Input Structure Effect of Total Factor Productivity Growth of Animal Husbandry

LI Xiu-shuang¹, ZHAO Liang² and YU Kang³
¹College of Economics and Management, Zhejiang A & F University, Hangzhou 31130, CHINA
²College of Economics and Management, South China Agricultural University Guangzhou 510642, CHINA
³College of Economics and Management, Zhejiang A & F University, Hangzhou 31130, CHINA

ABSTRACT
This paper uses the input-output panel data of China's animal husbandry industry from 1997 to 2017, based on the total factor decomposition framework of total factor productivity (TFP), and uses the Hicks-Moorsteen index completely decompose the growth of animal husbandry TFP. By measuring the effect of mixed efficiency on the development of TFP in animal husbandry and then evaluating the input structure effect of TFP growth in animal husbandry. The results show that the impact of input structure on the TFP growth of animal husbandry has also changed from negative to positive. From 1997 to 2007, the input structure of the Huanghaihai region alone contributed to the growth of TFP in animal husbandry, and the rest of the region was the opposite. From 2008 to 2017, the input structure of the Mengxin Plateau region hindered the growth of TFP in animal husbandry, while the rest of the region was the opposite.

Key word—Total Factor Productivity, Mixed Efficiency, Input Structure

I. INTRODUCTION
Since the reform and opening, the supply of livestock products has improved dramatically, and a supply balance has been achieved. With the population growth and the further adjustment of residents' dietary structure, consumers' demand for meat and eggs, and other products will further increase. Liu Gang et al., 2018. The increase of livestock production can be realized in two ways: one is to increase the input of production factors, which is mainly to expand the number of livestock and poultry and increase the input of feed; Second, to improve the total factor productivity (TFP) of animal husbandry. However, as the scale of animal husbandry production grows, the environmental pollution problem grows as well. According to published in 2010, the first national pollution source census revealed that livestock and poultry breeding pollutants accounted for more than 50% of agricultural pollution sources. Animal husbandry has evolved into an impolite industry. The costs of livestock and poultry breeding have risen significantly in terms of resources and the environment. It is not sustainable to continue to increase the yield of animal husbandry by increasing factor input. Therefore, improving livestock TFP is the fundamental way to ensure the future supply of livestock products.

In the case of multiple inputs and technological progress, technical efficiency, and scale efficiency, mixed efficiency is also an important factor in promoting TFP growth. Blak, 2001. Therefore, the driving factor of mixed efficiency for TFP growth cannot be ignored, and the improvement of mixed efficiency can be achieved by improving the factor input structure. This paper selects the period of China's animal husbandry modernization (1997-2017) for analysis. During this period, China's factor input structure has undergone significant changes. Feed input increased by 182.18%, machinery input by 114.97%, intermediate consumption by 85.24%, and the amount of main livestock raised by 4.99%. Then, how will this change in the factor input structure affect the TFP of the livestock industry? What about the impact? Existing studies do not provide a definitive answer.

In the existing studies, when analyzing the driving factors of TFP growth in broad agriculture and its sub-industries, scholars pay more attention to technological progress, technical efficiency and scale efficiency. Most of the literature have confirmed the role of technological advancement in promoting the growth of generalized agricultural TFP. In contrast, the effects of technical efficiency and scale efficiency on the growth of generalized agricultural TFP are different in regions and time. Mao and Koo, 1997; Wu et al., 2001; Gu Hai and MengLingjie, 2002; Fang Fuqian and Zhang Yanli, 2010; Gucheng Li et al., 2013. Only a few scholars used the method of aggregate quantity framework to complete decomposition of generalized agricultural TFP and discussed the effects of four driving factors on generalized TFP growth (Chen Zhaojiu and Hu Wen, 2016; Zhang Haixia and Han Peijun, 2018; Xi Liqing and PengKemao, 2010). For the research on the driving factors of TFP growth in agricultural sub-production, the main focus is...
still on the impact of technological progress, technical efficiency and scale efficiency on TFP growth in agricultural sub-production (Si Wei and Wang Jimin, 2011; Min Rui, 2012; Wang Li and Han Yali, 2016; Shi Changliang et al., 2017; Yu Zhanmin et al., 2017)[11-15], but not enough attention was paid to the driving factor of mixed efficiency. Zhao Liang and Yu Kang [16] (2019) focused on the driving effect of mixing efficiency change on grain TFP growth, and analyzed the relationship between input structure change and grain TFP change in main producing areas. However, the existing literature does not provide a clear answer to the effect of the change of factor input structure on the growth of livestock TFP.

At present, the research on the driving factors of TFP in agriculture and its sub-production mainly adopts the following two methods: (1) the Malmquist index method based on data envelopment analysis. However, it is accurate to use this method to measure and decompose TFP only when the return to scale is constant [17-18] (Grifell-Tatje and Lovell, 1995; Pastor and Lovell, 2005). (2) Stochastic Frontier Analysis (SFA). Under the strict assumption of input price, the SFA can decompose TFP into five parts: technological progress, technical efficiency, scale efficiency and factor allocation efficiency [19] (Kumbhaker and Lovell, 2000). Although these two methods have been widely used, they both ignore the effect of mixed efficiency on agricultural TFP growth, thus hindering the discussion on the relationship between factor input structure and agricultural TFP growth.

In view of this, based on the Aggregate Quantity Framework proposed by O’Donnell [20] (2010), this paper thoroughly decomposes the TFP growth by adopting the TFP index with complete product and focuses on the contribution of the mixed efficiency to the TFP growth of animal husbandry. Then the input structure effect of livestock TFP growth was evaluated.

II. ANALYSIS OF STRUCTURAL CHANGE OF ANIMAL HUSBANDRY FACTOR INPUT

Since 2007, China has vigorously developed standardized large-scale breeding, and the scale and intensive level of animal husbandry has been greatly improved. The livestock production has gradually changed from scattered small-scale breeding to large-scale operation, realizing a historic leap in the production mode [21] (Chen Weisheng et al., 2019). The change of production mode will affect the input structure of animal husbandry factors to some extent, so this paper is divided into two stages (1997-2007 and 2008-2017) (Table 1).

From 1997 to 2007, the changes of the four input factors were obviously different. Except for the change of the intermediate consumption, the other three factors all had great changes. The amount of animal husbandry increased by 381.01 billion yuan with a range of 75.8%, and the machinery input increased by 120.847 million kWh with a range of 93.8%. The feed input increased by 58.12 million tons or 89.16%, and the amount of livestock raised increased by 47.112 million or 5.9%. In this period, the variation range of input factors was large, and there was an obvious imbalance in the variation. What impact did this change of input structure have on the growth of TFP in animal husbandry?

### Table 1: Comparative analysis of input elements in animal husbandry

| elements     | 1997—2007years | 2008—2017years |
|--------------|----------------|----------------|
|              | Net increment  | Rate of change | Net increment | Rate of change |
| Feed         | 5812.03        | 89.16%         | 4728.39       | 34.60%         |
| Mechanical   | 12084.68       | 93.79%         | -963.63       | -3.36%         |
| Livestock    | 3810.14        | 75.78%         | -151.91       | -1.60%         |
| Intermediate | 4711.21        | 5.88%          | -2472.77      | -2.85%         |

From 2008 to 2017, the state vigorously developed standardized large-scale breeding, greatly improved the scale and intensive level of animal husbandry, optimized the input structure of animal husbandry, and effectively reduced the difference between the changes of input factors, so that the changes of each factor were more balanced. Of these, the consumption of intermediate substances was reduced by 15.19 billion yuan, or 1.6 percent; machinery input by 9.636 million kilowatt-hours, or 3.4 percent; feed input by 47.2839 million tons, or 34.6 percent; and the amount of livestock raised by 24.728 million head, or 2.85 percent. Does this change of input structure improve the growth of TFP in animal husbandry compared with the previous stage?

III. THE INFLUENCE MECHANISM OF INPUT STRUCTURE ON TFP GROWTH
(1) The Influence Path of Input Structure on TFP Growth

Theoretically, in the case of multiple inputs, in addition to technological progress, technical efficiency change and scale efficiency change, the change of mixed efficiency is also the driving force for TFP growth [2] (Blak, 2001). As shown in Figure 1, there are four driving factors for TFP growth, and the input structure influences TFP growth by changing the mixing efficiency.

![Figure 1: The influence path of input structure on TFP growth](image)

(2) Input Structure and Mixing Efficiency

Mixing efficiency is the focus of this paper. Assume that the production unit only uses two inputs, and the total input is \( x = \alpha_1 x_1 + \alpha_2 x_2 \). The curve in Fig. 2 is the production frontier, representing all input combinations with technical efficiency, \( x = x_1 + x_2 \), and the dotted line is the equal input line. If the input structure remains unchanged and the total input drops from point A to point B, it is called technical efficiency \( \text{ITE}_t = \| \partial B / \| B \| \) . If the input structure is variable, the total input can be further reduced from point B to point D, i.e., mixing efficiency \( \text{IME}_t = \| \partial D / \| D \| \), which is the ratio of TFP of point D to point E in Fig. 1. O’Donnell[12] also calls it residual mixing efficiency (RME).

![Figure 2: input-oriented efficacy](image)

(3) Mixed Efficiency and TFP Growth

1. Product Complete TFP Index

Assuming \( Q_t \) and \( X_t \) is respectively the total output and total input of the production unit in period T, \( q_t \in R^N \), \( x_t \in R^M \) are output and input vectors respectively. TFP of unit T period is: \( TFP_t = Q_t / X_t \) (Jorgenson and Griliches, 1967). TFP index of production unit from S period to T period: \( TFP_{st} = TFP_t / TFP_s = Q_{st} / X_{st} \), among them, \( Q_{st} = Q_t / Q_s \) is the output quantity index, \( X_{st} = X_t / X_s \) is Input quantity index. In other
words, TFP index can be expressed as the ratio of output quantity index and input quantity index. If the sum function \( Q(\cdot) \) and \( X(\cdot) \) are the function with non-negative, non-decreasing, and linear homogeneity, the TFP exponent is said to be product complete \[O’Donnell, 2010\].

2. Efficiency

O’Donnell \[20\] (2010) uses the ratio of TFP to define efficiency. The curve I and bar in Fig. 1 represent the pre-production line with constant and variable input structure, respectively. Line AB represents the efficiency defined under the premise that total output is certain, namely the so-called input-oriented efficiency. The total input in the figure is the total input of animal husbandry, and the total output is the total output value of animal husbandry (100 million yuan).

![Figure 3: Input-based efficiency](image)

Figure 3: Input-based efficiency

(1) 技术效率 (ITE): A点生产单位 \( t \) 期的技术效率:

\[
ITE_t = \frac{0A\text{斜率}}{OB\text{斜率}} \quad (1)
\]

(2) 规模效率 (ISE): A点生产单位 \( t \) 期的规模效率:

\[
ISE_t = \frac{0B\text{斜率}}{OD\text{斜率}} \quad (2)
\]

3. Decomposition of Product Complete TFP Exponent

The product complete TFP index has two decomposition paths. If only one decomposition path is used to measure the growth of the decomposition TFP, there may be deviation. Therefore, in this paper, the geometric average of the two decomposition is obtained in the following form:

\[
TFP_{st} = \frac{TFP^*_t}{TFP^*_s} \times \left[ \frac{ITE_t}{ITE_s} \times \sqrt{\frac{ISE_t}{ISE_s} \times \frac{RISE_t}{RISE_s}} \times \sqrt{\frac{IME_t}{IME_s} \times \frac{RME_t}{RME_s}} \right] \quad (3)
\]
The first item on the right of the equation is technological progress, and in the parentheses are the technical efficiency index, the scale efficiency index and the mixed efficiency index. If the index of technological progress and efficiency is greater than 1, the technological progress and efficiency promote the growth of TFP; otherwise, it hinders the growth of TFP. If the mixed efficiency index is greater than 1, it means that the change of factor input structure promotes the growth of TFP; otherwise, it restrains the growth of TFP.

4. Measure

In this paper, the Hicks -- Moorsteen TFP index with complete product was used to measure the growth of TFP in animal husbandry. The TFP index is of the following form:

$$\text{TFP}_{st}^{HM} = \frac{Q_s^M}{X_s^M} = \left[ \frac{D_s(x_s, q_s)}{D_s(x_s, q_s)} \frac{D_s(x_s, q_s)}{D_s(x_s, q_s)} \frac{D_s(x_s, q_s)}{D_s(x_s, q_s)} \right]^{1/2}$$

(4)

IV. Variables and data sources

(1) Input and Output Variables

Output variable: gross output value of animal husbandry, and the gross output value index of animal husbandry (2009=100) was used for deflating.

Input variables: the selection of input variables mainly refers to the input elements of animal husbandry selected by Chen Weihong and Qi Yanbin (2010)[23]. Since the input of animal husbandry machinery and feed cannot be obtained directly, the treatment method of Cao Jia et al. (2009)[24] is referred to.

1. Number of livestock raised (ten thousand): the sum of large livestock (cattle, horses, camels, etc.), pigs, sheep raised.

2. Animal husbandry machinery input (ten thousand kWh): Animal husbandry machinery input = total input of agricultural, forestry, animal husbandry and fishery machinery×牧业总产值/农林牧渔总产值

3. Feed input (ten thousand tons): feed input = national feed output×牧业总产值/农林牧渔总产值

4. Intermediate substance consumption (100 million yuan): Intermediate substance consumption of animal husbandry, which is reduced by the total output value index of animal husbandry (2009=100).

(2) The Data Source

In this paper, the data of 1997-2017 China’s 31 provinces (autonomous regions and municipalities directly under the central government) input-output panel data, animal husbandry, livestock feed quantity is derived from the animal husbandry in China statistical yearbook, calendar year feed input data from the foundation of the calendar year China feed industry yearbook, based data are measured and decomposed by DPIN3.0 software, and the calculation results were reported in Table 2. The different regions in Table 2 are divided into 7 regions of the 31 provinces (autonomous regions and municipalities directly under the central government) according to the Comprehensive Regionalization of Animal Husbandry in China: The northeast area (liaoniong, heilongjiang, jilin, huanghuai area (Beijing, tianjin, shandong, hebei, henan), loess tg-p (gansu, ningxia, shanxi, shaanxi), receive new tg-p (Inner Mongolia, xinjiang), the qinghai-tibet plateau, Tibet, qinghai) and southwest mountain area (yunnan, guizhou, sichuan and chongqing), southeast area (Shanghai, zhejiang, fujian, guangdong, jiangxi, widely West, Hunan, Hubei, Jiangsu, Anhui, Hainan).

1. The Overall Change of Structural effect of TFP Input in Animal Husbandry

From 1997 to 2007, China's TFP of animal husbandry increased by 0.6% annually, among which technological progress was the main driving force, with an annual growth rate of 1.9%. The average annual decrease of mixed efficiency was 1.1%, indicating that the mixed efficiency hindered the growth of TFP of animal husbandry, that is, the change of input structure hindered the growth of TFP of animal husbandry. This may be due to the large increase in feed, machinery and intermediate consumption (Table 1), resulting in the factor input structure is not reasonable, thus hindering the growth of livestock TFP. In addition, technical efficiency promoted the growth of TFP in animal husbandry with an average annual growth rate of 0.1%, while scale efficiency hindered the growth of TFP in animal husbandry with an average annual decrease rate of 0.3%.
Table 2: Measurement and decomposition results of TFP in animal husbandry from 1997 to 2017

| Time       | Region               | TFP   | Mixing efficiency | Advances in technology | Technical efficiency | Scale efficiency |
|------------|----------------------|-------|-------------------|------------------------|----------------------|------------------|
| 1997—2007年| Northeast            | 1.030 | 0.991             | 1.044                  | 1.011                | 0.984            |
|            | Huang-Huai-Hai       | 1.038 | 1.004             | 1.011                  | 1.001                | 1.021            |
|            | Loess plateau        | 1.024 | 0.984             | 1.018                  | 0.997                | 1.025            |
|            | Mengxin plateau      | 1.017 | 0.998             | 1.002                  | 1.005                | 1.011            |
|            | Tibetan Plateau      | 0.912 | 0.974             | 1.000                  | 0.977                | 0.959            |
|            | mountainous southwest| 0.910 | 0.954             | 1.002                  | 0.999                | 0.953            |
|            | south-east           | 1.031 | 0.997             | 1.029                  | 1.003                | 1.001            |
|            | Average              | 1.006 | 0.989             | 1.019                  | 1.001                | 0.997            |
| 2008—2017年| Northeast            | 1.031 | 1.008             | 1.000                  | 1.007                | 1.016            |
|            | Huang-Huai-Hai       | 1.021 | 1.006             | 1.000                  | 0.999                | 1.016            |
|            | Loess plateau        | 1.019 | 1.003             | 1.000                  | 1.003                | 1.013            |
|            | Mengxin plateau      | 1.020 | 0.994             | 1.000                  | 1.023                | 1.003            |
|            | Tibetan Plateau      | 1.047 | 1.010             | 1.000                  | 1.002                | 1.035            |
|            | mountainous southwest| 1.025 | 1.001             | 1.000                  | 1.015                | 1.008            |
|            | south-east           | 1.017 | 1.004             | 1.003                  | 1.002                | 1.008            |
|            | Average              | 1.022 | 1.004             | 1.001                  | 1.005                | 1.012            |

From 2008 to 2017, TFP of animal husbandry increased at an average annual rate of 2.2%. Among them, scale efficiency was the main driving force for TFP growth of animal husbandry, with an average annual growth rate of 1.2%, and mixed efficiency increased at an average annual rate of 0.4%, indicating that mixed efficiency promoted the growth of TFP of animal husbandry, that is, input structure brought the growth of animal husbandry and TFP. This may be due to the large scale and intensive level of animal husbandry, which makes the growth range of various factors relatively balanced (Table 1), which promotes the optimization of the input structure, and thus makes the positive effect of the TFP input structure of animal husbandry appear. Both technical efficiency and technological progress contributed to the growth of livestock TFP, with an average annual increase of 0.5% and 0.1%, respectively.

From the comparison between the two periods, the average annual growth rate of TFP in animal husbandry increased by 1.6%, among which, the average annual growth rate of mixed efficiency increased by 1.5%, which changed from negative effect to positive effect. The average annual growth rate of technological progress decreased by 1.8%, while the average annual growth rate of technical efficiency increased by 0.4% and the average annual growth rate of scale efficiency increased by 1.5%.

2. Regional Differences in Structural Effects of TFP Input in Animal Husbandry

In order to display the variation of mixing efficiency in different regions more intuitively, ArcGIS 10.6 software was used in this paper to perform visual processing on some data in Table 2, and the spatial distribution map of mixing efficiency as shown in Figure 4 was obtained by classifying the mixing efficiency values.
Figure 4: Spatial distribution of livestock mixing efficiency from 1997 to 2007 and from 2008 to 2017

From 1997 to 2007, TFP of animal husbandry decreased by 2.3% and 3.4% per year in Qinghai-Tibet Plateau and southwest mountainous areas, but increased to different degrees in other areas, especially in Huang-Huai-Hai region, which increased by 3.8% per year. At this stage, only the mixed efficiency in Huang-Huai-Hai area increased positively, indicating that the change of input structure hindered the growth of TFP in animal husbandry in Huang-Huai-Hai area was positive. The mixed efficiency of the other six regions all showed negative growth, which means that the TFP input structure effect of animal husbandry in the other regions is negative.

From 2008 to 2017, TFP of animal husbandry in seven regions all showed positive growth, among which the Qinghai-Tibet Plateau region showed the fastest growth rate, with an average annual growth rate of 4.7%. The mixed efficiency in Mengxin Plateau increased negatively, indicating that the change of input structure promoted the TFP of animal husbandry. In other regions, the mixing efficiency increased positively, which indicated that the change of input structure promoted the TFP of animal husbandry. However, the effects of technological progress, technical efficiency and scale efficiency on TFP growth of animal husbandry in different regions also showed great heterogeneity.

VI. CONCLUSION

This study uses panel data from 31 provincial regions from 1997 to 2017, based on the aggregated quantity framework, and adopts the complete product Hicks-Moorsteen TFP index to thoroughly decompose the growth of animal husbandry TFP. The impact of TFP growth in the livestock industry, and then assess the contribution of changes in the input structure to the growth of TFP in the livestock industry. The results show that: changes in input structure have temporal and spatial differences in the growth of animal husbandry TFP. From the overall impact, the mixed efficiency showed a negative growth from 1997 to 2007, that is, the input structure effect of the growth of the animal husbandry TFP during this period was negative, and the average annual growth of the mixed efficiency from 2008 to 2017 was positive, indicating that the animal husbandry TFP at this stage The input structure effect of growth is positive. From the perspective of the influence of each production area, from 1997 to 2007, only the input structure effect of TFP growth of animal husbandry in Huanghuaihai area was positive, while the input structure effect of TFP growth of animal husbandry in other regions was negative. From 2008 to 2017, only the input structure of animal husbandry TFP growth in the Mengxin Plateau was negative, and the input structure effect of animal husbandry TFP growth in other regions was positive.

From the perspective of the input structure effect of the growth of animal husbandry TFP, since 2007, the country has vigorously developed standardized scale breeding, and the scale and intensification of animal husbandry has been greatly improved, making the growth and fluctuation range of various factors relatively balanced, and optimizing the animal husbandry The production input structure has in turn promoted the growth of animal husbandry TFP. It can be seen that the larger the scale of operation, the more conducive to the optimization of the factor input structure, which in turn is conducive to promoting the growth of animal husbandry TFP.

REFERENCES

[1] Liu Gang, Luo Qianfeng, & Zhang Lixiang. (2018). The 40th anniversary of the reform and opening of animal husbandry: Achievements, challenges and countermeasures. Chinese Rural Economy, 12, 19-36.
[2] Balk B M. (2001). Scale efficiency and productivity
change. *Journal of Productivity Analysis, 15*(3), 159-183.

[3] Mao W, Koo W. (1997). Productivity growth, technological progress, and efficiency change in Chinese agriculture after rural economic reforms: A DEA approach. *China Economic Review, 8*, 157-174.

[4] Wu S X, David W, & STEPHEN D, etal. (2001). Productivity growth and its components in Chinese agriculture after reforms. *Review of Development Economics, 5*(3), 375-391.

[5] Fang Fuqian & Zhang Yanli. (2010). Analysis on the change of agricultural total factor productivity and its influencing factors in China: Based on the Malmquist index method from 1991 to 2008. *Economic Theory and Management, 9*, 5-12.

[6] Li Gucheng, Fan Lixia, Cheng Gang, & Feng Zhongchao. (2013). Agricultural total factor productivity growth: A reestimation based on a new window DEA productivity index. *Journal of Agrotechnical Economics, 5*, 4-17.

[7] Chen Zhaoju & Hu Wen. (2016). Factors supply and productivity growth of japonica rice in China: Technology drive or efficiency drive based on DEA-Tobit model. *Agricultural Economics and Management, 06*, 35-42.

[8] Zhang Haixia & Han Peijun. (2018). Agricultural total factor productivity measurement and convergent analysis based on Hicks-Moorsteen index. *Rural Economy, 6*, 55-61.

[9] ZHAO Liang & YU Kang. (2020). Growth of agricultural total factor productivity in China. *Journal of Henan Agricultural University, 54*(02), 354-36.

[10] Mugera AW, LangemeierM R, & Ojede, A. (2016). Contributions of productivity and relative price changes to farm-level profitability change. *American Journal of Agricultural Economics, 98*(4), 1210-1229.

[11] Si Wei & Wang Jimin. (2011). Total factor productivity of soybean production in China and its change. *Chinese Rural Economy, 10*, 16-25.

[12] Min Rui. (2012). Grain total factor productivity: An empirical analysis based on sequential DEA and county-level panel data in Hubei. *Journal of Agricultural Technical Economics, 01*, 47-55.

[13] Wang Li & Han Yali. (2016). An empirical analysis of China's cotton total factor productivity growth based on stochastic frontier analysis. *Journal of Agrotechnical Economics, 11*, 95-105.

[14] Shi Changliang, Jie Changliang, Shi Feng, & Wen Yali. (2017). The decomposition of forestry technical efficiency and total factor productivity growth in China: Estimation based on SFA-Malmquist method. *Scientia Silvae Sinicae, 53*(12), 126-135.

[15] Yu Zhanmin, Tang Zeng, Gao Jing, & Xi Juan. (2017). Dynamic analysis of total factor productivity of animal husbandry in China: Malmquist index method based on DEA model. *Chinese Journal of Animal Science, 53*(05), 132-136.

[16] Zhao Liang & Yu Kang. (2019). Factors input structure and growth of grain total factor productivity in major grain-producing areas: Based on input-output panel data from 1978 to 2017. *Journal of Hunan Agricultural University (Social Sciences Edition), 20*(05), 8-13.

[17] Griffel-Tatje E & Lovell C A K. (1995). A note on the malmquist productivity index. *Economics Letters, 47*, 169-175.

[18] Pastor J T & Lovell C K. (2005). A global malmquist productivity index. *Economics Letters, 88*(2), 266-271.

[19] Kumbhakar S C & Lovell C A K. (2000). *Stochastic frontier analysis*. Cambridge University Press.

[20] O'Donnell C J. (2010). Measuring and decomposing agricultural productivity and profitability change. *Australian Journal of Agricultural and Resource Economics, 54*(4), 527-560.

[21] Chen Weisheng, Yuan Long, & Huang Ruilin, et al. (2019). Study on sustainable development of animal husbandry in China. *Bulletin of the Chinese Academy of Sciences, 34*(02), 135-144.

[22] Jorgenson D W & Griliches Z. (1967). The explanation of productivity change. *The Review of Economic Studies, 34*(3), 249-283.

[23] Chen Weihong & Qi Yanbin. (2010). Analysis of the relationship between input factors and output value of animal husbandry. *Agrotechnical Economics, 08*, 39-46.

[24] Cao J, Xiao Haifeng, & Yang Guang. A study on total factor productivity of animal husbandry in China from 1978 to 2007. *Technology Economics, 28*(07), 62-66.