Environmental Efficiency and Random Convergence Analysis of Large-scale Pig Breeding in China *

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Abstract. As the scale of live pigs in China continues to accelerate, the agricultural non-point source pollution caused by it is becoming increasingly serious. In this paper, the SBM-Undesirable model was used to measure the environmental efficiency of pig breeding in different scales in year 2008-2017, and the efficiency was analyzed by random convergence. Results show: from the overall average, the environmental efficiency of pig breeding in China is medium-scale, large-scale and small-scale in order, and the three-scale pig breeding has random convergence characteristics. From the perspective of different regions, with the environmental efficiency as a judge, the three scales of potential development zones perform well, and only the small-scale pig breeding shows random convergence; large-scale mode in key development zones performs well with no signs of random convergence, has poor stability, while the other two remain stable at a low level; small and medium-scale modes perform better in moderate development zones, all showing no features of random convergence; the three scales in constrained development zones don’t perform well, and all remain stable at a lower level. Based on the above results, this paper put forward differentiated policies for different scales and regions to promote healthy and green development of pig scale breeding.

1. Introduction  
The pig industry occupies an important position in animal husbandry. According to statistics of the National Bureau of Statistics, the number of farmers (farms) that produce more than 50 pigs per year increased from 1.25 million to 2.02 million from 2008 to 2017, and the number of retail investors that produce less than 50 pigs per year decreased from 80.1 million to 35.71 million. With the continuous acceleration of the scale-up process of pig breeding in China, the emission of pollutants such as chemical oxygen demand (COD), total nitrogen (TN), and total phosphorus (TP) in pig breeding farms has increased year by year, becoming one of the important agricultural non-point source pollution. The central and local governments have successively issued various policies to support the development of pig-scale breeding. In 2013, the "Regulations on Pollution Prevention and Control of Livestock and Poultry-scale Breeding" was promulgated, opening the cycle of environmental protection; in 2015, the Ministry of Agriculture issued "Guiding Opinions of the Ministry of Agriculture on Promoting Adjustment and Optimization of Live Pig Breeding Layout in Southern Water Network Areas"; in 2016, a series of environmental protection policies such as "Technical Guidelines for Delineation of Prohibited
Livestock Breeding Areas” and "National Pig Production Development Plan" were intensively promulgated. Under the current background of strengthening of environmental regulations, the development of pig industry is facing severe challenges. How to balance economic benefits with environmentally friendly development and realize green ecological breeding has become an urgent problem. Therefore, it is of great practical significance to evaluate the environmental efficiency of China’s large-scale pig breeding from the perspective of resource and environmental constraints to promote the healthy and sustainable development of pig industry.

Many domestic scholars have studied the environmental efficiency of pig breeding. From the perspective of research methods, Du Hongmei [1] used non-radial and non-angle SE-SBM models to compare and analyze the environmental efficiency of pig breeding of three scales in Hunan province and the whole country, and pointed out that pig breeding in Hunan province needs to strengthen the innovation of feeding technology and feces utilization. Wang Dexin [2] adopted Malmquist-Luenberger productivity index method to analyze the production efficiency and decomposition of live pigs of different sizes under the environmental regulation and non-environmental regulation scenarios, and he concluded that it was not the larger the size, the higher the production efficiency of live pigs. Based on DEA thought, Wang Gangyi [3] constructed a non-radial directional distance function, and took the pig breeding in Heilongjiang province as an example to decompose its ecological efficiency into economic efficiency.

From the point of perspective of research content, Lin Jie [4] applied Bad-Output Model to analyze the environmental technical efficiency of the distribution density of water resources in different provinces from the point of view of water resources constraint, and concluded that unreasonable water resources input was the main factor that caused low environmental technical efficiency; From the perspective of nitrogen surplus in the feces of pigs, Zhang Xiaoheng [5] applied stochastic frontier function to calculate the environmental efficiency of pig breeding in six regions of China, namely, North China, Northeast China, Southeast China, Central South China, Southwest China and Northwest China, and proposed that the surplus of total nitrogen has inhibitory effect on pig production. Based on carbon emission constraints and the idea of green innovation, Zheng Weiwei [6] took methane and nitrous oxide emissions during pig breeding into account, calculated its green production efficiency with the DEA model under constant returns to scale, and proposed to strengthen pig training and develop appropriate scale breeding.

The research on the convergence of environmental efficiency is mainly focused on industry, and there is only a small number of researches focusing on the convergence of environmental efficiency, let alone the research on the convergence of environmental efficiency of agricultural pig breeding. Based on the perspective of environmental constraints, Zuo Yongyan [7] analyzed problems of TFP and convergence in scale pig breeding using SML index, spatial auto-correlation and convergence model β, in which he found absolute and conditional β convergence. That is in regions with similar influence factors, their TFP converge are at an uniform and stable level; Scholars including Teng Yuhua [8] measured the TFP efficiency of large-scale pig breeding in 2009-2013 using convergence methods β, and concluded that the TFP of large-scale pig breeding in China will gradually decrease as time goes by.

By analyzing relevant literature, we found that in aspect of measuring the environmental efficiency of pig breeding, most scholars use the Malmquist-Luenberger productivity index method, DEA, SE-SBM and other methods, which are relatively mature. But due to different time period and specific methods, there is no agreed conclusion. At the same time, we cannot simultaneously take input and output into consideration using the DEA method, which results in inaccurate efficiency estimates; undesired output pollutants are mainly considered from several factors such as total nitrogen, total phosphorus, methane, and nitrous oxide emissions which are not comprehensive enough, and most of them are relatively single. The regional research is mainly based on the geographic division. As for the research on the convergence of pig breeding efficiency, its testing method is mainly limited to the traditional testing method B, in which mainly uses cross-section data, thus has certain limitations.

Considering the above two points, this paper uses SBM -undesirable model to calculate the environmental efficiency of scale pig breeding in China. The chemical oxygen demand (COD), total
nitrogen (TN) and total phosphorus (TP) pollution factors discharged from scale pig breeding are regarded as the undesired output. In divergent perspectives, we measure the environmental efficiency of pig breeding in different regions, which from the nationwide and the four major regions of live pigs (key development zone, constrained development zone, potential growth zone, and moderate development zone). At the same time, using random convergence and unit root of panel data to examine in an attempt to make up for the lack of cross-section data in convergence B and analyze its dynamic evolution trend. It can study the environmental efficiency of pig breeding in China in a more accurate and objective way, point out the improvement direction of the environmental efficiency of pig breeding at different scales and in different regions, guide pig breeding to a green and sustainable development path and achieve coordinated development among regions.

2. Data selection and model construction

2.1. Index selection and data processing

Combined with the relevant statistical data of the "National Pig Advantage Regional Layout Plan (2008-2015)" and the annual pork output and the number of heads in the statistical yearbook, and taking the availability and integrity of the data into account. After collation, the sample we choose in this essay is the panel data of 2008-2017 from 24 provinces and cities except Beijing, Shanghai, Tianjin, Fujian, Xinjiang, Tibet, and Ningxia, and is divided into four areas with reference to the "National Pig Production and Development Plan (2016-2020)". They are: key development zone, constrained development zone, potential growth zone, and moderate development zone. With reference to the research results by Zuo Yongyan, Du Hongmei, etc, this article divides the input part of pig breeding into two parts: labor input and material service fee (less land input and severely lack of data). and the output into two parts: expected output and undesired output (Table 2).

Table 1. Selection of input and output indicators for large-scale pig breeding

| Input indicator                  | Output indicator                      |
|----------------------------------|---------------------------------------|
| **Labor input**                  |                                       |
| Working days                     | Expected output                       |
| Number of employees + self-employed workers | Net production of main products |
|                                  | Pig slaughter weight - piglet weight   |
| **Material service fee**         |                                       |
| Livestock cost                   | Undesired output                      |
| Feed cost                        | COD                                   |
| Concentrate feed + green feed fee | TN                                    |
| + feed processing fee             | TP                                    |
| Water fuel power fee             |                                       |
| Electricity fee + coal fee + other fuel power fee |   |
| Medical epidemic prevention fee  |                                       |

Among them, the pollutant discharge coefficient of chemical oxygen demand (COD), total nitrogen (TN) and total phosphorus (TP) is determined according to the different scales and different regions in the "Manual of pollutant Discharge Coefficient of Livestock and Poultry Breeding Industry", and the calculation formula is as follows:

$$FD_{site} = FD_{default} \times W_{site}^{0.75} \div W_{default}^{0.75}$$

$FD_{default}$ represents the emission coefficient after conversion. $FD_{default}$ indicates the corresponding coefficient in manual coefficient table. $W_{site}$ indicates the actual weight of the pig. $W_{default}$ indicates the reference weight in the manual.
2.2. Model Construction

2.2.1. SBM-Undesirable model. The principle of data envelopment analysis (DEA), represented by CCR and BCC models, is to maximize benefits, which can deal with multiple input and multiple output evaluation at the same time. However, the problem of slack variables and "bad output" are not taken into account, resulting in large deviation of efficiency evaluation results. In the process of pig breeding, some undesired outputs (emissions of COD, N, P, etc.) are included. In 2001, Tone put forward the model SBM based on non-radial and non-angle. At the same time, he calculates the inefficiency rate from the perspective of input and output. The SBM-Undesirable model derived from SBM model contains both the expected output and the undesired output, which can better reflect the nature of the environmental technical efficiency of pig breeding. This paper uses the SBM-Undesirable model based on variable scale (VRS) to calculate the environmental technical efficiency of pig breeding [9].

Suppose that there are n decision-making units in the production decision-making system of this model, each decision-making unit includes m kinds of input and s kinds of output (including s_1 kinds of expected output and s_2 kinds of undesired output), which are expressed respectively as \( x \in \mathbb{R}^m_+ \), \( y^g \in \mathbb{R}^s_+ \), and \( y^b \in \mathbb{R}^s_- \). The matrix is defined as \( X = [X_0, \ldots, X_n] \in \mathbb{R}^{m \times n} > 0, Y^g = [y^g_1, \ldots, y^g_n] \in \mathbb{R}^{s_1 \times n} \) and \( Y^b = [y^b_1, \ldots, y^b_n] \in \mathbb{R}^{s_2 \times n} \), and satisfies \( X > 0, Y^g > 0, Y^b > 0 \). The production possibility set can be expressed as Equation (1), where \( \lambda \) is a non-negative weight vector of \( \mathbb{R}^n_+ \).

\[
P = \{(x, y^g, y^b) | x \geq X\lambda, y^g \leq Y^g\lambda, y^b \leq Y^b\lambda, \lambda \geq 0\}
\] (1)

The SBM-Undesirable model with undesirable output in VRS mode can be expressed as follows:

\[
\rho^* = \min \frac{1 - \sum_{i=1}^{m} \frac{s_i}{y^g_i}}{1 + \frac{1}{s_1 + s_2} \sum_{r=1}^{s_1} \frac{r}{y^g_r} + \sum_{i=1}^{m} \frac{b_i}{y^b_i}}
\] (2)

\[
x_0 = X\lambda + S^-
\]

\[
y^g_0 = Y^g\lambda - S^g
\]

\[
y^b_0 = Y^b\lambda + S^b
\]

\[
S^- \geq 0, S^g \geq 0, S^b \geq 0, \lambda \geq 0
\]

\( \rho^* \) represents efficiency and \( S^- \), \( S^g \), \( S^b \) respectively represent the slack variables of input, desired output and undesirable output. \( y^g_0 \) represents desirable output. \( y^b_0 \) represents undesirable output. when \( \rho^* = 1, S^- = 0, S^g = 0, S^b = 0 \), the environmental technical efficiency of pig breeding reaches its best. Otherwise, it is necessary to consider improving input and output to raise the target efficiency value.

2.2.2. Convergence Analysis. Different from the traditional convergence, this paper adopts the random convergence method proposed by Evans and Krass, etc. And it is used to test whether the differences between the environmental efficiency of pig breeding in different scales in the region persist for a long time and maintain a relatively stable path of change. Assume that there are regions \( 1, 2, \ldots, N \), and there is convergence among the N regions. Equation (4) holds if and only if the common trend \( \alpha_t \) and parameters \( \mu_1, \mu_2, \ldots, \mu_N \) exist:

\[
\lim_{{k \to 0}} E_t(y_{lt+k} - \alpha_{t+k}) = \mu_t (t = 1, 2, \ldots, N)
\] (4)

Among them: \( y_{lt} \) is the environmental efficiency of large-scale pig breeding in the i region and \( \alpha_t \) is the regional common trend. The research period of this paper started from 2008 to 2017, and the span
was relatively short. If the random convergence test is carried out in pairs, the reliability of the results will be greatly reduced. Therefore, equation (5) is obtained by averaging equation (4) above:

$$\lim_{k \to 0} E_k (y_{i,t+k} - \alpha_{i,t+k}) = \frac{1}{N} \sum_{i=1}^{N} \mu_i$$  \hspace{1cm} (5)

$$\bar{y}_t = \frac{1}{N} \sum_{i=1}^{N} y_{i,t}$$  \hspace{1cm} (6)

Since $\alpha_t$ cannot be obtained directly, equation (5) is subtracted and then removed from equation (4) to obtain equation (7):

$$\lim_{k \to 0} E_k (y_{i,t+k} - \bar{y}_{t+k}) = \mu_t - \frac{1}{N} \sum_{i=1}^{N} \mu_i$$  \hspace{1cm} (7)

There is convergence among these regions if and only if regions $1, 2, \ldots, N$ are tested and judged to have a stationary sequence $(y_{i,t+k} - \bar{y}_{t+k})$ by the auto-regressive parameter $\beta_i$ in equation (8).

$$\Delta (y_{i,t} - \bar{y}_t) = \delta_i + \beta_i (y_{i,t-1} - \bar{y}_{t-1}) + \sum_{k=1}^{K} \delta_i \Delta (y_{i,t-k} - y_{i,t-k}) + \mu_{i,t}$$  \hspace{1cm} (8)

Among them: $i, t$, and $\delta_i$ represent regional effects; Parameter $\delta$ makes all unit roots of $\phi_i L$ lie outside the unit circle; $L$ represents a casual operator. At the same time, assume that there is no correlation between $N \to \infty$ and $\mu$ in equation (6) in these regions, and LLC, ADF and PP test models are applied to test whether the panel data is a stationary sequence. If two or more of them pass the test of significance, there is random convergence among the test regions. When $\beta_i = 0$, and $(y_{i,t+k} - \bar{y}_{t+k})$ is a stationary sequence, the output gap $(y_{i,t} - \bar{y}_t)$ obeys a stationary random process. It shows that when all regions move to a common equilibrium level, the exogenous impact on these regions is temporary, and the environmental efficiency of large-scale pig breeding in these regions shows random convergence. When $\beta_i \neq 0$ and $(y_{i,t+k} - \bar{y}_{t+k})$ is not a stationary sequence, unit root process output included, the exogenous impact on these regions will continue to accumulate, and the environmental efficiency of large-scale pig breeding in these regions will show random divergence [10].

3. Analysis on Environmental Efficiency of Large-scale Pig Breeding

3.1. Analysis on Environmental Efficiency of Large-scale Pig Breeding

3.1.1. Analysis of Scale Difference. The average level of environmental efficiency of pig breeding from year 2008 to 2017 is calculated in accordance with different pig breeding scales, as shown in table (2, 3 and 4), the conclusion that medium-scale (0.976) > large-scale (0.959) > small-scale (0.955) can be obtained in line with the numerical value. This indicates to some extent that there is a great contradiction between large-scale and small-scale pig breeding and environmental protection in China. The excessive emission of pollutants from large-scale pig breeding may result from the large breeding scale and the heavy financial pressure of both investment in feces treatment equipment and green production technology update. The excessive emission of pollutants from small-scale pig breeding may result from the fact that most small-scale pig farmers have low education level, inadequate green production and management experience, weak awareness of environmental protection, outdated pollution control facilities and even
no pollution control equipment. However, the higher environmental efficiency of medium-scale pig breeding reflects that moderate scale of pig breeding is conducive to the coordinated development of ecology, economy and environment.

Based on the trend from year 2008 to 2017, the environmental technical efficiency value of small-scale pig breeding presents a "W" curve with a cycle of decreasing at first and then increasing, with the lowest value of 0.911 in 2015 and the highest value of 0.990 in 2008; the environmental technical efficiency value of medium-scale pig breeding presents an "M" curve with a cycle of rising at first and then falling, with the lowest value of 0.962 in 2008 and the highest value of 0.990 in 2012; the environmental technical efficiency value of large-scale pig breeding presents an "M" curve with a cycle of rising at first and then falling, with the lowest value of 0.895 in 2017 and the highest value of 0.983 in 2013. It can be seen that the overall trend of small-scale and medium-scale pig breeding increased slowly after 2015. The reason lies in the fact that the country pays more attention to the issue of environmental pollution and promulgates a series of regulations similar to the Regulations on Prevention and Control of Pollution from Livestock and Poultry Scale Breeding, which effectively controls the emission of some pollutants from livestock and poultry. However, the pollution issue on large-scale pig breeding is still serious, and it is urgent to promote its green transformation and upgrading.

3.1.2. Analysis of Regional and Inter-Provincial Differences. This paper mainly analyzes the average environmental efficiency from 2008 to 2017 of pig breeding on three scales in each of the four major regions and provinces in the National Pig Production Development Plan issued by the Ministry of Agriculture in 2016. The results are shown in the following table.

The small-scale environmental efficiency is ranked as follows: potential growth zone (0.972) > moderate development zone (0.965) > key development zone (0.951) > constricted development zone (0.931); the medium-scale environmental efficiency is ranked as follows: moderate development zone (0.997) > potential growth zone (0.996) > key development zone (0.959) > constricted development zone (0.953); the large-scale environmental efficiency is ranked as follows: potential growth zone (0.988) > key development zone (0.967) > moderate development zone (0.961) > constricted development zone (0.918). It can be seen that the potential development zone performs the best, moderate development zone and key development zone performs the second, and constricted development zone performs the worst.

Key development zones: large-scale environmental efficiency performs well. Guangxi, Chongqing, and Hainan provinces are all at the forefront of production during this period. Hebei, Shandong, and Sichuan provinces have achieved the optimal input-output in more than half of the years, and Henan province performed the worst. Medium-scale environmental efficiency performs relatively poor. Hebei and Hainan provinces are at the production frontier during this period. Guangxi, Chongqing, and Sichuan provinces have achieved the optimal input-output in more than half of the years, and Shandong and Henan provinces performed worst. Small-scale environmental efficiency performance was relatively poor. Hebei and Chongqing provinces are at the production frontier during the period. Henan and Hainan provinces have achieved optimal input-output in more than half of the years. Shandong, Guangxi, and Sichuan provinces performs the worst. Therefore, it is imperative that pig-breeding in key development zones should stimulate green transformation and upgrading and promote large-scale and standardized development.

Potential growth zones: the three environmental efficiencies performed well. In most provinces, pig breeding of different scales are at the forefront of production from 2008 to 2017. The other provinces have achieved optimal input-output in more than half of the years. There are only two provinces——Yunnan and Liaoning province perform poorly in small-scale pig -breeding. It is mainly because that the regional environmental carrying capacity is relatively high, so it is necessary to give full play to the advantages of resources, expand the scale of production, and realize the combination of planting and nurturing.

Moderate development zones: The medium-scale environmental efficiency performs relatively well. Shaanxi and Qinghai provinces are both at the forefront of production during this period. Shanxi and
Gansu provinces have reached optimal input-output in more than half of the years. Small-scale environmental efficiency performs second: Shanxi and Gansu province are at the forefront of production during this period. Qinghai province have reached its optimal input-output in more than half of the years, and Shaanxi Province performs worst. Large-scale environmental efficiency performs relatively poor, the only province Shanxi is at the forefront of production during the period, and the other provinces have reached optimal input-output for more than half of the years. It is mainly because that the region has a unique geographical advantage, but water resources are comparatively scarce, so it is necessary to promote moderate-scale breeding and introduce efficient breeding technologies.

Constricted development zones: all three environmental efficiencies performs poorly, ranking at the bottom of the list, but it has a great potential to improve. There are only two provinces Jiangsu and Hunan in small and medium-sized level served as spearhead in production during the period. Jiangxi province have reached the optimal input-output in more than half of the years, and the other four provinces performed poorly. In big-scale environmental efficiency, the only one province Hunan is at the forefront of production during the period. Jiangsu, Jiangxi, and Hubei province have reached the optimal input-output in more than half of the years. The main reason is that the region is economically developed and has a large number of population and the task of water environment management is heavy. Therefore, it is necessary to optimize the regional layout and implement a green and efficient pig manure treatment mode.

### Table 2. Small-scale pig breeding environmental efficiency

| province      | 2008  | 2009  | 2010  | 2011  | 2012  | 2013  | 2014  | 2015  | 2016  | 2017  | Average |
|---------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|----------|
| Hebei         | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Shandong      | 1.000 | 1.000 | 1.000 | 0.859 | 0.747 | 0.805 | 0.897 | 1.000 | 1.000 | 1.000 | 1.000   |
| Henan         | 1.000 | 1.000 | 0.702 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Guangxi       | 1.000 | 1.000 | 1.000 | 0.839 | 0.925 | 0.931 | 1.000 | 0.821 | 0.772 | 0.753 | 0.904   |
| Hainan        | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.760 | 1.000 | 1.000 | 0.976   |
| Chongqing     | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Sichuan       | 1.000 | 0.766 | 1.000 | 1.000 | 0.816 | 1.000 | 1.000 | 0.702 | 0.770 | 0.712 | 0.876   |
| Average       | 1.000 | 0.966 | 0.957 | 0.957 | 0.927 | 0.962 | 0.985 | 0.898 | 0.935 | 0.924 | 0.951   |
| Guizhou       | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.820 | 0.880 | 0.100 | 1.000 | 1.000 | 0.962   |
| Yunnan        | 0.871 | 1.000 | 1.000 | 1.000 | 1.000 | 0.839 | 0.863 | 0.869 | 0.856 | 0.767 | 0.906   |
| Neimenggu     | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Liaoning      | 1.000 | 1.000 | 0.903 | 0.796 | 1.000 | 1.000 | 0.997 | 0.943 | 1.000 | 1.000 | 0.964   |
| Jilin         | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Heilongjiang  | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Average       | 0.978 | 1.000 | 0.984 | 0.966 | 1.000 | 0.973 | 0.947 | 0.935 | 0.976 | 0.961 | 0.972   |
| Jiangsu       | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Zhejiang      | 1.000 | 1.000 | 0.916 | 1.000 | 0.801 | 0.756 | 1.000 | 1.000 | 1.000 | 0.739 | 0.921   |
| Anhui         | 1.000 | 1.000 | 0.901 | 0.817 | 1.000 | 0.935 | 0.834 | 0.831 | 0.701 | 0.726 | 0.874   |
| Jiangxi       | 1.000 | 0.749 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.782 | 0.750 | 1.000 | 0.928   |
| Hubei         | 0.883 | 0.879 | 0.904 | 0.840 | 0.817 | 0.843 | 1.000 | 0.880 | 1.000 | 1.000 | 0.905   |
| Hunan         | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Guangdong     | 1.000 | 0.999 | 0.742 | 0.874 | 0.100 | 1.000 | 0.889 | 0.845 | 0.802 | 0.755 | 0.891   |
| Average       | 0.983 | 0.947 | 0.923 | 0.933 | 0.946 | 0.933 | 0.960 | 0.905 | 0.893 | 0.889 | 0.931   |
| Shanxi        | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Shanxi        | 1.000 | 1.000 | 1.000 | 0.761 | 0.702 | 0.756 | 0.763 | 0.806 | 1.000 | 0.999 | 0.879   |
| Gansu         | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Qinghai       | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.813 | 1.000 | 1.000 | 0.981   |
| Average       | 1.000 | 1.000 | 1.000 | 0.940 | 0.926 | 0.939 | 0.941 | 0.905 | 1.000 | 1.000 | 0.965   |
| National      | 0.990 | 0.978 | 0.966 | 0.949 | 0.949 | 0.952 | 0.958 | 0.911 | 0.951 | 0.943 | 0.955   |
Table 3. Medium-scale pig breeding environmental efficiency

| province   | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | Average |
|------------|------|------|------|------|------|------|------|------|------|------|----------|
| Hebei      | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00     |
| Shandong   | 0.771| 0.804| 0.787| 0.766| 0.784| 0.823| 0.832| 0.830| 0.869| 1.00 | 0.827    |
| Henan      | 0.999| 0.999| 0.772| 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.759| 0.820| 0.935    |
| Guangxi    | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.938| 0.994    |
| Hainan     | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00     |
| Chongqing  | 1.00 | 0.811| 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.981    |
| Sichuan    | 1.00 | 0.997| 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.802| 0.980    |
| Average    | 0.967| 0.944| 0.937| 0.967| 0.969| 0.975| 0.976| 0.976| 0.947| 0.937| 0.959    |
| Guizhou    | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00     |
| Yunnan     | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00     |
| Neimenggu  | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00     |
| Liaoning   | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.833| 1.00 | 0.983    |
| Jilin      | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.922| 1.00 | 0.992    |
| Heilongjiang| 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.987| 1.00 | 0.996    |
| Average    | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.972| 1.00 | 0.996    |
| Jiangsu    | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00     |
| Zhejiang   | 1.00 | 1.00 | 0.783| 1.00 | 1.00 | 0.858| 0.856| 0.863| 0.796| 0.779| 0.893    |
| Anhui      | 0.840| 0.920| 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.997| 1.00 | 0.867    |
| Jiangxi    | 0.785| 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.978    |
| Hubei      | 0.776| 0.927| 1.00 | 1.00 | 1.00 | 1.00 | 0.898| 1.00 | 1.00 | 1.00 | 0.960    |
| Hunan      | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00     |
| Guangdong  | 0.752| 0.796| 0.833| 0.879| 0.931| 0.933| 0.885| 0.881| 0.835| 0.873|          |
| Average    | 0.879| 0.949| 0.945| 0.983| 0.990| 0.965| 0.969| 0.964| 0.942| 0.945| 0.953    |
| Shanxi     | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00     |
| Shanxi     | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00     |
| Gansu      | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.940| 0.931| 1.00     |
| Qinghai    | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00     |
| Average    | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.985| 0.983| 1.00     |
| National   | 0.962| 0.973| 0.971| 0.987| 0.990| 0.982| 0.986| 0.974| 0.968| 0.970| 0.976    |
Table 4. Large-scale pig breeding environmental efficiency

| province     | 2008  | 2009  | 2010  | 2011  | 2012  | 2013  | 2014  | 2015  | 2016  | 2017  | Average |
|--------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|---------|
| Hebei        | 0.744 | 0.695 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.944   |
| Shandong     | 0.774 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.977   |
| Henan        | 1.000 | 1.000 | 0.774 | 1.000 | 1.000 | 1.000 | 0.991 | 0.818 | 0.741 | 0.799 | 0.912   |
| Guangxi      | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Hainan       | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Chongqing    | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Sichuan      | 0.747 | 0.729 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.864 | 0.934 |         |
| Average      | 0.895 | 0.918 | 0.968 | 1.000 | 1.000 | 1.000 | 0.999 | 0.974 | 0.963 | 0.952 | 0.967   |
| Guizhou      | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Yunnan       | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Neimenggu    | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Liaoning     | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Jilin        | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Heilongjiang | 0.638 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.964   |
| Average      | 0.940 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.967   |
| Jiangsu      | 0.991 | 1.000 | 1.000 | 0.982 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.997   |
| Zhejiang     | 0.702 | 0.734 | 0.734 | 0.715 | 0.776 | 0.825 | 0.849 | 0.770 | 0.789 | 0.675 | 0.757   |
| Anhui        | 1.000 | 1.000 | 0.848 | 0.756 | 0.763 | 0.786 | 0.874 | 0.876 | 1.000 | 1.000 | 0.862   |
| Jiangxi      | 1.000 | 1.000 | 1.000 | 0.883 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.807   |
| Hubei        | 0.683 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.968   |
| Hunan        | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Guangdong    | 0.663 | 0.770 | 0.855 | 1.000 | 0.816 | 0.907 | 0.888 | 0.836 | 1.000 | 1.000 | 0.873   |
| Average      | 0.863 | 0.929 | 0.920 | 0.905 | 0.908 | 0.931 | 0.945 | 0.926 | 0.970 | 0.886 | 0.918   |
| Shanxi       | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000   |
| Shandong     | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.820 | 1.000 | 1.000 | 0.744   |
| Gansu        | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.834 | 0.930 | 0.872 | 0.802 | 0.944   |
| Qinghai      | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.786 | 0.837 | 0.666 | 0.945   |
| Average      | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.913 | 0.983 | 0.915 | 0.803 | 0.961   |
| National     | 0.924 | 0.962 | 0.972 | 0.976 | 0.977 | 0.983 | 0.964 | 0.971 | 0.962 | 0.895 | 0.959   |

3.2. The Convergence Analysis of Large-scale Pig-breeding Environmental Efficiency

3.2.1. From the Nation-level Perspective. For the results of convergence tests on the environmental efficiency of large-scale pig-breeding in China, details in table 5, 6 and 7 can be found. From the nation-level perspective, it can be found that the LLC test, ADF-Fisher test, and PP-Fisher test of pig-breeding can reject the null hypothesis at a significance level of 1%, that is, the pig-breeding environment efficiency of all sizes in the country exists random convergence. Among them, the environmental efficiency of medium-scale pig-breeding has stabilized at a high level of convergence in recent years, and the environmental efficiency of small-scale pig-breeding has a tendency to converge at a medium level, but the environmental efficiency of large-scale pig-breeding has a tendency to converge at a low level. The capital investment and scale expansion of large-scale pig-breeding cannot be effectively linked, which may due to the country’s previous encouragement of large-scale pig-breeding. What’s more, the instrument and equipment are not advanced enough and the difficulty of feces treatment has amplified, which damaged the environment and benefits. The reason why small-scale pig-breeding efficiency can develop in a stable way is that the cost have been controlled, the management technology has been improved and the environmental efficiency has been stabilized under the constant pressure of
national environmental protection policies. Over expansion is not blindly pursued in medium-scale pig breeding, and the quality and quantity are developed concertedly, which have received good benefits in environment.

3.2.2. Regional level. The three small-scale pig breeding tests in the key development zone can reject the null hypothesis at 1%, and there exists random convergence features; The medium-scale LLC test and the PP-Fisher test can reject the null hypothesis at a 5% level. According to the principle of minority obeying the majority, there exists random convergence features; neither the large-scale LLC test nor the ADF-Fisher test can reject the null hypothesis. Only the PP-Fisher test can reject the null hypothesis at the 1% level. Therefore, there exists no random convergence features. However, although there is a trend of convergence between small and medium-scale pig breeding, efficiency has not improved, the large-scale pig breeding existing no trend of convergence phenomenon is mainly due to the large gap of efficiency between Henan and other provinces, especially with the average environmental efficiency fluctuated around 0.8 in the nearly three years. It shows that the efficiency of the breeding environment of Henan province needs to be improved urgently.

Both the small-scale pig breeding LLC test and the PP-Fisher test in the potential growth zone can reject the null hypothesis at the 1% level. According to the above principles, they tend to have random convergence features. Neither the medium-scale pig breeding LLC test nor the ADF-Fisher test can reject the null hypothesis. It is assumed that only the PP-Fisher test can reject the null hypothesis at the 1% level, and there exists no random convergence features; the large-scale pig breeding LLC test, ADF-Fisher test, and PP-Fisher cannot reject the null hypothesis, and there exists no random convergence features. Among them, the environmental efficiency of small-scale pig breeding maintains stable at a relatively high level; the medium-scale pig breeding mainly exist in Guizhou and Yunnan provinces. The environmental efficiency of medium-scale pig breeding in Guizhou province suddenly dropped from 1 to 0.833 in 2015 and the environmental efficiency of medium-scale pig breeding in Yunnan Province suddenly dropped to 0.922 in 2013, which have large fluctuation; The large-scale pig breeding mainly exist in the two provinces of Inner Mongolia and Yunnan. The environmental efficiency of large-scale in Inner Mongolia suddenly dropped from 1 to 0.637 in 2017, while it suddenly increased from 0.638 to 1 in Yunnan province in 2008. Both fluctuation range of the environmental efficiency of large-scale in Inner Mongolia and Yunnan province are large. Its stability needs to be further improved.

In constrained development zone, the small-scale LLC test and PP Fisher test can reject the original hypothesis at 1% level, and the ADF Fisher test cannot reject the original hypothesis. According to the above principles, they tend to have random convergence features; Three tests of the medium-scale and large-scale can reject the original hypothesis at the significant level of 1%, and there exists random convergence features; However, the three types of efficiency all tend to at the same low level which is in the downstream state lower than the national average level, and the efficiency of several provinces needs to be improved. In the small-scale and the medium-scale moderate development areas, only LLC test can reject the original hypothesis at 5% level. While PP-Fisher test and ADF-Fisher test cannot reject the original hypothesis, and there exists no random convergence features; in large scale areas, only PP Fisher test can reject the original hypothesis at 5% level, and LLC test and ADF-Fisher test cannot reject the original hypothesis, and there exists no random convergence features. Among them, the small-scale pig breeding mainly exist in Shaanxi and Qinghai province. The relevant ratio of Shaanxi suddenly dropped to 0.761 in 2011 which continued to decline in the following years and did not recover to the average level. While the relevant ratio of Qinghai Province dropped from 1 to 0.813 in 2015; the reason of medium-scale is due to the relevant ratio of Gansu Province which suddenly dropped from 1 to 0.940 in 2015, and then it did not recover to the average level in the following years which has a great fluctuation; the reason of large-scale pig breeding is due to Shaanxi, Gansu and Qinghai province which have a large fluctuation range of efficiency in recent years and whether the changing path of the gap between the provinces and cities within the region keep stable.
### Table 5. Small-scale random convergence analysis

| region                        | Panel unit root test | Levin, Lin & Chu t* | ADF - Fisher Chi-square | PP - Fisher Chi-square |
|-------------------------------|----------------------|---------------------|-------------------------|------------------------|
|                               | Statistic | Prob   | Statistic | Prob   | Statistic | Prob   |
| National                      | - 18.6559 | 0.0000 | 39.8213  | 0.0053 | 82.2598  | 0.0000 |
| Key development area          | - 2.02845 | 0.0213 | 5.46218  | 0.4860 | 15.2934  | 0.0181 |
| Potential growth zone         | 0.92242   | 0.8218 | 6.98668  | 0.1366 | 28.3944  | 0.0000 |
| Constrained development zone  | - 27.4173 | 0.0000 | 22.4730  | 0.0041 | 38.4451  | 0.0000 |
| Constrained development zone  | - 2.04539 | 0.0204 | 4.89946  | 0.0863 | 0.12686  | 0.9385 |

### Table 6. Medium-scale random convergence analysis

| region                        | Panel unit root test | Levin, Lin & Chu t* | ADF - Fisher Chi-square | PP - Fisher Chi-square |
|-------------------------------|----------------------|---------------------|-------------------------|------------------------|
|                               | Statistic | Prob   | Statistic | Prob   | Statistic | Prob   |
| National                      | - 18.6559 | 0.0000 | 39.8213  | 0.0053 | 82.2598  | 0.0000 |
| Key development area          | - 2.02845 | 0.0213 | 5.46218  | 0.4860 | 15.2934  | 0.0181 |
| Potential growth zone         | 0.92242   | 0.8218 | 6.98668  | 0.1366 | 28.3944  | 0.0000 |
| Constrained development zone  | - 27.4173 | 0.0000 | 22.4730  | 0.0041 | 38.4451  | 0.0000 |
| Constrained development zone  | - 2.04539 | 0.0204 | 4.89946  | 0.0863 | 0.12686  | 0.9385 |

### Table 7. Large-scale random convergence analysis

| region                        | Panel unit root test | Levin, Lin & Chu t* | ADF - Fisher Chi-square | PP - Fisher Chi-square |
|-------------------------------|----------------------|---------------------|-------------------------|------------------------|
|                               | Statistic | Prob   | Statistic | Prob   | Statistic | Prob   |
| National                      | - 18.6559 | 0.0000 | 39.8213  | 0.0053 | 82.2598  | 0.0000 |
| Key development area          | - 2.02845 | 0.0213 | 5.46218  | 0.4860 | 15.2934  | 0.0181 |
| Potential growth zone         | 0.92242   | 0.8218 | 6.98668  | 0.1366 | 28.3944  | 0.0000 |
| Constrained development zone  | - 27.4173 | 0.0000 | 22.4730  | 0.0041 | 38.4451  | 0.0000 |
| Constrained development zone  | - 2.04539 | 0.0204 | 4.89946  | 0.0863 | 0.12686  | 0.9385 |
4. Research conclusions and countermeasures

4.1. Research conclusions

4.1.1. The view of environmental efficiency pig breeding. In terms of the overall average value, the medium-scale pig breeding environment in China has the highest environmental efficiency with the large-scale followed by and the small-scale at last; From the changing trends, the efficiency value of medium-scale has not changed much and has stabilized at a relatively high level in recent years. The small-scale pig breeding has picked up recently after experiencing a relatively rapid decline. We should maintain its stable development. The large-scale pig breeding has shown a downward trend in the past two years, indicating that the problem of coordinated development of large-scale pig breeding and the environment is more prominent. From the perspective of regional development, the environmental efficiency of small-scale pig breeding in key development zone needs to be improved. Low efficiency may due to the government had paid too much attention to large- scale and medium-scale pig breeding and ignored the development of small-scale pig breeding; Relying on unique advantages of natural resources, the environmental efficiency of the potential growth zone performed well; The moderate development zone has poor performance in the environmental efficiency of large-scale pig breeding due to constraints such as lacking of water resources; Although the constrained development zone is one of the developed areas, it has poor performance due to a heavy task to control water pollution and key development not focusing on agriculture.

4.1.2. Analysis pig breeding environment convergence. On the whole, random convergence exists in all three scales pig breeding, of which medium-scale pig breeding is stable at a high level of convergence, small-scale pig breeding is stable at a medium-level convergence and large-scale pig breeding has a low-level convergence trend. Therefore, the coordinated development of scale and environment cannot be achieved possibly due to blind expansion of the breeding scale. From the perspective of regional development, the small-scale and medium-scale pig breeding in the key development zone are converging at a moderately low level. We should continue to promote their transformation and upgrading. Large-scale development still has large individual differences; In potential growth zone, only the small-scale pig breeding convergence exists the convergence phenomenon which has been improved. The stability of medium-scale and large-scale development is weak, and there is no convergence; the three types of efficiency in the constrained development zone all have convergence phenomenon with converging to a low level; In the moderate development zone, there are no convergence phenomenon exist in three scales which cannot maintain steady development with great change between provinces and cities in the moderate development zone.

4.2. Research Countermeasures:

4.2.1. At the overall level, there are different scales: We will promote the transformation of small-scale live pigs into“(companies)+(bases)+(cooperatives)+(farmers)”and facilitate the “breeding + farmland planting(orchard development)”breeding cycle mode. We will strengthen the awareness of small-scale farmers on ecological breeding, heighten technical training in green farming and pollutant treatment under the expert guidance and major farmers’ demonstration, boosting its development towards standardized, scientific and green farming.

We will stabilize the development of medium-scale pig breeding, consolidate the existing standardized scale to support the development of pig production, allocate policies and measures such as incentives for large counties and subsidies for superior breeds, do a good job in macro-control, and constantly introduce capital, technology and talents into the pig industry. The centralized ecological farming will be popularized and the government’s supervision and guidance will further strengthened.

We will guide the transforming and upgrading of large-scale green breeding, making possible its moderate development and rational distribution. Because large-scale breeding is much more difficult
than small- and medium-sized ones while treating swine feces, the overall capital investment is much larger. At each region breeding scale and plan should be formulated reasonably according to its environmental carrying capacity, land resources, economic conditions, feed storage and other aspects. Local governments should enhance research and development of green breeding technology and implement certain environmental protection subsidies in regions that have done well in environmental protection and ecological breeding.

4.2.2. **At the regional level, there are four major divisions:** The key development zones should value the environmental efficiency of small and medium-scale farms while prioritizing the development of large-scale farming, encourage small- and medium-scale pig farmers’ transition to large-scale pig breeding, and promote their integration with modern pig breeding. We should strengthen the source control of medium and small-scale breeding, popularize the excellent breeding varieties and high-efficient green breeding technology, improve the breeding efficiency, and encourage the cooperation with dragon-head enterprises, guiding them to transform into the breeding mode combining planting and breeding.

Potential development zones boast unique environmental advantages compared to other areas. At the same time, the national “South-to-North Pigs Delivery” policy makes them suitable for developing large and medium-scale pig breeding. A stable ecological pig breeding system should be established to promote their convergence to a higher level. According to the local environmental characteristics of different provinces, clean breeding technologies will be developed and large-scale enterprises with high environmental protection standards and advanced breeding management technologies will introduced to plan and construct ecological breeding communities and farms which will be transformed into combined farming and animal husbandry breeding mode.

Although the development environmental efficiency of the three-scale pig breeding in constrained development zones doesn’t do well, most areas are seeing fast-developing economy. They can learn from provinces with pig environmental efficiency advantages like Hunan, introducing advanced technologies of farming, management and cleaner production, enhancing green technology support and prioritizing the development of small- and medium-scale breeding. For some large-scale breeding, intensive and intelligent breeding can be implemented, and it is encouraged to intensify cooperation with famous schools and scientific research institutions.

Based on its resource endowment and relatively lagging economic development, the moderate development zones take the initiative to develop the large-scale breeding moderately, without blindly pursuing scale expansion. The government gives priority to supporting environmentally sound pig farmers who have met environmental protection standards, giving them ecological funding support, and at the same time accelerating the cultivation of operational service organizations for pollution control and raising the passion and capability of pig farmers in handling pollution.

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