

DETERMINANTS OF DOMESTIC ANIMAL BIODIVERSITY DYNAMICS IN ROMANIA: AN ECONOMETRIC ANALYSIS OF ECONOMIC TRANSITION AND AGRICULTURAL POLICY EFFECTS

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Abstract

Domestic animal biodiversity represents a strategic component of food security and agricultural sustainability, yet its dynamics are strongly influenced by economic and institutional transformations. In Romania, the transition from a centrally planned economy to a market economy, the restructuring of agriculture, and the integration into the Common Agricultural Policy (CAP) have generated major structural changes, whose effects on livestock biodiversity have been insufficiently investigated from a quantitative perspective. This paper aims to econometrically analyze the determinants of domestic animal population dynamics in Romania, using time-series and panel data structured by species, in order to assess the impact of economic transitions, agricultural policies, and rural socio-economic changes. By introducing dummy variables associated with major structural breaks and estimating regression models, the study captures the differentiated effects of regime changes on livestock biodiversity. The results suggest that structural and species-specific factors play a more significant role than aggregate policy variables in explaining livestock population dynamics, while policy effects appear to be indirect and heterogeneous. These findings contribute to the existing literature by providing an empirical assessment of the relationship between economic processes and domestic animal biodiversity, offering analytical support for the design of public policies aimed at the conservation of animal genetic resources and the sustainable development of agriculture.

Keywords: domestic animal biodiversity, livestock population dynamics, economic transition, econometric analysis, Common Agricultural Policy (CAP), panel data

1. INTRODUCTION

Domestic animal biodiversity constitutes a fundamental pillar of agri-food systems, with direct implications for food security, resilience to climate change, and the economic sustainability of agriculture. Beyond its biological dimension, the diversity of domestic animal populations reflects a complex historical process shaped by economic, institutional, and social factors that influence both agricultural production structures and the use of genetic resources [1], [2]. In recent decades, research on domestic animal biodiversity has primarily focused on genetic diversity, breed classification, and the risks associated with agricultural intensification. However, limited attention has been given to the quantitative analysis of the relationship between systemic economic changes and livestock population dynamics, particularly in transition economies.

This gap is especially relevant in the case of Romania, where economic and institutional transformations have been rapid, profound, and often discontinuous.

The transition from a centrally planned economy to a market-based system has led to a substantial restructuring of Romanian agriculture, characterized by farm fragmentation, a reduction in livestock populations, increased production specialization, and a decline in traditional rural households. Subsequently, integration into the European Union and the implementation of the Common Agricultural Policy (CAP) introduced new mechanisms of support, regulation, and compliance, with potentially ambivalent effects on domestic animal biodiversity.

In this context, livestock population dynamics cannot be understood solely through biological factors, but require an integrated approach that captures the economic and institutional determinants of change. At the same time, the literature emphasizes that agricultural policies generate heterogeneous effects across farming systems, depending on structural characteristics such as farm size, production specialization, and access to subsidies [3]. Moreover, structural transformations have driven a shift from integrated crop-livestock systems toward more specialized production models, with important implications for sustainability and biodiversity [4]. These findings highlight the need for a multidimensional analytical framework that integrates economic, structural, and policy-related factors. The originality of this study lies in approaching domestic animal biodiversity from an econometric perspective, treating livestock population dynamics as the outcome of measurable economic and institutional processes. The paper proposes a quantitative analysis of the impact of economic transitions and agricultural policies on livestock biodiversity in Romania, using time-series and panel data models, as well as dummy variables to capture structural breaks associated with major regime changes. In addition, a bibliometric analysis conducted using VOSviewer supports the relevance of the selected research directions, highlighting the central role of agricultural policy, sustainability, and management in the existing literature.

This study aims to answer the following research question: How have economic transitions, agricultural restructuring, and public policies influenced the dynamics of domestic animal population in Romania?

By addressing this question, the paper contributes to extending the analytical framework of domestic animal biodiversity research, integrating the economic dimension into a field traditionally dominated by biological and descriptive approaches. At the same time, the results provide a solid empirical basis for the formulation of public policies aimed at the conservation of animal genetic resources and the sustainable development of Romanian agriculture.

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2. LITERATURE REVIEW

Animal biodiversity represents a fundamental component of a nation's natural capital, encompassing both domestic species integrated into agricultural production systems and wild species that sustain ecosystem balance. In the case of Romania, biodiversity is particularly significant due to the presence of valuable genetic resources and long-standing livestock traditions. At the same time, recent studies emphasize the importance of developing comprehensive databases and coherent policy frameworks to support conservation and sustainable development of animal genetic resources [5]. The dynamics of livestock populations and their relationship with agricultural policy have been widely addressed in the specialized literature, particularly in the context of European agricultural transformations. The livestock sector plays a complex and multidimensional role within economic and environmental systems. On the one hand, livestock production contributes significantly to food security, income generation, and rural development. On the other hand, it is associated with environmental pressures, including biodiversity loss and increased resource use [1].

Recent studies emphasize that the effects of agricultural policies on livestock systems are not uniform, but rather context-dependent, generating both positive and negative outcomes simultaneously [1]. This complexity is reflected in the uneven distribution of Common Agricultural Policy (CAP) direct payments across farming systems and regions. Empirical evidence shows that approximately 20% of farmers receive nearly 80% of total subsidies, indicating persistent structural inequalities in the allocation of support [3]. These disparities are largely explained by structural factors such as farm size, production specialization, and farmer characteristics. Larger farms and specific sectors, particularly cattle and arable farming, tend to benefit more from CAP support, while traditional and small-scale farming systems often experience limited access to subsidies. Although successive CAP reforms have aimed to promote a more equitable distribution of payments, their effects remain heterogeneous, suggesting that agricultural policies generate differentiated impacts across sectors and regions rather than uniform outcomes [3]. A key transformation in European agriculture has been the reform of the CAP, particularly the decoupling of subsidies from production. By removing the direct link between subsidies and output, farmers gained greater flexibility in their production decisions, leading to structural adjustments within the agricultural sector.

Livestock farming, which has traditionally been highly dependent on subsidies, has been particularly affected by these changes. In some cases, subsidies accounted for more than total farm income, highlighting the strong reliance of the sector on policy support. As a result, CAP reforms have contributed to a decline in livestock production, while also generating potential environmental benefits through reduced pressure on natural resources and ecosystems [6]. In parallel, structural and technological transformations have driven a shift from integrated crop-livestock systems toward more specialized and segregated production models. This transition has important implications for both environmental sustainability and biodiversity, as integrated systems are generally associated with improved soil quality, reduced pollution, and greater resilience. At the same time, national policy frameworks play a crucial role in shaping farmers' decisions by creating incentives or disincentives for different production systems, thereby influencing livestock population dynamics and agricultural diversity [4]. Recent studies highlight the concept of zoocultural biodiversity, emphasizing that livestock diversity is not only a biological phenomenon, but also a cultural and socio-economic one. Traditional livestock systems, local breeds, and rural practices play a fundamental role in maintaining biodiversity and ensuring food security. The decline of traditional agricultural systems and rural households contributes to the erosion of both genetic resources and associated cultural knowledge, increasing the vulnerability of agri-food systems [7]. This perspective supports the hypothesis that structural transformations in rural areas, particularly the decline of traditional households, may represent a key driver of biodiversity loss in livestock populations.

The role of agricultural policy reforms in shaping livestock production decisions has also been highlighted in empirical studies. CAP reforms significantly influence farmers' behavior, including herd size adjustments and long-term investment strategies. Evidence suggests that reductions in agricultural payments may lead to a decrease in herd size and production intensity, as well as an increased likelihood of farmers exiting the sector [8]. At the same time, agricultural policies have evolved to address multiple objectives, including income stabilization, environmental protection, and rural development, transforming the CAP into a complex framework that integrates economic and sustainability goals [9].

Another important strand of literature focuses on the sustainability of livestock systems. Studies emphasize that livestock production must balance economic performance with environmental constraints, highlighting the need for sustainable farming models adapted to regional conditions. Moreover, policy measures can generate trade-offs between productivity, environmental protection, and farm viability, requiring a multidimensional assessment of their impacts [2], [10].

From a structural perspective, the literature indicates a long-term decline in livestock populations across the European Union, driven by economic restructuring, technological change, and policy adjustments. This trend reflects broader transformations in agricultural systems and highlights the increasing importance of environmental and climate-related policies.

The evolution of EU agri-climate policy has intensified the pressure on the livestock sector to reduce emissions and adopt more sustainable practices [11].

At the microeconomic level, farmers' decision-making processes play a crucial role in shaping livestock dynamics. Empirical evidence shows that policy reforms, such as the abolition of milk quotas and the introduction of environmental regulations, significantly influence management decisions, including culling behavior and herd structure. These findings indicate that institutional changes can directly affect livestock survival rates and population dynamics [12].

Finally, several studies underline the importance of risk, adaptation, and resilience in livestock systems, particularly in the context of climate change and market volatility. These factors contribute to shaping long-term trends in livestock populations and highlight the need for adaptive policy frameworks.

Overall, the existing literature suggests that livestock population dynamics are the result of a complex interaction between economic transitions, structural changes in agriculture, and evolving policy frameworks. These findings support the hypothesis that agricultural policies play a decisive role in shaping livestock population dynamics, both at the macro level and through farm-level decision-making processes, and justify the use of an integrated econometric approach such as the one adopted in this study.

3. METHODOLOGY

A bibliometric analysis was conducted in order to identify the main research trends related to livestock population dynamics and agricultural policy. The data were collected from the Web of Science Core Collection using the search query "livestock population" and "agricultural policy", covering the period 2004-2024.

The resulting dataset was exported in plain text format, including full records and cited references, and subsequently processed using VOSviewer software (version 1.6.20). A co-occurrence analysis of keywords was performed, considering all keywords provided in the database. The minimum number of occurrences of a keyword was set to 3, ensuring a balance between relevance and network clarity. Out of a total of 456 identified keywords, 28 met the established threshold and were included in the analysis.

For each of these keywords, the total strength of co-occurrence links with other keywords was calculated, allowing the identification of the most significant conceptual relationships within the literature. The final network visualization highlights the main thematic clusters and their interconnections, providing a foundation for the selection of variables used in the econometric analysis.

To investigate the determinants of domestic animal population dynamics in Romania, a panel data regression model with fixed effects was estimated. The dataset consists of annual observations for seven categories of domestic animals (cattle, swine, sheep, goats, equines, poultry, and bee colonies) over the period 2004-2024.

The dependent variable is represented by the natural logarithm of the number of animals for each species, allowing for the interpretation of coefficients in relative terms.

The explanatory variables include both economic and institutional factors. Economic influences are captured through variables such as agricultural output, while institutional effects are introduced through a dummy variable reflecting Romania's accession to the European Union and the implementation of the Common Agricultural Policy (CAP). Dummy variables are used to capture policy shifts and structural breaks.

In addition, species-specific fixed effects are introduced through dummy variables in order to control for structural differences between animal categories. A time trend is also included to capture general temporal dynamics affecting all species.

Based on the research objectives, the following hypotheses are tested:

H1: The transition from a centrally planned economy to a market economy had a significant negative effect on domestic animal biodiversity;

H2: Agricultural intensification and production specialization reduce the diversity of animal populations;

H3: European agricultural policies (CAP) have had differentiated effects across species;

H4: Structural changes in rural areas, particularly the decline of traditional households, contribute significantly to the loss of local livestock breeds and domestic animal biodiversity.

The econometric specification of the model can be expressed as follows:

$$\ln(\text{POP}_{it}) = \alpha + \beta_1 \text{PAC}_{it} + \gamma_i + \varepsilon_{it}$$

where i denotes the animal species and t the time period, while γ_i captures species-specific fixed effects and ε_{it} represents the error term.

4. RESULTS AND DISCUSSIONS

The analysis of the keyword co-occurrence network reveals a structured thematic organization of the literature into several interconnected clusters.

The first cluster is centered around agricultural policy and livestock production, including keywords such as agricultural policy, policy, CAP reform, cattle, and beef, highlighting the strong link between policy frameworks and species-specific production systems.

The second cluster is dominated by terms such as management, agriculture, sustainability, and environment, indicating a focus on the organizational and environmental dimensions of livestock systems.

A third cluster groups keywords related to economic performance and policy instruments, including efficiency, performance, risk, payments, and decoupling, reflecting the importance of economic mechanisms in shaping agricultural outcomes.

The fourth cluster emphasizes adaptation and system-level responses, with keywords such as adaptation, farming systems, direct payments, and impact, suggesting a research focus on how agricultural systems respond to policy changes and external pressures.

Finally, the fifth cluster captures the broader socio-economic context, including terms such as livestock, poverty, trade, and agriculture, underlining the interaction between livestock production and wider economic and social challenges.

Overall, the keyword co-occurrence network highlights the interdisciplinary nature of literature, integrating policy, economic, environmental, and socio-economic perspectives. The central role of management and policy-related terms suggests that future research is increasingly oriented toward integrated approaches combining farm-level decision-making, sustainability, and policy design. In more detail, the network structure reveals several central nodes and thematic concentrations. At the center of the network lies the term management, indicating its pivotal role in connecting multiple research areas. This suggests that management practices represent a key integrative component linking policy, production systems, and sustainability concerns.

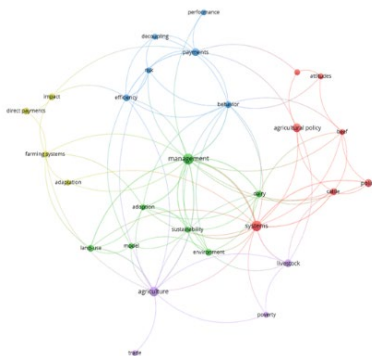


Figure 1. Keyword co-occurrence network for livestock population and agricultural policy literature (2004-2024)
Source: Own processing in VOSviewer based on Web of Science Core Collection data, using the keywords “livestock population” and “agricultural policy”, for the period 2004-2024

The central positioning of management suggests a growing focus on integrated approaches combining policy and sustainability. The overlay visualization highlights the temporal evolution of research topics, showing a shift from macroeconomic and policy-related themes toward more applied, sustainability-oriented approaches.

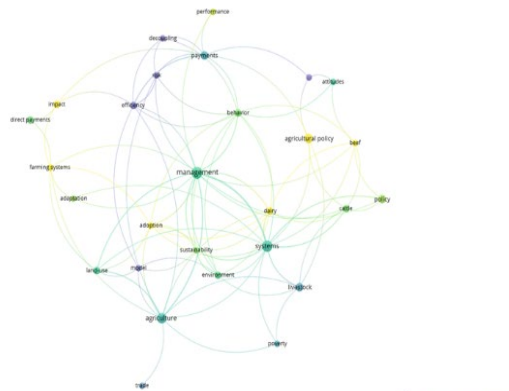


Figure 2. Temporal evolution of keyword co-occurrence in livestock population and agricultural policy research (2004-2024)

Source: Own processing in VOSviewer based on Web of Science Core Collection data, using the keywords “livestock population” and “agricultural policy”, for the period 2004-2024

The shift toward more recent themes centered on performance, impact, and sustainability reflects the increasing need for evidence-based policy evaluation in the livestock sector. The regression results indicate a high explanatory power of the model, with an R-squared value of approximately 0.98, suggesting that the included variables account for the vast majority of the variation in animal populations.

Regression Statistics									
Multiple R		0.988770147							
R Square		0.977666403							
Adjusted R Square		0.976541689							
Standard Error		0.23922259							
Observations		147							
ANOVA									
	df	SS	MS	F	Significance F				
Regression	7	348.2179805	49.74542579	869.2581578	2.1817E-111				
Residual	139	7.954615324	0.057227448						
Total	146	356.1725957							
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%	
Intercept	14.57784162	0.071140219	204.9170193	2.295E-174	14.43718476	14.71849847	14.43718476	14.71849847	
PAC	0.006845911	0.056385305	0.121413042	0.90353923	-0.104637858	0.118329681	-0.104637858	0.118329681	
Swine	0.799236822	0.073825694	10.82599806	3.45868E-20	0.653270304	0.94520334	0.653270304	0.94520334	
Sheep	1.455762384	0.073825694	19.71891224	4.17638E-42	1.309795866	1.601728902	1.309795866	1.601728902	
Goats	-0.583398447	0.073825694	-7.902378717	7.5446E-13	-0.729364965	-0.437431929	-0.729364965	-0.437431929	
Equines	-1.401918097	0.073825694	-18.98956878	1.9249E-40	-1.547884615	-1.255951579	-1.547884615	-1.255951579	
Poultry	3.601705022	0.073825694	48.78660558	2.47957E-89	3.455738504	3.74767154	3.455738504	3.74767154	
Bee colonies	-0.458278925	0.073825694	-6.206903027	5.84524E-09	-0.604195442	-0.312262407	-0.604195442	-0.312262407	

Figure 3. Econometric results of the fixed-effects model on domestic animal populations in Romania

Source: Author's calculations based on data from the National Institute of Statistics (INS), 2004-2024 (accessed on April 16, 2026)

Note: The dependent variable is the natural logarithm of animal populations. The model includes species fixed effects and a dummy variable capturing the post-EU accession period.

The coefficient associated with the PAC variable is positive but statistically insignificant, indicating that the accession to the European Union did not exert a statistically detectable effect on the overall dynamics of domestic animal populations during the analyzed period. This suggests that policy effects are indirect and mediated by structural factors. In contrast, the species-specific dummy variables reveal statistically significant differences across animal categories. Compared to the reference category (cattle), poultry and sheep exhibit significantly higher population levels, while goats, equines, and bee colonies display comparatively lower levels. These results highlight the existence of strong structural heterogeneity within the livestock sector, reflecting differences in production systems, economic relevance, and adaptability to market and policy changes. Given the lack of statistical significance of the PAC variable in the baseline specification, the analysis is further extended by incorporating additional economic and structural variables, in order to better capture the underlying drivers of livestock population dynamics. The extended econometric specification including the temporal trend variable is defined as follows:

$$\ln(\text{POP}_{it}) = \alpha + \beta_1 \text{PAC}_{it} + \beta_2 \text{TREND}_{it} + \gamma_i + \varepsilon_{it}$$

where:
 $\ln(\text{POP}_{it})$ represents the natural logarithm of the animal population for species i at time t ;

PAC_t is a dummy variable capturing the effect of Romania's accession to the European Union (equal to 1 for years from 2007 onwards and 0 otherwise);
TREND_t is a time trend variable capturing the general evolution of animal populations over the study period;
 γ_i represents species-specific fixed effects, introduced through dummy variables;
 ε_t is the error term.

In order to capture the temporal dynamics of livestock populations, a trend variable was introduced into the model. The estimated coefficient of the trend variable is negative, suggesting a general tendency of declining animal populations over time. However, the effect is not statistically significant, indicating that the downward trend is not sufficiently strong to be distinguished from random variation within the analyzed period.

Regression Statistics								
Multiple R	0.988951397							
R Square	0.978024866							
Adjusted R Square	0.976750945							
Standard Error	0.238153228							
Observations	147							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	8	348.3456552	43.5432069	767.728149	2.1892E-110			
Residual	138	7.826940514	0.05671696					
Total	146	356.1725957						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	14.59008755	0.071290979	204.6554526	2.9093E-173	14.44912365	14.73105146	14.44912365	14.73105146
PAC	0.071137079	0.070619422	1.007330231	0.315539104	-0.068498955	0.210773113	-0.068498955	0.210773113
Trend	-0.006122968	0.004080995	-1.500361749	0.135805155	-0.014192334	0.001946397	-0.014192334	0.001946397
Swine	0.799236822	0.073495682	10.87460924	2.80935E-20	0.65391355	0.944560094	0.65391355	0.944560094
Sheep	1.455762384	0.073495682	19.80745461	3.57477E-42	1.310439112	1.601085656	1.310439112	1.601085656
Goats	-0.583398447	0.073495682	-7.937860175	6.40122E-13	-0.728721719	-0.438075174	-0.728721719	-0.438075174
Equines	-1.401918097	0.073495682	-19.07483624	1.62916E-40	-1.547241369	-1.256594825	-1.547241369	-1.256594825
Poultry	3.601705022	0.073495682	49.00566847	3.68589E-89	3.45638175	3.747028294	3.45638175	3.747028294
Bee colonies	-0.458228925	0.073495682	-6.234773425	5.16342E-09	-0.603552197	-0.312905652	-0.603552197	-0.312905652

Figure 4. Econometric results of the extended model explaining domestic animal population dynamics in Romania

Source: Author's calculations based on data from the National Institute of Statistics (INS), 2004-2024 (accessed on April 16, 2026)

Note: The model includes species fixed effects and a time trend variable capturing temporal dynamics.

The PAC variable remains statistically insignificant even after controlling for temporal dynamics, suggesting that the effects of EU agricultural policies on livestock populations are not directly observable in the baseline specification of the model.

Overall, the results highlight that structural differences across animal species represent the main source of variation, while temporal and institutional factors appear to play a more limited role in explaining population dynamics.

Regression Statistics								
Multiple R	0.988961568							
R Square	0.978044984							
Adjusted R Square	0.976602683							
Standard Error	0.238911386							
Observations	147							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	9	348.3528206	38.70586896	678.1146464	5.8893E-109			
Residual	137	7.81977513	0.057078651					
Total	146	356.1725957						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	15.28470048	1.961773123	7.791268167	1.48156E-12	11.40542908	19.16397188	11.40542908	19.16397188
PAC	0.085439432	0.081537641	1.047852635	0.296551609	-0.075795644	0.246674508	-0.075795644	0.246674508
Trend	-0.002315293	0.011500143	-0.201327329	0.840741244	-0.025056036	0.020425449	-0.025056036	0.020425449
ln_Agri_GDP	-0.063020169	0.177867538	-0.354309558	0.72365166	-0.41474099	0.28870652	-0.41474099	0.28870652
Swine	0.799236822	0.073729655	10.84009991	3.7314E-20	0.653441502	0.945032142	0.653441502	0.945032142
Sheep	1.455762384	0.073729655	19.74459792	6.71335E-42	1.309967064	1.601557704	1.309967064	1.601557704
Goats	-0.583398447	0.073729655	-7.912670283	7.5995E-13	-0.729193767	-0.437603126	-0.729193767	-0.437603126
Equines	-1.401918097	0.073729655	-19.01430442	2.97897E-40	-1.547173417	-1.256122777	-1.547173417	-1.256122777
Poultry	3.601705022	0.073729655	48.85015458	1.49547E-88	3.455909702	3.747500342	3.455909702	3.747500342
Bee colonies	-0.458228925	0.073729655	-6.214980084	5.78355E-09	-0.604024245	-0.312433604	-0.604024245	-0.312433604

Figure 5. Fixed-effects panel regression results on livestock population dynamics in Romania

Source: Author's calculations based on data from the National Institute of Statistics (INS), 2004-2024 (accessed on April 16, 2026), and Eurostat (accessed on April 18, 2026)

Note: The dependent variable is the natural logarithm of animal populations. The model includes species fixed effects, a policy dummy (PAC), a time trend, and the logarithm of agricultural GDP

The estimation results indicate a very high explanatory power of the model, with an R-squared value close to 0.98. However, the coefficients associated with macroeconomic and institutional variables are not statistically significant. The PAC variable does not show a significant effect on livestock populations, suggesting that the impact of European agricultural policies is indirect or mediated by structural factors. Similarly, the time trend variable is not statistically significant, indicating the absence of a clear systematic trend in population dynamics. The economic variable, represented by agricultural GDP, also lacks statistical significance.

In contrast, species-specific fixed effects are highly significant, highlighting strong structural differences across animal categories. This suggests that livestock population dynamics are primarily driven by intrinsic characteristics of each species rather than by aggregate economic or policy variables.

5. CONCLUSIONS

This study provides an econometric assessment of the determinants of domestic animal population dynamics in Romania, within the context of economic transition, agricultural restructuring, and the implementation of the Common Agricultural Policy (CAP). By combining time-series and panel data approaches, the analysis captures both temporal and structural differences across species. The results indicate that livestock population dynamics are primarily driven by structural and species-specific factors, while the direct impact of aggregate policy variables remains limited. The CAP does not show a statistically significant effect, suggesting that policy influences are indirect and mediated by underlying structural characteristics.

Regarding the research hypotheses, the findings provide partial support. Hypothesis H1 is indirectly supported through the observed decline in livestock populations, while H2 is consistent with the importance of structural differences across species. Hypothesis H3 is only partially confirmed, as policy effects appear to be heterogeneous and not fully captured by aggregate indicators. The bibliometric analysis reinforces these conclusions by highlighting the central role of agricultural policy, management, and sustainability in the literature. Despite the robustness of the approach, the study has several limitations related to data availability, particularly regarding rural structural variables. Consequently, Hypothesis H4, concerning the decline of traditional households, could not be directly tested, although it remains conceptually relevant. Future research should incorporate additional structural and micro-level variables to better capture the socio-economic drivers of biodiversity loss. Overall, the study demonstrates that livestock population dynamics are shaped by a complex interaction of economic, structural, and institutional factors, providing a useful empirical basis for the development of sustainable agricultural policies.

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