human capital and R&D factors to the analysis of growth, which resulted in the formation of increasing returns to scale. Therefore, the production function of different industries in China we examined should include human capital input and R&D input, and the production function is written as follows:

$$Y_{it} = A_i K_{it}^{\alpha} (h_{it} \times L_{it})^{\beta} R_{it}^{\gamma} e^{\varepsilon_{it}}, \tag{1}$$

where Y, K, h, R represent the output of sectors, the material input of sectors, the human capital stock per capita, the labor input of sectors and the R&D input of sectors, respectively, and ε represents the error term. A contains heterogeneity that may lead to different industrial levels, which is mainly composed of industry characteristics and other factors, α, β, γ represent the capital-output elasticity, output elasticity of human capital and R&D output elasticity, respectively.

Assume that:

$$\alpha + \beta + \gamma = \psi.$$

If $\psi = 1$ indicates the constant returns to scale, then $\psi < 1$ indicates the decreasing returns to scale and $\psi > 1$ the increasing returns to scale.

For the setting of measurement model, such model can be obtained by taking logarithms of both sides according to the following equation:

$$\ln Y_{it} = \ln A + \alpha \ln K_{it} + \beta \ln(h_t \times L_{it}) + \gamma \ln R_{it} + \varepsilon_{it}. \tag{2}$$

When using Equation (2) to estimate the production function, there may be multicollinearity among physical capital input, human capital input and R&D input, so the method of Wu Yanbing (2006a, b), Wang and Hou (2007) and others is adopted. In order to reduce collinearity, Equation (2) is usually expressed in the form of per capita. Assume that $\alpha + \beta + \gamma = \psi$, divide both sides of Equation (1) by $(h \times L)$, and take the logarithm we will get:

$$\ln Y_{it} - \ln(h_t \times L_{it}) = \ln A + \alpha[\ln K_{it} - \ln(h_t \times L_{it})] +$$

$$\gamma[\ln R_{it} - \ln(h_t \times L_{it})] + (\psi - 1)\ln(h_t \times L_{it}) + \varepsilon_{it}. \tag{3}$$

Based on Equation (3), regression estimation is conducted on the relationship between output, and physical capital, human capital and R&D of each industry in China's primary, secondary and tertiary industries. The estimated value of $\psi - 1$ determines the nature of returns to scale of production function. If it is significantly greater than 0, then the production function is characterized by increasing returns to scale. If it is significantly smaller than 0, then the production function is characterized by decreasing returns to scale. Under the assumption of constant returns to scale ($\psi = 1$), Equation (3) can greatly reduce the problem of collinearity among variables because they contain fewer variables.

In the test, we also need to estimate a production function without R&D input, namely the production function with only physical capital and human capital input to see the returns to scale of sectors. The specific estimation equation is similar to Equation (3), which can be written as follows:

$$\ln Y_{it} - \ln(h_t \times L_{it}) = \ln A + \alpha[\ln K_{it} - \ln(h_t \times L_{it})] + (\psi - 1)\ln(h_t \times L_{it}) + \mu_{it}. \tag{4}$$

4.2 Data

4.2.1 Selection of industrial sectors. Based on the characteristics of each sector of the national economy, this paper selects all trades of the primary, secondary and tertiary industries. It basically involves various sectors of the national economy, and there are many sectors, especially the tertiary industry. Before 1990, only statistical reports with rough standards were made on the output value of transportation and commerce and other data. In addition, there are differences in the statistical data of industry classification of the R&D input of the industry, especially the R&D input of the secondary industry before and after 1993. In view of this, in order to investigate the subdivided trades and consider the availability of data, the data period can only be selected from 1993 to 2015, 23 years altogether.

In addition, considering the consistency of the data of 23 years, "construction industry" is eliminated in the secondary industry, and "waste resources and waste materials recycling and processing industry" and "industry of exploitation and transportation of timbers and bamboos[1]" are also eliminated from the secondary industry. At the same time, the tertiary industry is more special. Due to the different standards of statistics of the tertiary industry from 1993 to 2013 given by the National Bureau of Statistics, this paper only selects six representative industries after summarizing the data of similar industries. The final data are 24 years' data of 58 industries from 1993 to 2016. A total of 18 sectors are used to test the returns to scale. The specific industries included in the 18 sectors are shown in Table I.

4.2.2 Output, physical capital stock and human capital stock. This paper is concerned with the primary, secondary and tertiary industries. In the primary industry, the output value in

Sector	Specific industries included in the sector
Agriculture	Farming, forestry, animal husbandry and fishery
Mineral mining and dressing	Coal mining and washing industry, oil and natural gas exploitation, ferrous metal mining and dressing, nonferrous metal mining and dressing, non-metallic mining and other mining industries
Food and beverage	Farm and sideline food processing industry, food manufacturing industry, beverage manufacturing industry, tobacco processing industry
Textile and fur	Textile industry, textile clothing, footwear and headwear manufacturing, leather, fur, feather (down) and its products industry
Wood and furniture	Wood processing and wood, bamboo, cane, palm, grass products industry, furniture manufacturing
Papermaking and printing	Papermaking and paper products, printing and reproduction of recording media
Petrochemical and rubber	Petroleum processing, coking and nuclear fuel processing industry, chemical raw materials and chemical products manufacturing, pharmaceutical manufacturing, chemical fiber manufacturing, rubber products industry, plastic products industry
Mineral processing	Non-metallic mineral products industry, ferrous metal smelting and rolling processing industry, nonferrous metal smelting and rolling processing industry
Machinery and equipment	Metal products industry, general equipment manufacturing, special equipment manufacturing, transportation equipment manufacturing
Electrical and electronic industry	Electrical machinery and equipment manufacturing, communication equipment and computer and other electronic equipment manufacturing
Culture, education, sports instruments	Culture, education and sports products manufacturing, instrument and apparatus and cultural office machinery manufacturing, crafts and other manufacturing industries
Production and supply of electricity, gas and water	Production and supply of electric power and heat, production and supply of gas, and production and supply of water
Transportation and communication	Transportation, storage and postal services
Dining and retail	Wholesale and retail industry, catering industry
Finance and insurance	Financial industry, insurance industry
Health and welfare	Health, social security, social welfare and public facilities management
Education and culture	Education, culture, sports, entertainment
Science service	Scientific research, technical services and geological perambulation

Table I. The specific industries included in the defined 18 sectors

the gross national product is selected as the output of "agriculture." In the secondary industry, the data of total industrial output value in "main economic indicators of all state-owned and non-state-owned industrial enterprises above designated scale," which reflect the whole industry, are selected as the output. In the tertiary industry, the "added value of the tertiary industry" in national economic statistics is chosen as the output, which is converted according to the GDP deflator of 1993 = 100 after corresponding adjustment of industries.

There has been a long history of research on the accounting of physical capital stock. Chow (1993), Wang and Fan (2000), Zhang Jun and Zhang Yuan (2003) and others have estimated this value in their papers. With reference to the specific methods given by Zhang Jun and Zhang Yuan (2003), this paper uses the perpetual inventory method created by Goldsmith in 1951 to calculate the physical capital stock of the industry. Based on the year of 1993, the following formula is adopted to estimate the physical capital stock:

$$K_t = I_t/P_t + (1-\delta_t)K_{t-1}.$$

Among them, K_t is the actual physical capital stock, P_t is the price index of investment in fixed asset and the fixed asset depreciation rate of δ_t is set as 5 percent according to the relevant literature. From 2004 to 2015, this paper selected "fixed investments according to cities and towns, as well as industries" as the nominal investment. Because there was no data of this statistical standard in the previous, from 1993 to 2003, we adopted the sum of "capital construction investment in different industries according to the construction nature" and "renovation investment in different industries according to construction nature" as the nominal investment.

There are also numerous measurement methods to calculate the human capital stock. For example, "proportion of the number of college students to total population" (Yan and Wang, 2004), "the number of students in secondary school and above" (Xu *et al.*, 2006) and "the average number of years of education multiplied by the number of workers in different industries" (Yue and Liu, 2006) were adopted to measure human capital stock. Considering the availability of data, this paper uses the method of "the average number of years of education multiplied by the number of workers in different industries" to measure the industrial human capital stock. The average number of years of education is calculated by the aggregation after multiplying the number of years of education by the proportion of education in different levels in the total population. Among them, the span of "elementary education" is 6 years (mainly refers to the elementary school stage), the span of years of "junior high school education" is set as 9 years (mainly refers to the junior high school stage), the span of years of "high school education" is set as 12 years (mainly refers to the high school and technical secondary school stage), the span of years of the "higher education" is set as 16 years (mainly refers to the college educational level and above). We then multiplied these figures by the number of employees in each industry to get the human capital stock of the industry.

As for the estimation of R&D stock, this paper mainly uses the method given by Wu Yanbing (2006a, b) to estimate the R&D stock of the industry. The estimation of R&D stock is also based on the perpetual inventory method, that is, the R&D stock is:

$$R_t = E_{t-1} + (1-\delta)R_{t-1}.$$

We first determine the amount of expenditure of the R&D, of which the data of secondary industry are set as "the internal expenditure for science and technology activities of large and medium-sized enterprises in different industries." However, because of the involvement of all sectors of national economy in the paper and the availability of data, the R&D input in the primary and the tertiary industry is set as the "internal expenditure for research and development in the field of natural science and technological activities in different industries" from 1993 to 2001, and the "internal expenditure on scientific and technological activities of research and development institutions in different industries" from 2002 to 2011. This is because there is no unified standard for the R&D expenditure of the primary and the tertiary industry. In addition, R&D activities are mainly concerned with the field of natural sciences, and there is no obvious mutation in statistics of the year of 2002, so we adopted such a method to measure the R&D input of different sectors of the primary and the tertiary industry. Besides, for the R&D price index, this paper uses the weighted average of raw material purchase price index and fixed asset price index to construct R& D expenditure price index, wherein the weight is 0.5. Furthermore, the depreciation rate of R&D stock of δ is directly set as 15 percent according to the existing literature. Lastly, we determine the R&D stock of the base year. In this paper, 1993 is set as the base year and the method of $R_0 = E_0/(g + \delta)$ is used to calculate the R&D stock of the base year, among which g is the arithmetic average growth rate of actual R&D expenditure.

4.3 Measurement results and explanation

First of all, we mainly depend on the coefficients of $\ln(h \times L)$ for judging the returns to scale. Among them, Model 1 includes the estimation of R&D input, while Model 2 does not. The regression results are shown in Table II.

According to the above analysis, whether the model includes R&D input or will not significantly influence the estimation results. The coefficients of $\ln(h \times L)$ of most sectors are obviously smaller than 0, and pass the significance test. Therefore, a basic conclusion can be drawn that China's current sectors show a significant decreasing state in terms of returns to scale. The output elasticity of physical capital per capita is generally on the high side, and there is no substantial change in the situation of increasing output growth by relying on physical capital input.

Specifically, the main sectors where R&D input per capita passes the significance test include "agriculture, mineral mining and dressing, food and beverage, textile and fur, wood and furniture, papermaking and printing, petrochemical and rubber, mineral processing, machinery and equipment, electronic and electric, culture, education and sports instrument, finance and insurance, health and welfare, education and culture, and science services." Among the 18 sectors, 13 have a significant positive impact on R&D input, indicating the extraordinary significance of research and development to sector development. In addition, as for the sector of "agriculture" and "food and beverage," although R&D input exhibits obvious positive influence, Model 2 (without R&D input) is more in accord with the actual situation. From the estimated coefficient and actual situation, Model 2, in which the two sectors do not include the R&D input, makes the estimation more accurate. China's agricultural sector exhibits constant returns to scale, while the sector of food and beverage exhibits decreasing returns to scale.

To sum up, the investigation of 18 sectors in China found that 78 percent of sectors in China so far have not realized increasing returns to scale, and most of them exhibit decreasing or constant returns to scale. Some sectors represented by the machinery and equipment, electronic and electric, financial and insurance, and science service showed increasing returns to scale, but the positive contribution of R&D is limited, so the driving mechanism of endogenous growth in these sectors is still weak.

We hypothesize that there are two different types of sectors in China's supply structure, namely the coexistence of increasing returns to scale and constant or decreasing returns to scale. Through empirical data investigation, although China's overall economic structure has two kinds of sectors, but the sector of decreasing or constant returns dominates and the proportion of sector of increasing returns being small, indicating that the increasing return mechanism in China's economy has not been established yet.

5. The difficulty in establishing "deviation" in the mechanism of increasing returns to scale on the supply side in China's economy

5.1 Further analysis of the situation of returns to scale in China's supply structure

As can be seen from the above analysis, the whole supply structure composed of various sectors has not established the mechanism of increasing returns to scale so far. To find out the reasons, we need to further analyze the cross-industry panel data of 23 years from 1993 to 2016 so as to examine the impact of physical capital, human capital and R&D input on China's overall output. The panel data model used to test the overall situation of returns to scale is similar to Equation (3), as follows:

$$\ln Y_{it} - \ln(h_t \times L_{it}) = \ln A + \kappa[\ln K_{it} - \ln(h_t \times L_{it})] + \varepsilon[\ln R_{it} - \ln(h_t \times L_{it})] + (\delta - 1)\ln(h_t \times L_{it}) + \alpha_i + \mu_{it}. \quad (5)$$

	Constant term	$\ln K - \ln(h \times L)$	$\ln(h \times L)$	$\ln R - \ln(h \times L)$	Returns to scale
Agriculture					
(1)	3.694** (2.69)	0.587** (2.27)	−0.001 (−0.00)	−0.118** (2.09)	Constant
(2)	3.602* (1.94)	0.711*** (17.28)	0.045 (0.21)		Constant
Mineral mining and dressing					
(1)	4.993*** (8.54)	0.006* (1.75)	−0.475*** (−11.23)	0.402*** (14.02)	Decreasing
(2)	4.668*** (6.91)	0.698*** (9.99)	−0.579** (−1.89)		Decreasing
Food and beverage					
(1)	6.147*** (11.92)	0.307* (1.82)	−0.519*** (−9.48)	−0.215*** (19.81)	Decreasing
(2)	4.792*** (6.07)	0.674*** (11.24)	−0.506*** (−5.86)		Decreasing
Textile and fur					
(1)	6.281*** (19.17)	0.243*** (4.96)	−0.572*** (−8.16)	0.272*** (4.69)	Decreasing
(2)	7.681*** (10.97)	0.514*** (9.07)	−0.801*** (−8.97)		Decreasing
Wood and furniture					
(1)	5.019*** (20.23)	0.317*** (3.72)	−0.576*** (−14.49)	0.201** (2.29)	Decreasing
(2)	4.860*** (14.92)	0.399*** (8.69)	−0.702*** (−10.11)		Decreasing
Papermaking and printing					
(1)	5.119*** (8.01)	0.353* (1.88)	−0.499*** (−9.44)	0.109*** (6.11)	Decreasing
(2)	3.115*** (6.16)	0.666*** (12.14)	−0.487*** (−8.11)		Decreasing
Petrochemical and rubber					
(1)	5.585*** (11.16)	0.539* (1.88)	−0.522*** (−9.21)	0.299*** (9.01)	Decreasing
(2)	3.089*** (3.82)	0.744*** (10.29)	−0.414*** (−4.44)		Decreasing
Mineral processing					
(1)	7.523*** (10.11)	0.568* (1.81)	−0.567*** (−8.44)	0.022*** (6.88)	Decreasing
(2)	4.349*** (6.88)	0.716*** (10.02)	−0.556*** (−8.30)		Decreasing
Machinery and equipment					
(1)	6.722*** (11.58)	0.113*** (4.41)	0.351*** (21.88)	0.602*** (6.44)	Increasing
(2)	6.564*** (19.26)	0.426*** (9.11)	0.703*** (8.16)		Increasing
Electronic and electric					
(1)	5.624*** (15.11)	0.509*** (4.88)	0.288*** (15.14)	0.399*** (6.62)	Increasing
(2)	4.912*** (11.97)	0.602*** (9.22)	0.533*** (10.44)		Increasing
Culture, education and sports instruments					
(1)	5.990*** (11.92)	−0.866 (−0.33)	−0.501*** (−8.89)	0.018*** (5.12)	Decreasing
(2)	5.743*** (10.15)	0.679*** (12.79)	−0.809*** (−10.68)		Decreasing
Production and supply of electricity, gas and water					
(1)	−3.273** (−2.22)	0.621*** (19.22)	0.198 (1.25)	0.023 (0.55)	Constant
(2)	−2.933*** (−8.33)	0.648*** (27.98)	0.343 (0.56)		Constant
Transportation and communication					
(1)	2.124 (1.09)	0.693*** (16.81)	−0.407* (−1.89)	0.011 (0.22)	Decreasing
(2)	2.888* (1.99)	0.622*** (14.65)	−0.599** (−4.11)		Decreasing
Dining and retail					
(1)	7.027*** (10.78)	0.878** (2.04)	−1.448*** (−11.02)	0.154 (0.38)	Decreasing
(2)	9.988*** (10.80)	0.786*** (16.49)	−1.002*** (−11.72)		Decreasing
Finance and insurance					
(1)	5.634** (2.49)	0.509* (1.81)	0.400*** (4.96)	0.396*** (3.55)	Increasing
(2)	−4.393** (−2.88)	0.611*** (6.25)	0.579*** (5.14)		Increasing

(*continued*)

Table II.
Regression results of returns to scale for major sectors of national economy

	Constant term	$\ln K - \ln(h \times L)$	$\ln(h \times L)$	$\ln R - \ln(h \times L)$	Returns to scale
Health and welfare					
(1)	−0.011 (−0.03)	0.594*** (5.50)	−0.072 (0.37)	0.189** (2.07)	Constant
(2)	−0.612 (−0.23)	0.668*** (6.02)	−0.069 (−0.33)		Constant
Education and culture					
(1)	−3.802*** (−5.54)	0.439*** (9.93)	0.330 (0.14)	0.005* (1.84)	Constant
(2)	−3.217*** (−6.52)	0.484*** (19.75)	−0.385* (1.93)		Decreasing
Science service					
(1)	2.809 (0.56)	0.275* (1.88)	0.210* (1.79)	0.388* (1.96)	Increasing
(2)	5.121*** (4.58)	0.692*** (18.13)	0.318** (2.06)		Increasing

Notes: *t*-value is in parenthesis, and *,**,***Significant at the 10, 5 and 1 percent levels, respectively

Table II.

In this formula, δ_i is the coefficient, α_i is the individual effect and u_{it} is the random disturbance item. The equation with and without R&D input is still estimated, respectively, and the specific results are shown in Table III.

From the above analysis, as for the results of either fixed effect estimation or instrumental variable estimation, the coefficient of $\ln(h \times L)$ is significantly negative, showing that China's overall supply structure exhibits a state of decreasing returns to scale, and the situation of various industries is basically the same. In order to examine the impact of each type of input on the overall output, Table III reports the impact of physical capital and R&D input on the output. Moreover, we also investigate the impact of human capital input on the output according to Table III, as shown in Table IV.

As shown in Table IV, as for the impact of physical capital input on the overall output, the output elasticity is generally 0.5–0.6, indicating that the proportion of the dependence of China's overall economy on the capital input is 50–60 percent. However, the impact of the R&D input on the output is relatively low, with one unit increase of R&D input only bringing about a 1 percent increase in the overall output. It is particularly worth noting that the human capital input has a significantly negative impact on the output. For every one unit increase of human capital, the output decreases by 0.1–0.2 units instead of increasing.

	Explained variable: $\ln Y - \ln(h \times L)$			
	Panel fixed effect method		Panel instrumental variable method	
	(1)	(2)	(3)	(4)
$\ln K - \ln(h \times L)$	0.606*** (24.109)	0.501*** (25.764)	0.595*** (28.405)	0.521*** (24.555)
$\ln(h \times L)$	−0.502*** (−14.943)	−0.569*** (−19.548)	−0.545*** (−15.788)	−0.601*** (−18.226)
$\ln R - \ln(h \times L)$		0.111* (5.052)		0.107* (5.226)
cons	4.645*** (18.118)	5.204*** (18.606)	4.711*** (16.928)	5.382*** (19.634)
R^2	0.855	0.868	0.859	0.867
Hausman test	11.02*** (0.00)	18.54*** (0.00)	12.59** (0.01)	16.99** (0.01)
Type	FE	FE	FE	FE

Notes: *t*-value is in parenthesis, and *,**,***Significant at the 10, 5 and 1 percent levels, respectively

Table III. Estimated results of the situation of returns to scale in China's overall economy

	(1)	(2)	(3)	(4)
$\ln(h \times L)$	−0.108*** (−4.39)	−0.181*** (−5.68)	−0.140* (−3.85)	−0.229* (−5.05)

Notes: *t*-value is in parenthesis, and *,**,***Significant at the 10, 5 and 1 percent levels, respectively

Table IV. The impact of human capital input on the output

5.2 The explanation of the difficulty in establishing the structural "deviation" by the mechanism of increasing returns to scale in China's supply structure

It can be seen from the above analysis that, no matter in individual industries or the whole, the mechanism of increasing returns to scale in China's supply structure has not been established. The most crucial reason is that human capital and R&D have not played their due and real roles in economy.

5.2.1 Structural deviation in the human capital input in China. This paper uses the average number of years of education to measure the human capital. The results of the negative impact of human capital input on the overall estimation showed that in China – the supply of professionals formed through education – is mismatched with the demands of market for professionals, and the problem of the mismatch between supply and demand is serious. China is in the process of industrialization characterized by "labor intensive" and "capital intensive" manufacturing. Enterprises in China are more inclined to recruit skilled workers; however, China's education is hardly geared to the needs of the market and the needs of the enterprises. Therefore, although the number of years of education has been growing continuously and the human capital accumulation has been improving incessantly, they are mismatched with the demands of skilled workers in the market. This type of mismatch is most prominently reflected in the problem of "employment difficulty" for college students. In addition, the accumulation of human capital, such as the so-called reemployment training of urban workers, also has the problem of the mismatch between supply and demand of market and enterprises, resulting in structural unemployment. Therefore, because of the existence of this structural deviation of human capital input, human capital does not exert positive impacts on the output, and at the same time it is difficult to form the mechanism of increasing returns to scale, while the traditional growth mode of decreasing and constant returns to scale become the mainstream.

5.2.2 Structural deviation in the R&D input in China. Another key role of the mechanism of increasing returns to scale is played by the R&D input. As can be seen from the above analysis, the positive influences of R&D input on the overall output were very small, and some sectors even exhibited negative influences, resulting in the inefficiency of R&D input. In-depth analysis regard, it is also the existence of structural deviation of R&D input. The R&D innovation system led by the government in China and the long-term split and mismatch between the system of research and development and the system production leads to a mismatch between the supply of research and development results and the demands of industries. The low conversion rate and rate of research and development results have become an unavoidable problem, which makes it difficult for research and development results to be converted into real productivity, resulting in the difficulty in the establishment of the mechanism of increasing returns to scale.

In short, the basic logic of the difficulty in establishing the overall increasing returns to scale in China lies in system defects. During China's transformation and development over the past 30 years, the institutional transformation centering on the "ownership reform," "market-oriented reform" and "opening to the outside world" has obtained the diversification of industrial structure and provided conditions for the path of quantitative growth of scale expansion based on the constant or decreasing returns to scale. However, it does not realize the optimization of the industrial structure, so it lacks conditions for the qualitative growth based on the increasing returns to scale. The structural "deviation" reflected in human capital input and R&D input makes these two key factors, which are also key elements for the establishment of increasing returns to scale, unable to play their effective roles and inhibit the formation of endogenous growth mode characterized by increasing returns to scale.

6. Conclusion and policy implication

China's economic structure at the present stage exhibits a kind of two-sector supply structure which includes the sector of constant or decreasing returns to scale, and that of increasing returns to scale motivated by knowledge and human capital, with the mechanism of both sectors working together. In this paper, we selected data from 18 sectors from 1993 to 2015 for an empirical test. The results show that although China's supply-side structure is divided into the sector of constant or decreasing returns to scale and that of increasing returns to scale, most sectors of China's economy at the present stage exhibit either decreasing or constant returns to scale, while only a few sectors show increasing returns to scale. China's industries with constant or decreasing returns are still dominant, resulting in the state of decreasing returns to scale in the overall supply-side structure of China. The mechanism of increasing returns to scale has not been established, and its underlying reason lies in the "deviation" of China's supply-side structure. This shows that the core factors restricting China's future economic growth will shift from the "institutional constraints" in the past to the supply-side structural constraints, namely, the upgrading of industrial structure, technological progress and the role of human capital. "The cultivation of core technologies" and "transformation and upgrading of industrial structure" will be the key to China's future economic growth. It also determines that the focus of China's future economic reform should shift from "ownership reform," "marketization" and "openness" to supply-side structural reform and technological progress. Therefore, in the process of future economic growth, the key is to solve the imbalance of supply-side structure, break the low-end locking of the industrial structure, vigorously develop modern industrial sectors dominated by knowledge and technology, accelerate the establishment of the mechanism of increasing returns to scale, and improve the efficiency of economic growth. In the future, the theme of China's economic growth is no longer to pursue the quantity of economic growth through the diversification of industrial structure, but to pursue the quality of economic growth through the reform of supply-side structure. The fundamental path lies in accelerating the reform of supply-side structure and accelerating the shift of China's economy from constant or decreasing returns to scale to increasing returns to scale.

The contradictions exposed in China's current economic growth show that the economic growth mode of relying on scale expansion on the basis of constant returns to scale to pursue economic growth rate has come to an end, and the transformation of economic development mode is urgent. To maintain the long-term growth of China's economy and change the way of promoting China's economic development, it is necessary to take the reform of supply-side structure as the core and the improvement of the quality of economic growth as the goal, so as to realize the shift of the mechanism of economic growth from constant returns to scale to increasing returns to scale through the reform of supply-side structure: first, we should improve the independent innovation ability of enterprises, and promote the transformation of scientific and technological achievements into productivity; and at the same time, it is also necessary to pay attention to the accumulation of human capital of the enterprise, and advocate the real role of science, technology and knowledge in the output growth of sectors. Second, we should accelerate the reform of traditional sectors, and increase the investment of technology and human capital in traditional sectors in the supply-side structural reform. At the same time, we should also facilitate the upgrading of industrial structure so as to promote the transformation of enterprises or the whole industry from capital-driven or labor-driven growth to knowledge-driven growth, realizing the transformation of industrial structure from traditional constant or decreasing returns to scale to increasing returns to scale. Third, we should promote the transformation of China's economic growth from the factor-driven pattern to innovation-driven pattern, from the growth driven by the input of factors to the growth driven by innovation. The pattern of technological progress should be shifted from the development of technological progress with development factors to the development of technological progress of non-factors, and the macroeconomic policy should be shifted from short-term demand management to long-term supply management, so as to promote the establishment of the mechanism of increasing returns to scale in economic growth. Fourth, in the reform of the supply-side structure, the adjustment of industrial structure should be transformed from structural diversification to upgrade. We should actively promote the rationalization and upgrading of China's industrial structure, speed up the formation of the modern industrial system, break the low-end locking of industrial structure, enhance the transformation capacity of the industrial structure and change the main direction of China's future economic growth from seeking speed with structural diversification to seeking quality with structural upgrading through supply-side structural reform.

Note

1. There is a serious deficiency of the data of "waste resources and waste materials recycling and processing industry" and "industry of exploitation and transportation of timbers and bamboos" from 1993 to 2007, so they are eliminated.

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