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Valuing Indigenous Pig Breeds in China：Empirical Analysis Based on Their Utilization Status and Sustainable Development

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Abstract

China is one of the countries with the richest Animal genetic resources (AnGR) in the world, and also the largest producer and consumer of pigs.The pig industry is huge, but more than 90% of pork consumption relies on imports, while local pig breeds are neglected, and many of them are even on the verge of extinction.In order to study the utilization status of local pig breeds and promote the protection、development, and utilization, this study conducted an in-depth analysis of the utilization status of local pigs by combing the utilization status and cost-benefit analysis.The results showed that the overall population of Min pig has increased and has been extensively used in production. However, due to the high input cost and low output income, the income is negative and production efficiency is low. Therefore, the pigs have not been fully and effectively utilized by the people.The study further observed that in the general commercialization environment over the years, a range of incentives and protection measures have achieved a balance. This has resulted in a certain level of balance between policy implementation and commercial development, leading to an increase in the number of pigs and improving the situation of endangered varieties. The findings of this study provide a theoretical foundation for the preservation, development, and sustainable utilization of local pig genetic resources.

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Abstract： China is one of the countries with the richest Animal genetic resources (AnGR) in the world, and also the largest producer and consumer of pigs.The pig industry is huge, but more than 90% of pork consumption relies on imports, while local pig breeds are neglected, and many of them are even on the verge of extinction.In order to study the utilization status of local pig breeds and promote the protection、development, and utilization, this study conducted an in-depth analysis of the utilization status of local pigs by combing the utilization status and cost-benefit analysis.The results showed that the overall population of Min pig has increased and has been extensively used in production. However, due to the high input cost and low output income, the income is negative and production efficiency is low. Therefore, the pigs have not been fully and effectively utilized by the people.The study further observed that in the general commercialization environment over the years, a range of incentives and protection measures have achieved a balance. This has resulted in a certain level of balance between policy implementation and commercial development, leading to an increase in the number of pigs and improving the situation of endangered varieties. The findings of this study provide a theoretical foundation for the preservation, development, and sustainable utilization of local pig genetic resources.

Keywords： Min pig；Domestic animals; Protection of genetic resources; Bioeconomic model; Cost-benefit analysis

1. Introduction

The diversity of domestic animal genetic resources (AnGR) serves as the fundamental basis for the advancement of animal husbandry[1]. Native breeds have contributed significantly to various aspects of human survival and economic development[2]. Over the past few decades, there has been a growing focus on the diversity of AnGR. Numerous studies have comprehensively examined the historical development and hybrid utilization of local varieties[3,4], analyzed the impact of climate change on domestic animals[5,6], evaluated the value of animal genetic resources[7-9], and emphasized the importance[2,10-14] and priority of their conservation[15,16]. Table 1 summarizes the most representative literature regarding AnGR diversity in the past, and all the studies included in the table highlight the significance of preserving native varieties.

Table 1 The most representative documents of AnGR diversity

Time	Author	Describe
2001	G Cicia et al	This paper highlights the importance of using contingent valuation and bio-economic models to evaluate the benefits and costs of local variety protection plans. This approach can provide valuable insights for decision-making on origin protection [17].
2007	Food and Agriculture Organization of the United Nations (FAO)	For the first time, all countries in the world have established a unified action framework aimed at preventing the loss of AnGR for agriculture and supporting the sustainable use, development, and protection of AnGR [18].
2010	Hoffmann	This paper examines the impact of AnGR on species diversity and variety diversity, as well as the influence of variety diversity on agricultural biodiversity [19].
2010	Hiemstra et al	The paper highlights that the ideal scenario for local varieties is to achieve self-sufficiency through sustainable resource use, without relying on external subsidies [20].
2015	FAO	The diversity of AnGR can assist in adapting the current production mode to future challenges. For impoverished communities, the role of AnGR and the value it provides to people remains highly diverse and significant [21].

The protection of AnGR diversity is a global concern, and China is one of the countries with the most abundant livestock genetic resources in the world [22]. As the largest producer and consumer of live pigs, China has taken various regulatory, guidance, and policy measures aimed at preserving AnGR diversity in order to fulfill the requirements of the Convention on Biological Diversity. However, due to the development of intensive animal husbandry [23,24], farmers' preference for high-yield varieties at the expense of local genetic resources [25,26], the expansion of market and economic globalization [27], climate change and habitat destruction [28], the overall decline trend of local varieties has not been effectively curbed, and the diversity of genetic resources is still gradually declining.

The pig industry in China is vast, with over 450 million pigs in stock and over 700 million pigs slaughtered in 2022, and 410 million pigs slaughtered in 2021. While industrial upgrading has achieved remarkable results, more than 90% of pork consumption relies on foreign breeds, with Duroc, Landrace, and Yorkshire dominating the market, making it difficult for local pig breeds to compete.The majority of breeding pigs in China are imported from the United States, accounting for 37% of the total. Conversely, the United States has refrained from importing breeding pigs from China since 1989, resulting in a significant trade deficit in the bilateral trade of breeding pigs between China and the United States[29]. Numerous factors contribute to this situation, including the inadequate organizational cooperation in the identification and evaluation of pig genetic resources[30], the low efficiency of cooperation in protection and sharing[31], and the limited policy impact on innovation and transformation[32,33]. The most evident reason underlying this situation is that, despite their widespread use in production, local pig breeds have yet to achieve self-sustainable development, posing a potential threat of extinction.

Due to changes in market demand, the lean meat yield of purebred pigs has decreased, which no longer aligns with the eating preferences of most consumers[34]. Currently, Min pig are primarily bred for cross-breeding with foreign breeds. After crossing, production performance exceeds the average of both parents, litter performance improves, stress resistance remains, and meat quality enhances, as intramuscular fat content can exceed 2.0. Min pig have slower breeding rates, longer slaughter times, and thicker carcasses, leading to a decreasing population. Breeding populations in production regions are shrinking, and species conservation breeding bases are dwindling, which were on the brink of extinction a few years ago[35]. After decades of rescue, preservation, protection, and development efforts, the population of domestic pigs is currently stable but remains at the species conservation level. In this context, analyzing the survival and utilization status of local pig breeds with a growing population but an extinction risk can assist governments in formulating effective preservation measures, producers in improving breeding practices, and in establishing local pig breed-centered industrial chains[36]. The global AnGR strategy developed by FAO emphasizes that the effective utilization of varieties is integral to preservation efforts and can be highly beneficial. Based on this perspective, this paper presents a model for estimating the economic value of pig populations and conducts a cost-benefit analysis of domestic pigs, analyzing their utilization status. This analysis provides a theoretical foundation for the preservation, utilization, and sustainable development of local pig breeds.

2. Characteristics and Utilization Status of Min pig Germplasm

2.1 Germplasm characteristics of Min pig

Min pig is one of the ancient breeds in the northeast of China, which has been designated as a national protected breed of livestock genetic resources by the Ministry of Agriculture and included in the global inventory. Native to regions of Northeast China and North China, it is divided into three types: Big Min pig, Dual Min pig, and Poached pig. Currently, the Big Min pig has become extinct. The Min pig have black hair, long and dense manes, and dense fluff during the winter (Figure 1). They possess a straight and long facial structure, wrinkled denomination, large and drooping ears. Their back and waist are narrow, their abdomen droops but does not touch the floor, and their buttocks are slightly inclined. The limbs are thick, their hind legs are slightly bent, and there are folds on the upper part and axillary side of the hock joint. They have more than 7 pairs of effective nipples. The advantages of Min pig include strong reproduction, large litter size, cold tolerance and disease resistance, and relatively high fat content (4.7-5-1) in their meat. However, they also have disadvantages such as slow reproduction speed, long slaughter time, and thick reserves (40-50mm)[37].

(a)male pig （b）female pig

Fig1 Appearance characteristics of Min pig

2.2 Utilization status of Min pig

The cross-breeds of Min pig have been widely utilized in production. An increasing number of enterprises have joined the breeding and cross-breeding efforts, utilizing Min pig as raw materials, leading to the creation of several brands[38]. Yichun Baoyu Agricultural Company won the "2016 World Golden Pig Award for Welfare Breeding" and became the first registered enterprise to sell black pig products in Hong Kong and Macao. Lanxi County registered the trademark of pork, and "Lanxi Min Pig" was certified as a geographical indication. In 2020, "Lanxi Min Pig" ranked seventh in the value appraisal conducted by the Heilongjiang Brand Strategy Promotion Association, with a brand strength of 830 and a brand value of 2.713 billion yuan. In June 2023, the mating line of "Longmin Black Pig," utilizing Min pig as breeding material, passed the examination, and the expert group concurred that this breed holds significant market potential, anticipated to further advance pig industrialization in Heilongjiang Province. As of 2021, there are 43 Min pig farms in China, housing a total of 8,316 pigs, including 3,101 fertile sows and 390 breeding boars. Please refer to Table 2 for specific national quantity differences and regional distribution. It is evident that the number and distribution of Min pig vary significantly across different regions. The population is largest in Northeast China, accounting for 76.33% of the country's population, followed by North China at 22.23%, aligning closely with the characteristics of the Min pig breed.

Table 2 Quantity Distribution of` Min pig Area

Region	Province	Quantity
Northeast China	Jilin province	1472
	Heilongjiang province	1774
	Liaoning province	3102
North China	Inner Mongolia Autonomous Region	722
	Hebei Province	960
East China	Hubei province	191
South China	Hainan province	39
Southwest China	Guizhou Province	6
Northwest China	Xinjiang production and construction corps	50

3. Research method

3.1 production model

Drawing upon the economic value estimation model for pig breeding put forth by A.G. DEVRIE[39] and L. Houska et al. [40], and with reference to the scale Min pig production process in China, this paper has developed a pig population economic calculation model to simulate the complete lifecycle of a group of sows, from purchase to elimination.

3.1.1 Production cost and income of sow

In the production system, the overall production cost of sows throughout their lifecycle is primarily categorized into three components: feed cost, fertilization cost, and non-feed cost (labor, water and electricity, epidemic diseases, depreciation of fixed assets, and investment interest). The calculation of feed cost is influenced by the fluctuation of feed prices and variations among different buyers. For this study, the relevant parameters were taken at their average levels as of November 2022, with the specific values presented in Table 3.

Table 3 Parameters of Cost and Price System

Project	Parameter	Project	Parameter
Price of purchasing each 120-day-old sow	2000	Feed price per kilogram per sow during fertilization	4
Feed price per kilogram for each sow from purchase to early estrus	4.4	Price per dose of semen	50
Feed price per kilogram per sow during pregnancy	4	Pollution-free treatment price	50
Feed price per kilogram per sow during lactation	4.3	Feed price per kilogram of piglets in conservation period	5.3
Non-feed cost per sow per day from purchase to early estrus	9.45	Non-feed cost per day for each piglet in conservation period	7.007
Non-feed cost per sow during pregnancy every day	8.64	Feed price per kilogram of fattening pigs	3.45
Non-feed cost per sow during lactation	38.46	Non-feed cost per fattening pig per day	9.366
Non-feed cost per sow per day during fertilization	9.86	Selling price per kilogram of fattening pigs	27

The fertilization cost varies depending on whether local cross-breeding or artificial insemination is used. Currently, large-scale pig farms overwhelmingly adopt artificial insemination. In this scenario, the fertilization cost for sows encompasses feed cost, non-feed cost, and semen expenditure cost during the fertilization process. Additionally, the overall cost of sows throughout their lifecycle includes the purchase cost of reserve sows, the cost of iron supplementation for breeding sows (which is included in the cost for epidemic diseases), the cost of castration and tail removal (which is included in the labor cost), and the proceeds from selling eliminated sows. The primary source of income for sows is their sale proceeds at elimination. Typically, sows are not culled on site but instead are turned into fattening pigs. Normal pigs and those that die are humanely disposed of, and each pig disposed of humanely generates a revenue of 50 yuan.

The specific calculation formula is as follows:

I.Total cost of sow life cycle:

$$TCS = Nsow_0(CPR + CS_0) + Nsow_0 \times \left(1 - \sum_{m=1}^{2} culp_m 1\right) \times CS_{41} + \sum_{i=1}^{MF} \{Nsow_i[(CS_1 + CS_2) + (i-1)CS_{42}]\}$$
$$- DOR$$

(1)

In the formula, TCS is the total life cycle cost of purchasing sows; $Nsow_0$ is the number of sows purchased; $Nsow_i$ is the number of fertile sows after elimination in each cycle; CPR is the price for purchasing each sow; CS_0、CS_1、CS_2 are the total cost of each sow from purchase to estrus, pregnancy and lactation; $culp_m 1$ is the probability that sows will be eliminated due to their physical appearance, stiff pigs and other problems ($m = 1,2$); CS_{41}、CS_{42} are the total costs during estrus from pregnancy to pregnancy and from weaning to pregnancy；i is the parity; MF is the largest parity that sows can produce in their lifetime; DOR is the reward for the elimination of sows.

II.Number of sows in each stage:

$$Nsow_1 = Nsow_0 \times (1 - \sum_{m=1}^{2} culp_m 1 - culp_1 2) \quad (2)$$

$$Nsow_i = Nsow_{i-1} \times (1 - culp_i 2) \quad \textbf{（i=2、3....9）} \quad (3)$$

$$Wsow_i = Nsow_{i-1} - Nsow_i \quad (4)$$

In the formula, $culp_i 2$ is the probability that sows will be eliminated due to reproductive problems in the i-th fetus; $Wsow_i$ is the number of sows eliminated per cycle.

III.Length of sow's life in each stage:

$$NPT = DS_1 + \sum_{j=1}^{NIC} \{[D1I + (j-1)k] \times PI_j\} \quad (5)$$

$$WPT = \sum_{j=1}^{NIC} \{[D2I + (j-1)k] \times PI_j\} \quad (6)$$

$$DAYS = Nsow_0 \times DS_1 + Nsow_0 \times \left(1 - \sum_{m=1}^{2} culp_m 1\right) \times NPT + \sum_{i=1}^{MF} \{Nsow_i[(i-1)WPT + DS_2 + DS_3]\}$$

(7)

In the formula, NPT、WPT are the time intervals from never pregnancy to pregnancy, and from weaning to pregnancy again; DS_1、DS_2、DS_3 are the time interval (days), pregnancy interval (days) and lactation interval (days) from purchase to estrus of each sow; NIC is the maximum number of fertilization per cycle; D1I、D2I are the time intervals from purchase to first fertilization and from weaning to first fertilization, respectively; j is the number of estrus; k is the interval between two estrus cycles (two insemination cycles); PI_j is the pregnancy ratio of sows after the j th insemination cycle; DAYS is the total number of days in the whole life cycle of purchased sows.

IV.Cost per sow at different stages:

$$CS_0 = DS_1(FIB \times CFB + FXCG) \quad (8)$$

$$CS_1 = DS_2(FIP \times CFP + FXCP) \quad (9)$$

$$CS_2 = DS_3(FIL \times CFL + FXCL) \quad (10)$$

$$CS_{41} = NID \times CID \times NIC + NPT(FIX \times CFX + FXCX) \quad (11)$$

$$CS_{42} = NID \times CID \times NIC + WPT(FIX \times CFX + FXCX) \quad (12)$$

In the formula, FIB、FIL、FIP are the feed intake of each sow from purchase to estrus, lactation and pregnancy (kg/ day); CFB、CFP、CFL are the feed prices of each sow from purchase to estrus, pregnancy and lactation respectively. Non-feed cost of FXCG、FXCP、FXCL sows every day from purchase to estrus, pregnancy and lactation;NID is the semen dose of each fertilization cycle; CID is the price of semen per dose; FIX、CFX are the feed intake (kg/ day) and feed price per kg of each sow during fertilization, respectively; FXCX is the non-feed cost of each sow during fertilization.

V.Return on elimination of sows:

$$culp_3 = 1 - \sum_{m=1}^{2} culp_m 1 - \sum_{i=1}^{MF} culp_i 2 \quad (13)$$

$$DOR = \sum_{i=1}^{MF} (Wsow_i) \times RKFAT \times WSFAT + POP \times \left[Nsow_0 \times culp_3 - \sum_{i=2}^{MF} (Nsow_{i-1} \times culp_i 2) \right]$$

(14)

In the formula, $culp_3$ is the probability of sow death and scouring; WSFAT、RKFAT are the carcass weight and price (kg/ yuan) of fattening pigs when they are sold; POP is the price of pollution-free treatment.

VI.Average profit per sow per year:

$$PSY = 365(TRFAT - TCS - CPIG - CFAT)/(DAYS \times Nsow_0) \quad (15)$$

In the formula, TCS is the total cost of sow life cycle, CPIG is the total cost of piglets in nursery period, CFAT is the total cost of fattening pigs, and DAYS is the total number of days to buy sows in the whole life cycle.

3.1.2 Costs and benefits of future generations

After weaning, piglets progress through two growth stages: the conservation period (40 days) and the fattening period (180 days). The elimination rates for piglets during these two stages are 5% and 2% respectively. For the overall cost of the two stages of piglet conservation and fattening, which includes feed cost and non-feed cost (labor, water and electricity, epidemic disease, depreciation of fixed assets, investment interest), the cost breakdown and pork selling price are based on the average levels as of November 2022. The specific values are presented in Table 3. In this study, the total cost of suckling piglets from birth to weaning is not calculated separately but rather is encompassed within the cost of sows. As Min pig are primarily utilized for breeding and the production of hybrid offspring, this study assumes that semen from imported breeds such as Large White Pig and Duroc will be used for hybridization with sows. Currently, the market selling price for the carcass of dual-fattened pigs is not significantly different from that of regular black pork, typically ranging from 27 yuan/kg.

The specific calculation formula is as follows:

I.Total cost of piglets in nursery period:

$$CPIG = Nsow_0 \times TNBW[FIPIGK \times CFPIG \times (FW - WW) + FXPIGD \times PRP] \quad (16)$$

In the formula, $Nsow_0$ is the number of sows purchased; TNBW is the number of fattening pigs provided by each sow for life; FIPIGK、FXPIGD are divided into the feed amount per kilogram of each piglet in the nursery period and the daily non-feed cost; CFPIG is the feed price per kilogram of each piglet in the nursery period; FW、WW are the average weights of piglets at the end of nursing and weaned piglets respectively; PRP is the duration of the conservation period (days).

II.Total cost of fattening pigs:

$$TNFAT = TNBW \times (1 - culp_4) \times (1 - culp_5)$$

$$CFAT = Nsow_0 \times \left\{ \begin{array}{l} TNFAT \times [FIFATK \times CFFAT\,(WFAT - FW) + FXFATD \times FP] \\ + culp_1 1 \times [FIFATK \times CFFAT\,(WFAT - WOJ) + FXFATD \times FP_1] \end{array} \right\} \quad (17)$$

In the formula, TNFAT is the number of fattening pigs provided by each sow for life; $culp_4$、$culp_5$ are elimination rates in conservation period and fattening period, respectively; TNFAT is the number of fattening pigs provided by each sow for life; FIFATK、CFFAT、FXFATD are the feed quantity, feed price per kilogram and daily non-feed cost required for each fattening pig in fattening period respectively; FP、FP_1 are the length of fattening period (days) and the fattening period (days) after six-month-old sows are fattened; WFAT、WOJ are the average weight of slaughtered pigs and the weight of six-month-old sows respectively.

III.Total income of finishing pigs:

$$TRFAT = Nsow_0 \times TNFAT \times RKFAT \times WSFAT \quad (18)$$

In the formula, TRFAT is the total income of fattening pigs; RKFAT is the selling price per kilogram of fattening pigs (yuan); WSFAT is the weight (kg) of fattening pigs when they are sold.

IV.Average profit of fattening pigs:

$$PFAT = \frac{TRFAT - TCS - CPIG - CFAT}{Nsow_0 \left(TNFAT + culp_1 1 \right)} \quad (19)$$

In the formula, $culp_1 1$ is the probability that sows will be eliminated because of their physical appearance, stiff pigs and other problems; CPIG、CFAT are the total costs of piglets and finishing pigs in the conservation period, respectively.

V.Average profit per kilogram of fattening pigs:

$$PCW = PFAT \ / WSFAT \quad (20)$$

In the formula, PFAT is the average profit of fattening pigs; WSFAT is the carcass weight of fattening pigs when they are sold.

3.2 Production mode

We simulated the initial purchase of 100, 1000, and 10000 gilts at the age of 150 days. After three fertilization cycles, sows that are not pregnant are eliminated. After successful mating, the sows progress through three stages: pregnancy, lactation, and weaning to pregnancy again, and then enter the production cycle (Figure 2). Elimination of sows can be attributed to three main reasons:

Type 1: Newly-purchased gilts were eliminated at the age of 6 months and 9 months due to their physical appearance and growth retardation.

Type 2: Elimination due to reproductive problems throughout the production cycle, such as estrus, abortion, etc.

Type 3: Elimination due to illness or natural death.

The 6-month-old reserve sow will undergo normal fattening and rearing processes after elimination. The 9-month-old reserve sow and the fertile sow, which are eliminated due to reproductive issues, will be slaughtered and sold directly. The deceased pigs will be disposed of humanely. Typically, if a pig is humanely disposed of, it may be subsidized by up to 50 yuan. If it has been insured in advance, the compensation amount may reach approximately 1,200 yuan. Since not all pigs across all farms participate in pig insurance, and various insurance costs are involved, we assume that all deceased pigs will be disposed of humanely.

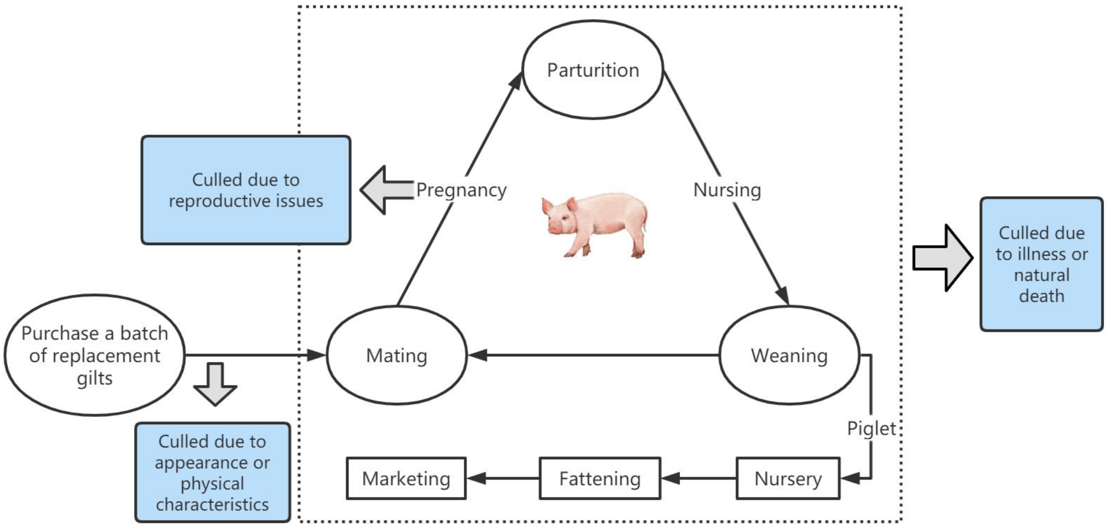

Fig2 Production Mode Diagram

3.3 Data source and parameter determination

The most significant input parameters for the model are presented in Tables 3 and 4, with the data obtained from the farm survey data of the Heilongjiang Academy of Agricultural Sciences. It is challenging to determine the reproductive parameters of sows, as significant variations exist among individuals. Therefore, in this study, the population average index was utilized. For instance, the maximum number of births a sow can produce in her lifetime is 9; the estrus cycle is 21 days; the age at which a reserve sow experiences her first estrus is 150 days, but she is not bred during this estrus and will be bred only after she reaches physical maturity. The specific values are provided in Table 4.

Table 4 Parameters of reproductive production performance system

Project	**Parameter**	**Project**	**Parameter**
Maximum parity of a sow in its lifetime	9	When the sow is six months old, the probability of being eliminated due to body appearance, stiff pig and other problems (%)	5
Time interval (days) from purchase to estrus of each sow.	30	At the age of nine months, the probability of sows being eliminated due to problems such as body appearance and stiff pigs (%)	5
Pregnancy interval per sow	114	The probability of sows being eliminated due to reproductive problems in the I-th fetus (%)	2
Breastfeeding interval per sow	40	Number of weaned piglets provided by each sow for life	108
Time interval from first love to first insemination	240	Feed requirement for piglets to gain weight per kilogram in conservation period (kg)	3.2
Time interval from weaning to re-insemination	7	Average weight of weaned piglets (kg)	7
Interval between two estrus cycles (two insemination cycles)	21	Average weight of piglets at the end of conservation (kg)	15
Maximum fertilization times per cycle	3	Length of piglet care period	40
Pregnancy rate of sows after the first insemination cycle (%)	98	Elimination rate during conservation period (%)	5
Pregnancy rate of sows after the second insemination cycle (%)	85	Elimination rate in fattening period (%)	2
Pregnancy rate of sows after the third insemination cycle (%)	75	Feed requirement for fattening pigs to gain weight per kilogram (kg)	4.9
Daily feed intake of each sow from purchase to estrus (kg/day)	2.7	Average weight of slaughtered pigs (kg)	130
Daily feed intake of each sow during lactation (kg/day)	3.5	Weight of six-month-old sow (kg)	70
Daily feed intake of each sow during pregnancy (kg/day)	2.5	Length of Fattening Period	180
Daily feed intake of each sow during fertilization (kg/day)	2.35	Fattening period of six-month-old sows after fattening	75
Semen dose (dose) per fertilization cycle	2	Weight of fattening pigs at the time of sale (kg)	120

4. Results and analysis

4.1 Influence of the change of breeding scale on cost and benefit

According to the theory of scale benefit, as the breeding scale expands, the average total cost of farms decreases with the increase in output, leading to increased economic benefits [41].

However, due to significant fluctuations in feed prices and the susceptibility of the industry to buyer variations, the influencing factors of pig breeding are complex [42]. Therefore, in this study, we assume that all other parameters remain constant except for the breeding scale and slaughter weight.

After calculations, it is found that currently, the overall production of civilian pigs is in a state of loss, with an average loss of 12.98 yuan per kilogram of pork sold. If a large-scale farm initially purchases 1,000 sows, the total cost of these sows throughout their lifespan is 72,514,400 yuan. The total cost of producing piglets and fattening pigs is 409,994,200 yuan, and the total income from fattening pigs is 325,775,500 yuan. The average annual loss solely from purchasing sows is 15.50 yuan, and the average loss from fattening pigs is 15,581 yuan. As can be seen in Table 5, changes in the breeding scale will also affect costs, income, and profits. When only the number of pigs is varied, the larger the scale of pig production, the higher the total cost, the higher the total income, and the annual loss from purchasing sows will be reduced; however, the net profit from selling pork remains unchanged.

Table 5 Cost-benefit of sow from purchase to elimination

Breeding quantity	TCS	CPIG	TNFAT	TRFAT	PSY	PFAT	PCW
100	7251434.5	4492368	36507052	32577550	154.98004	1558.0135	12.983446
1000	72514352	44923680	365070528	325775520	15.498002	1558.0135	12.983446
10000	725143424	449236800	3650705408	3257755136	-1.5498006	-1558.0137	12.983447

3.2 Influence of slaughter weight change on cost and benefit

As can be seen from Table 6, with other factors held constant, as the slaughter weight increases, the total cost of sow breeding throughout their lifespan will decrease, while the total cost of producing piglets and fattening will remain unchanged. The total income from fattening pigs will increase. This is because as the slaughter weight increases, the sow elimination return also increases, and the total cost of the sow's lifespan is calculated as the cost of the sow at different stages MINUS its elimination return. Therefore, as the slaughter weight increases, the total cost of the sow's lifespan decreases. In summary, with the expansion of breeding scale and an increase in slaughter weight, the population remains in a state of loss and production efficiency is relatively low.

Table 6 Influence of slaughter weight change on cost-benefit

Slaughter weight	Breeding quantity	TCS	CPIG	TNFAT	TRFAT	PSY	PFAT	PCW
120	100	7251434.5	4492368	36507052	32577550	-154.98004	-1558.0135	-12.983446
	1000	72514352	44923680	365070528	325775520	-15.498002	-1558.0135	-12.983446
	10000	725143424	449236800	3650705408	3257755136	-1.5498006	-1558.0137	-12.983447
150	100	6779688.5	4492368	36507052	40721940	-69.782364	-701.52179	-4.6768117
	1000	67796888	44923680	365070528	407219392	-6.9782381	-701.522	-4.6768131
	10000	677968832	449236800	3650705408	4072193792	-0.69782412	-701.52216	-4.6768146

5. Discuss

5.1 Discussion on Bio-economic Model

Currently, the focus of bio-economic modeling research is to consider the overall situation of the population rather than the situation of individual pig farms. Some scholars often study and analyze pig genetics, reproduction, and breeding from the perspective of trait evaluation, with most research objects being foreign commercial breeds such as Landrace and Duroc [26,43,44]. Bio-economic models can provide valuable information for evaluating local pig breeds [17], and discussions on variety diversity protection cannot be separated from cost-benefit analysis [45]. Therefore, based on neoclassical economic theory [46], this paper conducts a cost-benefit analysis to calculate the economic value of Min pigs during their growth and reproduction, and then discusses the risk of species extinction.

5.2 Discussion on the existing hidden dangers of civilian pigs

Judging from the current situation and results, it is evident that regional development support policies and commercial utilization are effective in protecting and increasing the number of local pig breeds to a certain extent. However, there are also potential risks involved, including: (1) The risk of genetic resource loss. As commercialization tends to favor "high-yield, high-performance" exotic varieties, the genetic resources of local varieties may be ignored or lost, leading to potential genetic resource loss for Min pigs; (2) The risk of losing cultural and ecosystem value. Local varieties are often closely linked to the traditions and ecosystems of specific regions, and excessive commercialization may result in neglecting or losing the cultural and ecosystem values of local varieties; (3) Market demand fluctuation risk. Commercial market demand can be affected by market trends, consumer preferences, and competition, etc. If Minzhu pigs rely solely on the commercial market, they may face the risk of demand fluctuations, which could adversely impact their economic benefits.

5.3 Discussion on making local varieties achieve self-sustainable development

Whether in developed or developing countries, intensive management gradually replaces extensive production. Compared with native varieties, exotic varieties have shorter growth cycles, larger litter sizes, and relatively good carcass qualities, making them more suitable for the "high input, high output, and high income" standard[47]. Simply relying on government support is clearly insufficient for simple development. To eliminate hidden dangers and enable local varieties to achieve self-sustainable development, multiple measures should be taken. These include promoting and improving farmers' understanding of local varieties, funding the establishment of gene banks, and selling local varieties' by-products[48]. Additionally, conveying information about positive externalities such as high product quality to consumers may help to improve their acceptance of products associated with local pig breeds[49]. At the same time, community-based in-situ protection, establishment of breeders' associations, collective ex-situ protection on institutional farms, and innovative product marketing are effective strategies for protecting underdeveloped local pig breeds[50]. Other tools such as increasing product traceability and transparency, strengthening supply chain relations, accelerating business diversification, and encouraging tourism can also be utilized[51].

6. Conclusion

In this paper, the cost-benefit analysis of civilian pigs is conducted through a pig population economic model. The results indicate that people's pigs have high input costs, low output income, negative income, and low production efficiency. In combination with the current utilization status of people's pigs, it is pointed out that over the years, a series of incentive and protection measures have achieved a certain balance in the universal commercialization environment. This has led to the implementation of policies and commercial development to a certain extent, increased the number of people's pigs, and improved the endangered situation of varieties. However, they still face risks in the future. Therefore, it is necessary to continue to take effective measures to protect and develop local pig breeds, such as promoting farmers' understanding of local varieties, funding the establishment of gene banks, and selling local varieties' by-products. At the same time, it is also necessary to strengthen supply chain relations, accelerate business diversification, encourage tourism activities, and other strategies to protect local pig breeds.

In conclusion, the protection and development of local pig breeds is a complex system project, which requires the joint efforts of all parties, including government departments, enterprises, farmers and social organizations. First, the government should formulate relevant policies to encourage and support the protection and development of local pig breeds, including providing economic subsidies, tax incentives and other preferential policies, and strengthening the supervision and management of relevant industries. Second, enterprises should establish an effective marketing strategy for local pig breeds, and fully utilize their genetic characteristics to develop differentiated high-quality products with high added value. At the same time, they should also strengthen cooperation with farmers to ensure the sustainable supply of raw materials and improve product traceability and transparency. Finally, farmers should increase their understanding of local pig breeds, strengthen their self-protection awareness, and actively participate in local pig breed protection activities. In short, only through the joint efforts of all parties can we effectively protect and develop local pig breeds, realize their self-sustainable development, and promote the balanced development of the pig industry.

The implementation of the above methods is closely related to the conditions of local governments and producers. What policies may be ineffective? It is known that technical efficiency is the key factor affecting product value. Will the improvement of technical efficiency make some policies invalid and the situation unbalanced? This is what we plan to do next.

7.Data Availability Statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation, to any qualified researcher.

8.Author Contributions

YG and GW conceived and designed the research.

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10.Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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