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Quantitative Evaluation of China's Livestock Environmental Regulation Policies Based on the Policy Modeling Consistency Index Model

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Abstract The livestock environmental policy is crucial to controlling agricultural pollution under a sustainable development strategy, and the evaluation of relevant policy is an important basis for reducing policy implementation deviations and protecting the production and living environment in rural areas. This study conducted text mining of 56 Chinese centrally released livestock environmental regulation policies, analyzed policy tool preference tendency, and with the evaluation system established by the Policy Modeling Consistency index model, this study made a quantitative analysis of 8 key livestock environmental regulation policies since 2001. Research results show that, overall, Chinese policy tools tend to be control-oriented, but in recent years, incentive-based tools are also considered. The current policy needs improvement in terms of policy nature, policy-issuing institutions, and measures. This study is helpful to fully understand the advantages and disadvantages of Chinese livestock environmental regulation and provides a valuable evaluation basis for future policy releases.

Keywords: • livestock environmental regulation • policy modeling consistency index • quantitative analysis • policy tendency • policy tools

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1 Introduction

The livestock industry in China, a cornerstone of its agricultural sector, has experienced unprecedented growth in recent decades (Bai et al., 2018). Since 1979, China has seen a tenfold increase in meat production (Jia et al., 2018). However, the expansion has not only contributed significantly to food security and economic development but has also brought forth profound environmental challenges. These challenges encompass issues such as water pollution (D. Pan, Chen, Zhang, & Kong, 2023), land degradation (Bahta, Jordaan, & Phatudi-Mphahlele, 2019), and greenhouse gas emissions (Zhou et al., 2024), all of which have caused serious problems with the sustainability of China's livestock production. Meanwhile, the consequences resulting from improper livestock farm management also constitute a primary source of pollution in rural China (Gu, Du, & Khan, 2023).

In response to these environmental concerns, the Chinese government has undertaken a series of environmental regulation policies to mitigate the adverse effects of livestock production (D. Pan et al., 2023; Qian, Song, Hu, & Ying, 2018). These policies encompass diverse strategies, including improved waste management, land-use planning, and targeted reductions in pollution emissions. The environmental issue caused by livestock waste is a worldwide topic, and some countries have proposed corresponding measures. The national plan for circular livestock supply chains in the Netherlands, "Agriculture, Nature and Food: Valuable and Connected", aims to promote the cooperation between livestock farmers, arable farmers, and horticulture farmers, making manure into high-quality fertilizer (Bouma, 2016; Mehrabi, Gill, Wijk, Herrero, & Ramankutty, 2020). Based on the Nitrates Directive (ND) (91/676/EEC), in Ireland, the agri-environmental schemes control cattle exclusion from watercourses to achieve the purpose of improving water quality (Kilgarriff, Ryan, O'Donoghue, & Green, 2020). In New Zealand, nitrates-reducing policy, like legislated standard can reduce nitrogen losses (Doole, Marsh, & Ramilan, 2013). Compared with developed countries, China still lacks practical experience and a complete policy system in sustainable livestock management (Jin et al., 2021; Qian et al., 2018; Zhu et al., 2022). Because of the authoritarian environmentalism in China's environmental governance, the central government holds primary authority over the design and formulation of environmental policies (Gilley, 2012; X. Li, Yang, Wei, & Zhang, 2019; L. Liu, Zhang, & Bi, 2012). The policy-making is top-down, and the central government's decision-making affects local responses to a large extent (C. Wang & Lin, 2010). Therefore, the policies issued by the central government can intuitively reveal the focus of China's livestock and poultry environmental protection department. To establish a sustainable mechanism for pollution control and environmental management in livestock farming, it is necessary to further improve the relevant LER policies and make reasonable adjustments based on the current status of the livestock breeding industry.

Therefore, it is essential to assess the existing LER policies and propose targeted improvement strategies.

Policy evaluation is a crucial component of the public policy analysis process, providing a basis for the rational allocation of policy resources and the effective assessment of policy outcomes (Dai, Zhang, Zong, Y. Wang, & Wang, 2021; Vedung, 2017; Z. Wang, Xie, Yang, & Liu, 2024). The quantification of policy can lead to more effective and interactive governance (Sanderson, 2002). Some studies attempt to summarize the policy instrument and objective of China's livestock environmental regulation (LER) policies through historical review and case studies (Mao, Jin, Hu, Weeks, & Ye, 2022; Wei, Zhu, Zhao, Chadwick, & Dong, 2021). However, there is a limited adoption of quantitative analysis methods and a lack of comparative and analytical studies on key livestock environment policies, which are necessary for systematically improving policy content. Simultaneously, assessing livestock environment policies can uncover patterns in policy issuance and common issues therein. It can also potentially provide new avenues for policy improvement from the standpoint of policy coherence. The study seeks to bridge this gap and endeavors to evaluate LER policy by introducing the Policy Modeling Consistency (PMC) Index Model. Though a rigorous quantitative assessment of policies, the study more accurately summarizes the patterns of policy formulation, identifies issues in policy texts, and provides a reference for future policy optimization.

2 Policy overview and literature review

2.1 Overview of China's LER policy

China's policy on livestock pollution control was formulated relatively late. In 2001, the Chinese government first issued a specialized regulation, "Livestock Pollution Prevention and Management Measures", aimed at addressing environmental pollution in the livestock industry. After that, the China LER policy has undergone significant developments and transformation (Jiang, Hu, & Wang, 2023). Starting to issue dedicated LER policies signifies a shift in the development and growth of China's livestock industry from an emphasis on output and quantity towards a focus on quality and efficiency, and signaling a departure from sacrificing the environment for the sake of livestock industry development. The revised "Water Pollution Prevention and Control Law" in 2008 specifies that "livestock and poultry farms, as well as breeding communities, should ensure the normal operation of comprehensive utilization or harmless treatment facilities for manure and wastewater, preventing water environment pollution." This signifies that thereafter, the Chinese government's requirements for the control of pollution from livestock and poultry farming became more specific, but the implementation and progress of policies were still relatively slow at this time. In 2013, the

"Regulations on the Prevention and Control of Pollution from Large-scale Livestock and Poultry Breeding", regarded as the first peak of LER policy implementation, were implemented. This "Regulations" stands as the paramount and all-encompassing policy, with subsequent specific policy tools formulated in accordance with it. This marks the first national-level administrative regulation in the Chinese rural and agricultural environmental protection field and stands as a milestone in the construction of agricultural and rural environmental protection systems. The enactment of this regulation also indicates a shift in the policy objectives of controlling pollution from livestock farming. The focus has moved from a mere emphasis on pollution control to a comprehensive direction aimed at promoting the healthy development of the breeding industry and reducing the use of chemical fertilizers. This transformation holds profound significance. After 2015, the LER policy entered a period of rapid development. Currently, China has initially established an LER policy system, focusing on source reduction, process control, and diversified utilization of waste to address pollution. Meanwhile, through measures such as the delimitation of prohibited breeding areas, pollution risks are mitigated at the source.

2.2 Literature review

Policy evaluation contributes to the design, implementation, and adjustment of future policies. Organization for Economic Co-operation and Development (OECD) uses a six-evaluation criteria framework: relevance, effectiveness, efficiency, impact, sustainability, and coherence. Relevance is about the focus of policies and whether it is justified in the context of a specific region. In the case of livestock environmental regulation, this has been extensively discussed and justified (D. Pan et al., 2023). Effectiveness is about reaching objectives and is also typically assessed in different scientific papers (Morse, 1996; Weersink & Eveland, 2006). The LER policy implementation effectiveness primarily includes two aspects: the impact on the environment and the impact on the livestock industry. Environmental regulations have played a crucial role in preventing grassland degradation and improving grassland conditions, but they have had a negative impact on the local livestock production industry (M. Liu, Dries, Huang, Min, & Tang, 2019). Efficiency is about the trade-off between the environmental objectives and the economic cost and how well policies improve the environmental objectives at the lowest costs. Also, this aspect has been extensively addressed in the scientific literature (D. Pan & Chen, 2021; Zheng, Liu, Bluemling, Mol, & Chen, 2015). Environmental issues are generally complex and require collaboration among multiple departments (Wagner, Torney, & Ylä-Anttila, 2021). In terms of the inherent characteristics of policies, the larger the goals, the more stakeholders involved, and the more types of pollution addressed, the more challenging it is to smoothly implement the policy and lower the policy efficiency. Impact (Hu et al., 2019), the difference between a specific

intervention (Zheng et al., 2015), and the sustainability, and the lasting policy benefits (X. Sun, Liu, Zhao, & Zhu, 2021) are also typically addressed in policy evaluation literature. The main criterion of policy evaluation that is missing in the scientific literature is coherence. Coherence is about the consistency of different policy initiatives and whether they fit together instead of counteracting themselves. This paper proposes textual content analysis of policies as a tool to evaluate the coherence of different livestock environmental policies. This would explain livestock environmental regulation policy from a new perspective.

Quantitative research is currently a popular approach in policy evaluation studies. Quantitative methods for policy text analysis mainly include bibliometrics, content quantification, and semantic analysis of texts. In bibliometrics, the emphasis is on examining characteristics such as the time series and issuing authorities of policy documents (Kowalewski, Lavis, Wilson, & Carter, 2014; Yang, Huang, & Su, 2020). Content quantification is primarily based on the extraction and coding of policy thematic content, thereby analyzing the deeper meanings behind the data (Arenal, Feijoo, Moreno, Ramos, & Armuña, 2021). Text semantic analysis often relies on methods such as natural language models, machine learning, and text mining to explore the content of policy documents (Y. Li, He, Liu, Li, & Xiong, 2021; X. Wang, Huang, Daim, X. Li, & Li, 2021). For the quantitative evaluation of individual policies, the PMC index model established by Estrada offers a novel approach (Estrada, 2011). Currently, this method has been applied in various fields of policy evaluation such as disaster relief (Z. Li & Guo, 2022), energy security (X. Zhao, Jiang, Wu, & Zhou, 2023), and vehicle industry (X. Wang et al., 2021). Existing research results indicate that the PMC index model has some applicability and scientific validity in public policy evaluation, but there is little research applying it to the evaluation of livestock environmental regulation.

Through a review of previous studies, it can be concluded that attention to LER policies primarily focuses on relevance, effectiveness, efficiency, impact, and sustainability. These studies have tended to overlook the textual aspects of policies themselves and the gaps between various LER policies internally. The PMC model offers a quantitative consistency evaluation framework that scrutinizes policy content across various dimensions and suggests pathways for enhancement. Therefore, this study focuses on LER policies, quantitatively analyzes policy texts by constructing the PMC index model, proposes targeted improvement suggestions, provides a decision-making basis for subsequent policy optimization, and contributes to a more comprehensive evaluation of LER policies. This is crucial for enhancing policies implemented, advancing the treatment level of livestock manure, and improving the production and living environment in rural areas.

3 Materials and method

3.1 Data sources and research samples

The Livestock Environmental Regulation (LER) Policy refers to a series of governmental policies aimed at addressing pollution issues arising from the livestock breeding industry, with the primary goal of safeguarding the environment in rural areas. The Beida Fabao (PKULAW) website, which serves as the professional, mature, and advanced platform system for retrieving Chinese comprehensive legal, regulatory, and policy information (X. Zhang & Yang, 2019), primarily constitutes the main source of data for this research. To ensure uniformity and equality in the policy evaluation, only policies issued at the national level, originating from the central government rather than regional governments, were considered for analysis. Policies were identified through keyword searches using "livestock" and "pollution," resulting in a set of policies selected for evaluation. It is important to note that for comprehensive policy documents containing provisions related to livestock environmental management, only sections with relatively high relevance were retained for general statistical analysis. Following the search and screening process, a total of 56 LER policies issued between 2001 and 2023 were ultimately identified for analysis.

3.2 Construction of the PMC-Index model

The Policy Modeling Consistency (PMC) index was created by Estrada and provides a new way to quantitatively evaluate the coherence of a single policy (Estrada, 2011). The PMC index model can conduct a comprehensive evaluation of a single policy, reflect the advantages and disadvantages of the policy from multiple objectives, and compare policies with contradicting outcomes. Moreover, the original data of the model comes from the policies of text data mining, which can avoid the subjectivity of evaluation to a large extent. Generally, there are 4 steps for constructing the PMC-Index model. First, it is necessary to classify variables and parameters, determine first-level indicators for policy evaluation, and establish a policy analysis framework. Then, the secondary variables of policy evaluation are determined based on the analysis framework and text mining results, and a complete evaluation index system is established. Second, based on the construction of evaluation variables, a multi-input-output table is established to form a calculation matrix. The third step is to calculate the PMC-Index based on the matrix. Finally, the visual expression is obtained through the PMC surface.

3.2.1 Variable classification and parameter identification

Policy text analysis is the base of variable classification and parameter identification. Initially, by organizing 56 LER policy texts and establishing the database for analysis, import them into the text analysis software ROSTCM 6.0 for word frequency statistics and analysis. In the customized word list, customize professional terms such as " livestock breeding ", " environmental protection ", " prohibited breeding areas ", etc. The final result is the list of high-frequency words appearing in the top 40 rankings in LER policies. As is shown in Table 1, livestock, mainly hogs, is the primary focus of policy attention. Environmental protection and pollution control are the main objectives of policy implementation. Technology and facilities are important means to achieve these goals.

Based on the high-frequency words, further analysis is conducted to obtain the co-word matrix table, generating a semantic network diagram of core keywords (Figure 1). In this network, each keyword constitutes a node, with the size of the node increasing proportionally to the frequency of the keyword. The lines connecting each node indicate a co-occurrence relationship between the high-frequency words, meaning they commonly appear in the same sentence. The thicker the line, the stronger the co-occurrence relationship between them (Xiong, Zhang, & Qi, 2023). Through the visualization of the high-frequency word network structure, it can be observed that "livestock breeding", "environment", " facilities ", and " construction" exhibit higher centrality. As the policy primarily focuses on the industry type, "livestock breeding" occupies the center of the network, with the highest frequency and the widest range of influence. The network also reflects the diversity of policy implementers, policy objectives, and implementation pathways. The "regulatory authorities" and government "institutions" are the primary actors in policy issuance and supervision. The main goals of implementing LER policies include large-scale livestock farms, the utilization of livestock manure resources, the comprehensive utilization of waste, and the prevention and control of pollution from livestock farms. Strengthening supporting facility construction, standardizing technologies, and establishing emission standards are the primary pathways and means to achieve LER goals.

Combining existing literature (Estrada, 2011; Kuang, Han, Lu, Zhang, & Fan, 2020; Y. Li et al., 2021; Potter et al., 2022; Xiong et al., 2023) and the preliminary text analysis results for LER (Table 1 and Figure 1), a comprehensive evaluation index system for LER policies is formulated. As it is shown in Table 2, there are 9 primary variables, including policy nature (X_1), policy release agency (X_2), policy object (X_3), policy priority (X_4), policy function (X_5), policy tool (X_6), policy field (X_7), policy measure (X_8) and policy evaluation (X_9). Each primary variable has several secondary variables, totaling 42 variables.

Table 1: Statistics of high-frequency words of livestock environmental regulation policies

Sequence	High-frequency words	Frequency	Sequence	High-frequency words	Frequency
1	Livestock breeding	691	21	Environmental protection	290
2	Environment	591	22	Husbandry	254
3	Technology	589	23	Utilization	254
4	Faculties	524	24	Pollute	251
5	Livestock	516	25	Pattern	246
6	Construction	490	26	Waste	242
7	Deal with	476	27	Pollution	234
8	Development	403	28	Institution	233
9	Breeding	390	29	Monitor	228
10	Comprehensive utilization	389	30	Livestock farm	224
11	Standard	387	31	Discharge of pollutants	223
12	Large-scale breeding	355	32	Promote	223
13	Livestock manure	353	33	Enhance	215
14	Emission	350	34	Implement	214
15	Hog	327	35	Policy	208
16	Pollution control	325	36	Agriculture	207
17	Management	324	37	Supporting	207
18	Project	320	38	Measure	202
19	Regulation	316	39	Region	196
20	Manure	308	40	Feces	193

Figure 1: LER high-frequency words network diagram

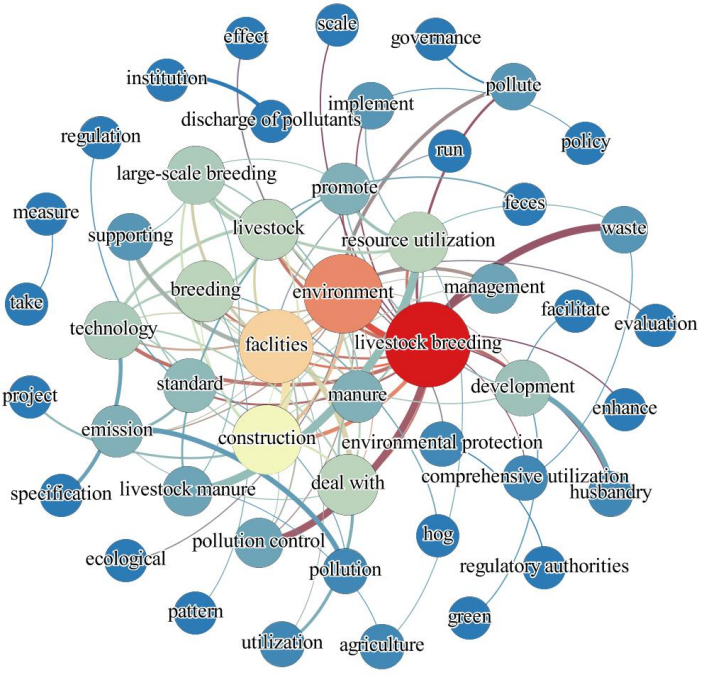


Table 2: Variable settings for quantitative evaluation of the livestock environmental regulation policies

Primary variables	Secondary variables	Reference
X_1: Policy nature	X_{11}: Legislation	Kuang et al. (2020)
	X_{12}: Plan	
	X_{13}: Recommend	
	X_{14}: Measure	
	X_{15}: Guidance	
X_2: Policy release agency	X_{21}: State Council of the People's Republic of China (PRC):	Xiong et al. (2023)
	X_{22}: Ministry of Agriculture and Rural Affairs of the PRC or Ministry of Ecology and Environment of the PRC	
	X_{23}: Other Ministries and Commissions of the State Council of the PRC	
	X_{24}: Multi-agency joint issue	
X_3: Policy object	X_{31}: Government	High-frequency word statistic and semantic
	X_{32}: Environment management department	

Primary variables	Secondary variables	Reference
	X_{33}: Agriculture management department	network diagram
	X_{34}: Livestock farm	
	X_{35}: Social organization	
X_4: Policy priority	X_{41}: Comprehensive utilization of waste	High-frequency word statistic and semantic network diagram
	X_{42}: Utilization of manure resources	
	X_{43}: Environmental assessment system construction	
	X_{44}: Development of planting and breeding cycle	
	X_{45}: Large-scale and standardized development of livestock farms	
	X_{46}: Pollution prevention and control in the livestock breeding industry	
	X_{47}: Delimitation of prohibited breeding areas	
X_5: Policy function	X_{51}: Clarify the authority, responsibility, and function of the department	High-frequency word statistic and semantic network diagram
	X_{52}: Standardize workflow	
	X_{53}: Establish a supervisory system	
	X_{54}: Construct standard system	
X_6: Policy tool	X_{61}: Compulsory type	Potter et al. (2022)
	X_{62}: Voluntary type	
	X_{63}: Mixed type	
X_7: Policy field	X_{71}: Environmental	Estrada (2011)
	X_{72}: Economic	
	X_{73}: Social	
	X_{74}: Technical	
X_8: Policy measure	X_{81}: Law and regulation	Y. Li et al. (2021)
	X_{82}: Special fund	
	X_{83}: Policy supply	
	X_{84}: Technical support	
	X_{85}: Talent support	
	X_{86}: Assessment and evaluation	
	X_{87}: Rewards and Punishments	
X_9: Policy evaluation	X_{91}: Sufficient basis	Y. Li et al. (2021)

3.2.2 Construction of multi-input-output table

The multi-input output table (Table 3) is a database analysis framework that allows the storage of data for measuring individual variables. In this framework, all sub-variables are assigned equal weight, maintaining balance between the variables through binary representation. Specifically, if the LER policy text contains content that matches the description of the variable, the parameter is set to 1; otherwise, it is set to 0.

Table 3: Multi-input-output table

Primary variables	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
Secondary variables	X_{11}	X_{21}	X_{31}	X_{41}	X_{51}	X_{61}	X_{71}	X_{81}	X_{91}
	X_{12}	X_{22}	X_{32}	X_{42}	X_{52}	X_{62}	X_{72}	X_{82}	X_{92}
	X_{13}	X_{23}	X_{33}	X_{43}	X_{53}	X_{63}	X_{73}	X_{83}	X_{93}
	X_{14}	X_{24}	X_{34}	X_{44}	X_{54}		X_{74}	X_{84}	
	X_{15}		X_{35}	X_{45}				X_{85}	
				X_{46}				X_{86}	
				X_{47}				X_{87}	

3.2.3 PMC-Index calculation

The main calculation steps for the PMC Index are as follows:

$$X \sim N[0,1] \tag{1}$$

$$X = \{XR : [0,1]\} \tag{2}$$

$$PMC = \sum_{i=1}^{m}\left(X_i\left[\sum_{j=1}^{n}\frac{X_{ij}}{T\left(X_{ij}\right)}\right]\right) \tag{3}$$

Where, '*i*' represents primary indicators, while '*j*' signifies secondary indicators under the primary ones. Variables are identified and assigned values of 0 or 1 based on equations (1) and (2). Subsequently, the PMC Index for LER policies is calculated using equation (3). This procedure results in the PMC Index scores for the selected LER policies, as depicted in Table 6. In accordance with previous research (Kuang et al., 2020), the PMC Index scores have been categorized into different levels, and detailed information regarding these categories is presented in Table 4.

Table 4: Livestock environmental regulation policies PMC-Index evaluation criteria

PMC-Index	**0~2.99**	**3~4.99**	**5~6.99**	**7~9**
Evaluation	Low consistency (LC)	Acceptable consistency (AC)	Great consistency (GC)	Perfect consistency (PC)

3.2.4 PMC-Surface

A Three-Dimensional surface chart of policy research samples based on the PMC index is constructed. The surface chart provides an intuitive representation of

model evaluation results. The score and internal consistency level of the policy can be assessed based on different levels of convexity and smoothness. Higher scores are represented by the raised parts of the surface, while lower scores are depicted by the concave areas. The smoother the surface, the higher the internal consistency, and vice versa. Consisting of scores from 9 primary variables, the matrix is following.

$$PMC = \begin{pmatrix} X_1 & X_2 & X_3 \\ X_4 & X_5 & X_6 \\ X_7 & X_8 & X_9 \end{pmatrix} \tag{4}$$

4 Results

4.1 Analysis of LER tendency

Command control regulation and market incentive regulation represent two types of measures commonly used in environmental regulation (Lamperti, Napoletano, & Roventini, 2020; Xiongfeng Pan, Ai, Li, Pan, & Yan, 2019). Command control regulation refers to the government using legal and administrative means to enforce regulations on the behavior of polluting enterprises. Market incentive environmental regulation policies, on the other hand, involve utilizing various economic mechanisms to adjust the costs and profits of polluting enterprises, incentivizing them to proactively reduce pollutant emissions (Iraldo, Testa, Melis, & Frey, 2011). Due to the mandatory nature of command control regulation, it directly publicizes the regulatory requirements and deadlines for environmental rectification. This poses challenges for enterprises in adjustment and adaptation periods, consequently dampening their enthusiasm for innovation. Comparatively, market incentive environmental regulations provide indirect ways for enterprises. Based on market demands, these regulations design rules and systems that can offer material incentives for enterprises to invest in environmental technologies, thereby promoting technological progress and achieving the goal of guiding corporate behavior through market mechanisms (Z. Sun, X. Wang, Liang, Cao, & Wang, 2021).

The government aims to protect the environment and enhance environmental quality by employing diverse policy tools (Horbach, Rammer, & Rennings, 2012; R. Li & Ramanathan, 2018). In general, incentive regulations are more flexible than control regulations and are better at stimulating technological innovation in enterprises (Xiongfeng Pan et al., 2019). However, the effectiveness of market-incentive regulation is always constrained by factors, including market effectiveness, pollutant characteristics, spatial aspects, and monitoring capacity.

Therefore, the necessity for command-control regulation remains indispensable (N. Shen, Liao, Deng, & Wang, 2019).

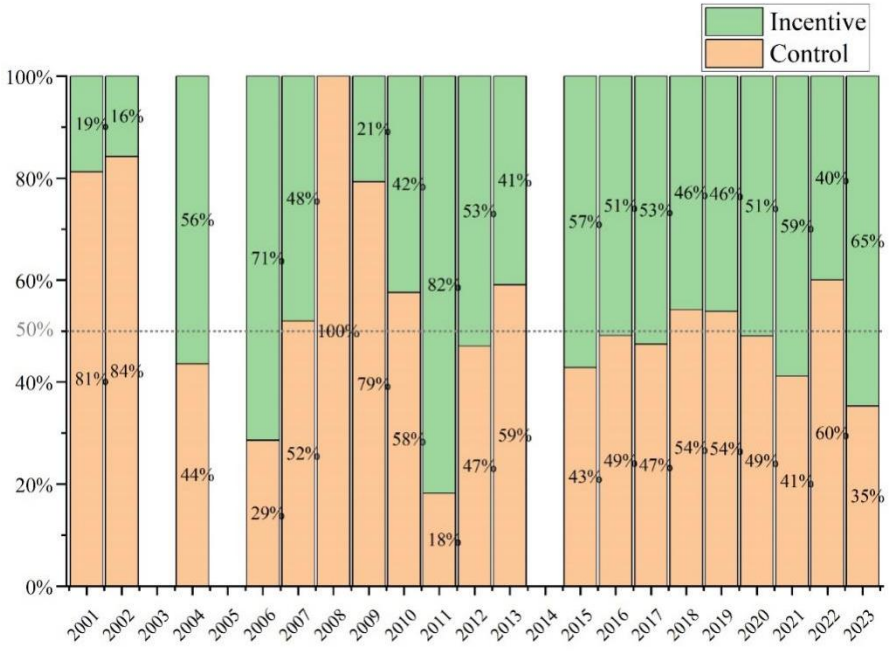
LER also widely adopts both of these two policy tools. Sentiment analysis (also known as opinion mining) can be used to capture the preferences and tendencies of Chinese LER policy concerning the choice between control and incentive.

The application of sentiment analysis in textual analysis is a common method for extracting the attitude tendencies embedded in the text. In this study, the approach of sentiment analysis is borrowed and applied to the analysis of policy tool tendencies. Initially, through frequency analysis and filtering, 70 words representing the two inclinations were obtained and defined as the LER policy tool dictionary. Among the 70 items, there are 31 incentive-oriented words and 39 control-oriented words. Figures 2 and 3 display word cloud representations for incentive-oriented and control-oriented vocabularies, respectively. Overall, it indicates that the Chinese LER policy tends to prefer the use of mandatory ways to address environmental issues in livestock farming. Subsequently, a tendency analysis is carried out on the policy texts year by year, specifically calculating the proportions of control-oriented and incentive-oriented words in each year's text. Figure 4 presents the tendencies in the policy tools adoption from 2001 to 2023. It can be observed that before 2013, prior to the enactment of the first formal regulation, the tendency of LER was relatively extreme, frequently displaying a singular bias, with significant interannual shifts. It indicates that during this period, LER demonstrated weak continuity and stability in the policy tools application. After 2013, the tendency of LER has been more stable, with a more comprehensive selection of policy manners. In this phase, LER integrated the application of both incentive and control approaches, aiming to achieve policy goals through a trade-off and synergy across multiple methods.

Figure 2: Words cloud of incentive trend words

Figure 3: Words cloud of control trend words

Figure 4: Tendency analysis result of LER policy text



4.2 The PMC index for 8 livestock environmental regulation policies

Based on the LER evaluation variables constructed in the preceding sections, the PMC index for each policy is computed. Subsequently, the consistency level of each policy is determined using the PMC index, and the results are shown in Table 5. It is shown that the average score of the PMC index of 8 LER policies is 4.69. The ranking of the 8 policies from highest to lowest scores is as follows: P3, P2, P8, P5, P7, P4, P1, P6. Among the 8 policies, 3 policies have achieved the Great level (P2, P3, P8), while the remaining 5 are at the Acceptable level. With P3 receiving the highest score, this signifies that its quality is relatively superior to other policies. It provides a comprehensive and scientifically sound response to the environmental issues in the livestock and poultry farming industry, making it a seminal document in the LER field. Despite being in force for a decade, the influence of P3, as a regulation specifically targeting the livestock and poultry farming industry (Regulations on the Prevention and Control of Pollution from Large-scale Livestock and Poultry Breeding), is profound. Subsequent releases of each LER policy are formulated based on P3 as a guideline and reference.

For a more intuitive display of the scores of primary variables for each policy and a comprehensive comparison of the dimensions of the 8 LER policies, a Debra chart is used for visual presentation (Figure 5). Among the primary variables, the averages of policy object (X_3) and policy evaluation (X_9) are high, at 0.75 and 0.79 respectively. On one hand, this indicates that the Chinese LER policy involves a comprehensive range of entities, and the governance of the livestock breeding environment through policies is a systematic undertaking that requires the collective participation of all stakeholders in society. On the other hand, the high score of X_9 reflects that the objectives of the policies are very clear and are often based on various standards, laws, and former documents, providing a solid foundation for policy formulation. From the perspective of policy tools (X_6), among the 8 policies, 3 adopt compulsory tools, 1 adopt voluntary tools, and the remaining use mixed type tools. This indicates that mandatory and control-oriented policy tools have consistently been the preferred choice in Chinese LER. This conclusion aligns with the results of the previous tendency analysis.

Figure 6 shows the PMC surfaces of these 8 LER, which were drawn according to the PMC matrix. PMC-surface provides a more intuitive representation of the score for each dimension of each policy.

P1 is Livestock Pollution Prevention and Management Measures, with a PMC index of 3.86, ranking seventh and the level of policy assessment is acceptable. Among all variables, only policy nature (X_1) and policy priority (X_4) scored above the average. The comprehensive content of the policy is the advantage of P1, but as this policy is issued by a single environmental department, it possesses limited

authority (Xiong et al., 2023), leading to a lack of policy tools and guarantees.

P2 is the 12th Five-Year Plan for the Prevention and Control of Pollution from Livestock and Poultry Breeding, jointly released by the Ministry of Environmental Protection and the Ministry of Agriculture, has a PMC index of 6.36, and is classified as great. Each variable is not lower than the average. P2 is a long-term planning policy for China's twelfth five-year plan. It sets clear requirements for the goals and key tasks, and guarantees measures of livestock pollution prevention and control. It has been comprehensively deployed in various policy areas such as the environment, economy, society, and technology.

P3 is Regulations on the Prevention and Control of Pollution from Large-scale Livestock and Poultry Breeding. The PMC index of P3 is 6.65 ranking first among 8 policies, with the assessment level of Great. The score of X_2 (Policy release agency) is lower than the average. Despite being issued by a single institution, P3 is published by the State Council of PRC, which is the executive organ of the highest national authority. Therefore, as a regulation, P3 holds a high policy status and serves as the reference foundation for subsequent LERs. With full scores for X_4, X_5, and X_9, overall, P3 has comprehensive and complete policy content with abundant policy measures.

P4 is the Technical Guide for Demarcating Prohibited Breeding Areas for Livestock and Poultry Breeding, and the PMC-index is 4.26 with an Acceptable level and 6^{th} ranking. This policy is jointly released by the Ministry of Environmental Protection and the Ministry of Agriculture, involving multiple issuing institutions. Therefore, the X_2 value is above the average, but the other variables are below the average. This policy provides detailed explanations, clear guidance, and standardized requirements for the designation of prohibited breeding areas. It serves as an important guide for designing prohibited breeding areas. However, due to the policy's excessive targeting and relatively narrow focus, its PMC index is not high.

P5 is the Action Plan for The Utilization of Livestock and Poultry Manure (2017–2020), with a PMC index of 4.76, ranking fourth, and a policy consistency level of acceptable. This is a programmatic policy for a four-year period, aiming to accelerate the resource utilization of manure in China. Among the variables of P5, only X_3 and X_7 are above average, while the other variables are below average. In particular, the gaps between X_4 and X_5 and the average are slightly large, reflecting that P5 is relatively weak in terms of policy focus and function.

P6 is the Notice on Further Clarifying the Requirements for Returning Livestock Manure to Fields and Strengthening the Supervision of Breeding Pollution. With a PMC index of 3.81, it has the lowest score among the 8 LERs. Except for X_2 and

X_5, the scores of the other variables are below average. This is because this policy is intended to provide further supplements to the previous requirements regarding the utilization of manure for farmland, and compared to other policy texts, P6 has a shorter length, involves relatively single policy fields and entities, and provides relatively fewer policy measures.

P7 is Opinions on Promoting High-Quality Development of Animal Husbandry, with a PMC-index of 4.56, and the ranking is fifth, the level is Acceptable. This policy is a comprehensive policy for the all-round development of the livestock industry. The text also regulates environmental governance issues, making it involve a wide range of policy fields (X_7). From the perspective of the policy release agency (X_2), although this policy is issued by the State Council, it covers a wide range of areas, and there may be challenges in inter-departmental collaboration during policy implementation (Z. Li & Guo, 2022).

P8 is Guiding Opinions on Promoting the Construction of a Standard System for Resource Utilization of Livestock Manure. The PMC index is 5.49, and it gets a Great level with a ranking of third. This is a policy document jointly issued by multiple departments, with strong enforcement. Among the variables, only X_5 (policy function), X_7 (policy field), and X_9 (policy evaluation) are slightly below the average. As a recently released and instructive policy, its content indicates the Chinese government's commitment to manure management by promoting standardized and regulated utilization.

Table 5: Representative livestock environmental regulation policies

Item	Policy name	Release agency	Release time	Reason
P1	Livestock Pollution Prevention and Management Measures	State Environmental Protection Administration (abolished and reintegrated into the Ministry of Ecology and Environment)	2001.5	It is the earliest departmental regulation explicitly aimed at addressing environmental pollution issues in animal husbandry, and it is also the earliest government document proposing the establishment of animal and poultry protection zones (Jiang et al., 2023).
P2	The 12th Five-Year Plan for the Prevention and Control of Pollution from Livestock and Poultry Breeding	Ministry of Environment Protection (abolished and reintegrated into Ministry of Ecology and Environment), Ministry of Agriculture (abolished and reintegrated into Ministry of Agriculture and Rural Affairs)	2012.11	It is the first specialized plan dedicated to the prevention and control of pollution in livestock and poultry farming in China (R. Li, Shen, & Jin, 2015)

Item	Policy name	Release agency	Release time	Reason
P3	Regulations on the Prevention and Control of Pollution from Large-scale Livestock and Poultry Breeding	State Council	2013.12	It is the first set of policies and regulations in China specifically addressing environmental protection in the agricultural and rural sectors, marking the legalization and standardization of pollution management in China's livestock industry (Jiang et al., 2023).
P4	Technical Guide for Demarcating Prohibited Breeding Areas for Livestock and Poultry Breeding	Ministry of Environment Protection (abolished and reintegrated into Ministry of Ecology and Environment), Ministry of Agriculture (abolished and reintegrated into Ministry of Agriculture and Rural Affairs)	2016.10	Prohibiting breeding is an integral element in China's livestock environmental regulation (Wu, Xu, & Geng, 2022).
P5	Action Plan for The Utilization of Livestock and Poultry Manure (2017–2020)	Ministry of Agriculture (abolished and reintegrated into Ministry of Agriculture and Rural Affairs)	2017.8	The release of the policy announcement signifies that the level of environmental supervision in the livestock industry reached its peak during the "Thirteenth Five-Year Plan" period (D. Pan et al., 2023).
P6	Notice on Further Clarifying the Requirements for Returning Livestock Manure to Fields and Strengthening the Supervision of Breeding Pollution	Ministry of Agriculture and Rural Affairs, Ministry of Ecology and Environment	2020.6	It specifies the standards for the utilization of manure in farmland (J. Zhao & Liu, 2022).
P7	Opinions on Promoting High-Quality Development of Animal Husbandry	State Council	2020.9	It represents the top-level strategic deployment for promoting high-quality development of the livestock industry (Yu, Huang, & Wang, 2021).
P8	Guiding Opinions on Promoting the Construction of a Standard System for Resource Utilization of Livestock Manure	Standardization Administration, Ministry of Agriculture and Rural Affairs, Ministry of Ecology and Environment	2023.8	It marks the first national-level guidance on constructing a standard system specifically addressing comprehensive manure utilization throughout the entire supply chain (Yuran, 2023).

Table 6: The PMC-index and level of the 8 livestock environmental regulation policies

	P1	P2	P3	P4	P5	P6	P7	P8	Average
X_1	0.60	0.60	0.80	0.40	0.40	0.20	0.40	0.60	0.50
X_2	0.25	0.50	0.25	0.50	0.25	0.50	0.25	0.75	0.41
X_3	0.40	1.00	0.80	0.60	1.00	0.40	0.80	1.00	0.75
X_4	0.57	0.71	1.00	0.29	0.43	0.43	0.43	0.57	0.55
X_5	0.50	0.75	1.00	0.50	0.50	0.75	0.50	0.50	0.63
X_6	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
X_7	0.25	0.75	0.75	0.50	0.75	0.25	0.75	0.50	0.56
X_8	0.29	0.71	0.71	0.14	0.43	0.29	0.43	0.57	0.45
X_9	0.67	1.00	1.00	1.00	0.67	0.67	0.67	0.67	0.79
PMC	3.86	6.36	6.65	4.26	4.76	3.81	4.56	5.49	4.97
Rank	7	2	1	6	4	8	5	3	
Level	AC	GC	GC	AC	AC	AC	AC	GC	

Figure 5: Debra chart of representative livestock environmental regulation policy

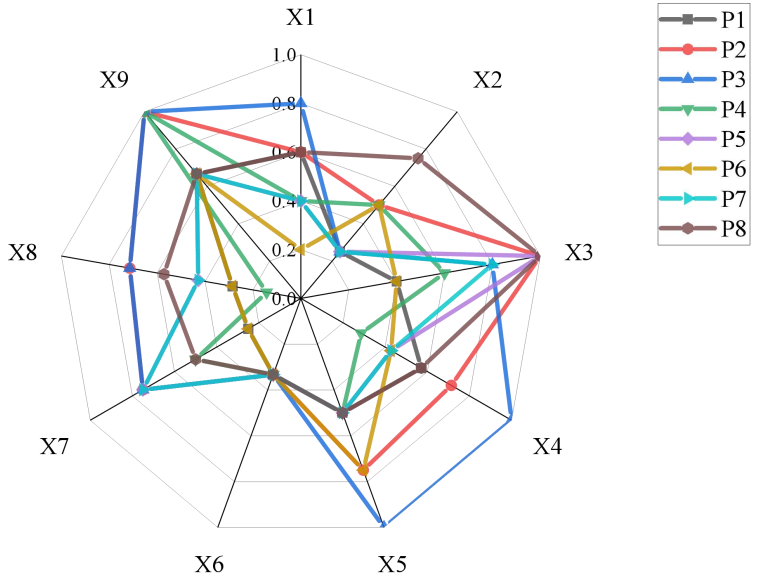
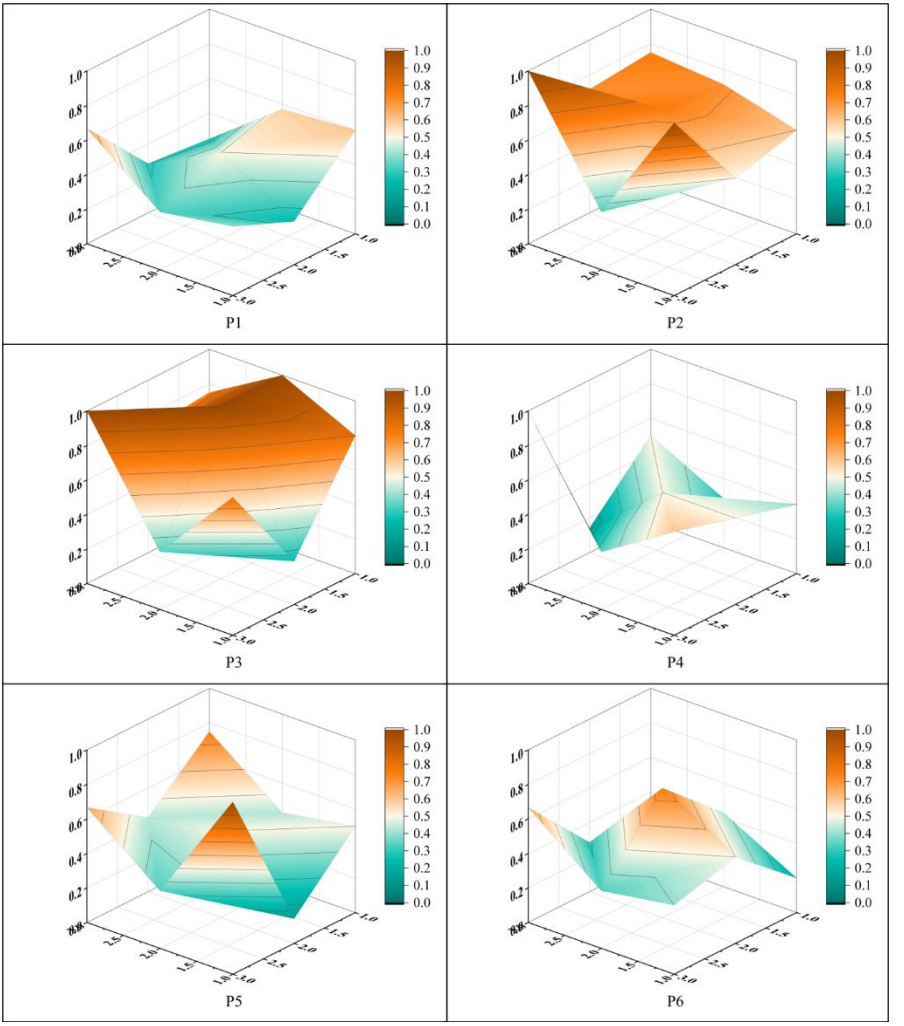
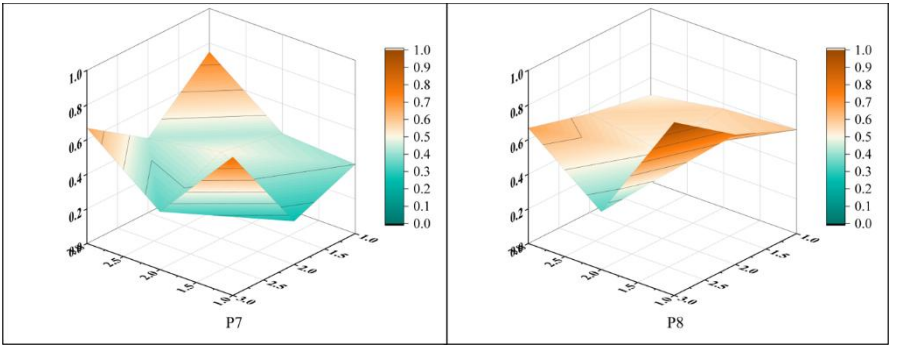


Figure 6: DThe PMC surfaces for P1–P8





5 Discussion

The previous analysis described China's LER policy tools preferences changing and identified shortcomings in key documents regarding policy nature, policy release agency, and policy measures.

In terms of the temporal evolution of policy tool preferences, early Chinese central LER policy tools primarily relied on command-control approaches, with later phases integrating incentive policies in combination. For instance, the changes in the policy of prohibited breeding areas exemplify this characteristic. The prohibited area is a control-oriented LER policy tool, referring to the prohibition of large-scale livestock farming within a designated area with the principle of distancing from populated zones, water sources, and natural reserves. However, due to the initial issuance of this directive by the central government only specifying principles for area demarcation without stipulating farm scale requirements, there exist discrepancies in the practices of local governments in livestock breeding environmental governance. For example, in Nanjing city hog farms with an annual output of more than 50 heads are considered as large-scale farms, while in Guangxi province, only hog farms with an annual output exceeding 500 heads would be relocated (Jin, Han, & Wu, 2018). This indicates that local governments have excessive power and operational space, leading to a one-size-fits-all approach. From 2015 to 2017, 90,000 prohibited breeding areas were established, covering 820,000 square kilometers of land, and over 260 thousand hog farms were closed (Bai et al., 2019; Mao et al., 2022). The overuse of this policy tool impacted livestock product supply. From 2014 to 2017, the annual slaughter of hogs decreased by 46 million (Bai et al., 2019), affecting overall societal welfare (Y. Shen, Nie, Liu, & Wang, 2023). Subsequently, the Chinese central government issued multiple statements in 2016 and 2018 opposing the "one-size-fits-all" enforcement practices (Mao et al., 2022), leading to adjustments in the application of control tools. From another perspective, it can be observed from the text term and environmental governance objectives, that the

early principle for livestock waste treatment was achieving standardized harmless emissions, which represents mandatory control-oriented constraints. However, the later direction of governance shifted towards the resource utilization of livestock waste. In 2013 the Regulations on the Prevention and Control of Pollution from Large-scale Livestock and Poultry Breeding stipulates that processed manure should be treated as a renewable resource that can be reused in agricultural production, rather than as environmental pollutants (Mao et al., 2022). This implies considering livestock waste not as pollution but as a resource that is valuable and can be traded and circulated through the market economy (Jin et al., 2018). The shift in conveyed ideas in the text indicates a gradual acceptance of administrative forms involving incentive tools in policy implementation. However, due to the long-term influences of the planned economy, China still prioritizes administrative commands rather than market economy measures in environmental governance (Carter & Mol, 2013; X. Li et al., 2019; Palmer, 1998). Therefore, although the Chinese government attempts to adopt incentive policies, the methods of incentives are relatively monotonous, primarily relying on subsidy-based financial arrangements. Overall, whether it's control-oriented or incentive-based policies, based on the central policy texts, it mainly relies on government administrative power for implementation. Market-based approaches such as pollution rights trading and the development of manure markets are underutilized, despite being proven effective in countries such as Belgium (Van der Straeten et al., 2011) and Italy (Peerlings, Arata, & Sckokai, 2013). Confronted with cyclical fluctuations in the livestock farming industry (Y. Shen et al., 2023), policies often lag behind, struggling to capture sensitive market changes. Therefore, in China, incentive-based policy tools can be experimented with to enable the market to play a more effective role.

The scores for policy nature are generally low in the policies under analysis. In China's LER policies, there are more plan, recommend, measure, and guidance types, while legislation is relatively fewer. This aligns with the overall state of environmental governance policies in China, as environmental legislation in China has been relatively late and limited in development (Mu, Bu, & Xue, 2014). Research has shown that environmental planning policies in China are more effective in promoting the achievement of environmental governance goals than environmental legislation (X. Li et al., 2019). Local governments are the practical implementers of environmental governance in China, and the promotion of local officials is determined by the central government (Chow, 2010; Ran, 2017). Compared to legislation, policies such as plans can better and more conveniently allow the central government to assess the performance of local governments through quantifiable targets, and also facilitate the allocation of relevant fiscal budgets according to the plan objectives. Therefore, local governments have stronger motivation and better outcomes in implementing such policies (X. Li et al., 2019; Mao et al., 2022). Thus, in China, these types of policies are more

frequently formulated rather than legislated. But there are also ambiguities, contradictions, and inconsistencies in the content and objectives of China's LER planning (Mao et al., 2022). For example, In the "Implementation Opinions on Winning the Tough Battle Against Agricultural Non-Point Source Pollution" issued in 2015, the Ministry of Agriculture proposed the goal of "by 2020, the proportion of large-scale livestock farms with supporting waste treatment facilities should exceed 75%", while the purpose displayed in "National Agricultural Sustainable Development Plan (2015-2030)" and "Nation Agricultural Modernization Plan (2016-2020)" was "the comprehensive utilization rate of livestock waste should reach 75%". Compared to these 2 goals it can be found that, on the one hand, the second target included farms of all scales, unlike the first. On the other hand, from the content, despite both sides proposing the 75% target, the installation of treatment facilities does not necessarily mean that all waste can be effectively and comprehensively used, reflecting the inconsistency in the goal of livestock farming environment governance. Therefore, the subsequent "Opinions on Accelerating the Utilization of Livestock and Poultry Farming Waste Resources" issued in 2017 further proposed a new plan, which is "to achieve a comprehensive utilization rate of over 75% for livestock and poultry manure nationwide, and to ensure that the rate of large-scale farms with supporting facilities exceeds 95%". Based on the above, in the future LER policy system, there should be a strengthening of the release of legislative policies, reinforcing incentive and constraint mechanisms for local governments in central policy texts. Additionally, when formulating plan policy texts, the comprehensiveness of objectives should be considered to better serve as a basis for local government practice.

From the results, it can be observed that the limited involvement of departments involved in policy formulation and implementation. The number of policy-issuing institutions reflects the level of attention to the issue and the degree of coordination in collaborative efforts among government departments (Xiong et al., 2023). The livestock industry is a cross-departmental industry. Pollution control in the livestock industry is not only an environmental issue but also relates to the development of related agricultural industries (Galloway et al., 2008), the rational utilization of agricultural resources (C. Zhang et al., 2019), and the livestock production industry chain (Jiang et al., 2023). The policies released by a single government department may suffer from the hidden issue of excessive specificity at the cost of comprehensiveness. Policies are communicated vertically within the department, and the horizontal expansion of policies is restricted, leading to a narrow scope of policy recipients. This is not conducive to the efficient advancement of practical work (Dong & Liu, 2020). Additionally, in the process of policy implementation, problems of responsibility evasion may occur due to unclear delineation of responsibilities. Hence, in addressing livestock environment governance issues, it is essential to highlight and specify the division of

responsibilities and tasks for each department in the text (Fan et al., 2023). Cooperation and coordination among government departments should also be enhanced.

Compared to other variables, the score of a policy measure is also relatively low, primarily due to insufficient utilization of law and regulation as well as talent support. In the case of developed countries and regions, the Nitrates Directive (ND), the Water Framework Directive, the National Emission Ceilings Directive (NECD) in the European Union (Van Grinsven, Tiktak, & Rougoor, 2016), as well as the Clean Water Action (CWA), the National Pollutant Discharge Elimination System (NPDES), and the Clean Air Act (CAA) in United States (Copeland, 2010; Frarey &Pratt, 1995) have provided institutional guarantees for local livestock environmental governance. In China, the legal system for livestock breeding, production, and other aspects is relatively sound, but there is still a lack of legal measures for pollution prevention and treatment. In the future, the Chinese government should enact more legislation measures for livestock manure management targeting various types of pollution, including nitrogen loss, air pollution, and water pollution. Talent support is similarly lacking in LER policy texts. Talent support for addressing environmental issues can be divided into external support and internal support. The former requires social entities to provide outsourcing services, while the latter involves strengthening the environmental management capabilities of livestock producers themselves. Currently, China lacks governmental institutions, and third parties to organize manure transported to plant farms, and the legal framework doesn't encourage the establishment of environmentally friendly nonstate actors (K. M. Zhang & Wen, 2008). Moreover, there is a shortage of manure-spreading machinery, manure nutrient recommendation systems, and related training to guide farmers and advisors in applying manure nutrients to crops (Wei et al., 2021). Hence, strengthening legal requirements, fostering institutions in the market, and enhancing farmer training may be more meaningful in the practice of livestock environment governance.

6 Conclusion

Through text mining of 56 LER policy documents, incorporating previous research, and establishing a PMC index model with secondary evaluation variables is performed. This research analyzes the consistency of LER policies released by the Chinese central government. It further delves into and compares 8 LER policy documents, using PMC surfaces to visually display the consistency across various dimensions. The conclusions drawn are as follows:

Generally, Chinese LER policies tend to favor command-control policy tools, but in recent years, incentive-based policy tools have been considered more frequent, making the selection of policy instruments more balanced.

The overall design of LER policies is reasonably sound, with the PMC index of the eight policies showing an upward trend, rising from 3.86 to 5.49. This indicates the Chinese government's emphasis on environmental issues and pollution control in the livestock and poultry industry.

Existing LER policies have considerable room for improvement. In terms of consistency levels, five policies are at an acceptable level, three are at a great level, but none reach a perfect level. Scores for indicators such as policy nature, policy release agency, and policy measure are relatively low.

Based on the analysis results and thorough exploration of China's LER policy content, the following aspects are considered to further policy improvement. Firstly, market-based policy tools should be strengthened to leverage the market's significant role in livestock environmental governance, allowing for more flexible governance measures and efficient resource allocation by the market. Secondly, it is crucial to strengthen and improve the construction of the legal system, particularly by clarifying and detailing governance objectives to avoid conflicts and contradictions. Additionally, clear task allocation and cooperation among departments are equally important, and cross-departmental management should be emphasized. Finally, farmers and institutions are the primary actors in livestock pollution control and manure management. Therefore, it is essential to strengthen cultivation and support them to ensure pollution control from the source.

7 Limitation

The scope of policies evaluated in this study only includes central-level documents and the local-level documents are not considered. Although central directives are nationwide, there are significant differences between regions in China, including variations in livestock quantity, structure, and animal breed selection. Particularly after the outbreak of African Swine Sever, the "Guiding Opinions on Strengthening the Prevention and Control Measures of African Swine Fever" restricted the inter-provincial transportation of hogs, exacerbating the differences in hog farming among different provinces in China (J. Liu et al., 2020). Naturally, hog farming is not the only exception. Within the national scope, significant differences exist in livestock production systems across regions (Xu, Ma, Yuan, Tian, & Zhao, 2023), inevitably leading to different policy focuses. Based on the above, analyzing local policies in the context of local industrial development, natural geography, and climatic conditions is also meaningful.

Therefore, future studies could consider exploring the emphasis of texts in different regions from a diverse perspective.

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