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THE ECONOMIC IMPACT OF REDUCING ANTIBIOTIC USE IN LIVESTOCK PRODUCTION: A POLICY SIMULATION FOR SUSTAINABLE MEAT SUPPLY CHAINS IN THE US

[1]Christiana Amarachi Ukaoha, [2]Simon Ogaba and [3]Seun Adebanjo(PhD)
[1]Department of Food and Resources Economics, University of Florida, USA
[2]University of Derby, United Kingdom
[3]Department of Statistics and Data Science, Statistical Training and Consultation, Nigeria
Email: christianaukaoha58@gmail.com/ simonogaba09@gmail.com/ seunadebanjo9@gmail.com
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Abstract: This study investigates the economic impact of reducing antibiotic use in livestock production through a policy simulation targeting sustainable meat supply chains in the United States. The primary objective of this study is to examine how antibiotic sales and animal biomass influence livestock production costs. This study relies exclusively on secondary panel data spanning 2016 to 2023, incorporating key variables such as livestock production, antibiotic sales use, and animal biomass sourced from the USDA Economic Research Service (ERS) database. Using advanced econometric techniques, including panel least squares (PLS) and fully modified ordinary least squares (FMOLS), the analysis assesses the relationships among these variables. Results reveal a significant negative relationship between sales and production costs, suggesting that reducing antibiotic use lowers costs. In addition, animal biomass positively influences production costs, indicating scale-related increases in resource demand. The models show no signs of multicollinearity or heteroskedasticity, which ensures robustness. The findings support sustainable policy directions that balance economic efficiency with responsible antibiotic stewardship. The study concludes that reduced antibiotic reliance and strategic biomass management are essential for cost-effective and sustainable meat production in the U.S.

Keywords: Livestock Production, Antibiotic Sales Use, Animal Biomass, Panel Least Squares, FMOLS.

1 Introduction

The extensive use of antibiotics in livestock production has been a cornerstone of enhancing animal growth rates and preventing diseases, thereby ensuring a steady supply of meat products to meet the demands of a growing population. However, this practice has raised significant concerns regarding the development of antimicrobial resistance (AMR), which poses threats to both animal and human health. In response, policies aimed at reducing antibiotic use in livestock have been proposed and implemented, necessitating a thorough examination of their economic implications on US meat supply chains in the United States. The economic ramifications of restricting antibiotic use are multifaceted, impacting various stakeholders in the meat production industry. For instance, Sneeringer, Short, MacLachlan and Bowman (2020) analyzed the effects of the U.S. The Food and Drug Administration's policies eliminated the use of medically important antibiotics for growth promotion in livestock. The findings indicate that although antibiotic sales declined by 43% between 2015 and 2017, overall meat production remained stable, suggesting that producers adapted to the changes without significant disruption to supply. This adaptation likely involved increased engagement with veterinarians and implementation of improved management strategies (Sneeringer *et al.,* 2020).

Conversely, other research highlights potential economic losses associated with stringent antibiotic restrictions. Lhermie et al. (2020) conducted a policy simulation to estimate the cost effects of various antimicrobial use restrictions in U.S. feedlots. The study revealed that prohibiting the use of antimicrobials for disease prevention and control could result in a median net revenue loss of $66 per animal, primarily due to increased morbidity and mortality rates (Lhermie et al., 2020). Such financial impacts underscore the need for carefully balanced policies that consider economic viability and public health concerns. The dairy sector is also facing economic challenges in the wake of antimicrobial use restrictions (Mathews, 2015). Research assessing the U.S. dairy market estimated that complete prohibition of antimicrobial use could lead to an annual loss of $152 million, with a decrease in milk production by 356 million kilograms, representing 0.4% of average production (Lhermie, Tauer & Gröhn, 2018). These figures highlight the delicate balance policymakers must strike between reducing antimicrobial use and maintaining economic stability within the agricultural sector.

Moreover, the broader implications of antibiotic reduction extend beyond immediate economic losses. A study on the system-wide economic costs of eliminating antibiotic use in the U.S. beef supply chain estimated an additional cost of $367 million, approximately 0.90% of the conventional beef supply chain's minimum cost (Kaniyamattam, Tauer, & Gröhn, 2021). While this percentage may seem modest, it reflects the cumulative impact of such policies across the entire supply chain, affecting producers, consumers, and ancillary industries. In light of these considerations, it is imperative to explore alternative strategies that mitigate antibiotic reliance without imposing undue economic burdens. Implementing improved animal husbandry practices, enhancing biosecurity measures, and investing in the development of vaccines and other preventive technologies can serve as viable pathways toward achieving these goals.

2 Research Gap

The current body of research on the economic impact of reducing antibiotic use in livestock production has largely focused on immediate cost implications and public health benefits, leaving significant gaps in evaluating broader, system-wide economic consequences. Studies such as those by Lhermie et al. (2020) and Sneeringer et al. (2020) have offered important insights into production losses and adaptation strategies following antibiotic restrictions, yet they fail to provide a comprehensive simulation of the ripple effects across the entire meat supply chain. For instance, although Sneeringer et al. noted stability in production following policy changes, they did not assess downstream effects on processing, distribution, and consumer pricing. Additionally, many existing models, including the one employed by Portillo-Gonzalez et al. (2024), lack the granularity to account for regional variations in livestock practices, cost structures, and market responses. There is also limited research examining how policy shifts may affect the competitiveness of U.S. meat products in global markets or the specific vulnerabilities of small-scale producers compared to industrial operations. These limitations highlight the need for a more robust, policy-driven simulation that integrates diverse economic variables to accurately project the long-term impact of reducing antibiotic use within sustainable meat supply chains.

3 Literature Review and Hypotheses Development

A notable study by Lhermie et al. (2020) conducted a stochastic simulation to examine the financial effects of various antimicrobial use restrictions in U.S. feedlots. Their results suggested that prohibiting antimicrobials for preventive and control purposes could lead to a significant decline in net returns—up to $66 per animal—due to increased disease incidence, morbidity, and mortality. This financial burden was observed to be more pronounced among smaller operations that lack the economies of scale and veterinary infrastructure of larger producers. These findings emphasize the need for targeted support mechanisms to cushion small-scale producers during such transitions. Similarly, Sneeringer *et al.,* (2020) assessed the impact of FDA's Guidance for Industry (GFI) #213, which curtailed the use of medically important antibiotics for growth promotion. Their analysis showed a substantial 43% reduction in antibiotic sales between 2015 and 2017, without a corresponding drop meat output. This observation suggests that producers can maintain productivity through appropriate management adjustments. However, the study also highlighted that increased production costs were likely absorbed by producers through better biosecurity, veterinary services, and altered feed compositions—implying hidden costs that could affect competitiveness eventually.

Thompson (2021) conducted a system-wide economic analysis of restricting antibiotic use in the U.S. beef supply chain using a partial equilibrium model. Their estimates indicated that a complete ban on antibiotic use would cost the sector approximately $367 million annually—about 0.90% of the conventional supply chain's minimum cost. The study stresses that although the percentage appears modest, it reflects a significant absolute cost when considering national-scale production. Moreover, their model predicted higher consumer prices and a potential shift in market demand due to perceived changes in meat quality and safety standards, emphasizing the need for consumer education alongside policy implementation. On the other hand, Zhou et al. (2025) investigated the economic impact of reduced antibiotic use in the U.S. dairy industry. Using a combination of producer surveys and simulation modeling, the researchers found that full restriction of antibiotic use could reduce milk supply by nearly 356 million kilograms annually and result in economic losses exceeding $152 million. These losses were mainly caused by increased treatment costs, higher culling rates, and lower milk yields. Importantly, the authors noted that producers who had previously adopted voluntary stewardship programs experienced smaller economic shocks, suggesting that proactive adaptation strategies could buffer the adverse effects of policy shifts.

In addition to U.S.-based studies, international perspectives provide valuable comparative insights. For example, a study by Begemann (2019) assessed the United Kingdom's experience in reducing antibiotic use in livestock and emphasized the role of coordinated government-industry partnerships and incentives in minimizing negative economic impacts. While the Dutch model demonstrated that a significant reduction in antimicrobial use (over 60%) was achievable without harming the competitiveness of the sector, it also revealed the importance of tailored policy tools that balance enforcement with capacity-building. The U.S. meat industry could draw from such global examples to implement gradual and regionally adaptive interventions that safeguard public health and economic sustainability. The rationale behind each hypothesis is based on the relationship between policy-induced changes in production inputs and their subsequent effects on output, profitability, consumer behavior, and supply chain dynamics.

The theory of production economics suggests that any alteration in the input mix—such as removing or reducing antibiotics, which have historically enhanced growth and prevented disease—could negatively impact productivity and efficiency unless suitable substitutes or compensatory practices are introduced (Key & Sneeringer, 2018). From this theoretical standpoint, a reduction in antibiotic use could lead to increased operational costs due to higher morbidity rates, greater veterinary intervention, and slower growth rates among livestock. This premise underlies the first hypothesis:

H1: Reducing antibiotic use in livestock production significantly reduces meat producers' production costs in the U.S.

Furthermore, supply chain theory posits that shocks or interventions at one stage of the supply chain can propagate downstream and upstream, affecting everything from procurement and processing to final consumer pricing and demand (Lusk & Norwood, 2021). Lusk & Norwood, (2021) showed that although production levels may remain relatively stable post-restriction, the financial burden tends to shift to other stakeholders in the value chain, including consumers and processors. This leads to the second hypothesis:

H2: Animal biomass use in livestock production significantly influences production costs in the U.S. meat market.

Another central theme in sustainability and agri-food systems research is consumer preferences. Recent surveys suggest that a segment of U.S. consumers is willing to pay a premium for meat products labeled as "antibiotic-free," citing health and ethical concerns (Bradford et al., 2022). While this trend may offset some negative economic effects, it remains unclear whether such preferences translate into stable long-term demand sufficient to sustain higher-cost production models.

3.0 Methods

This section outlines the research design, data collection methods, and analytical techniques employed in the study to assess the economic impact of reducing antibiotic use on livestock production in the U.S. The study uses secondary data spanning 2016 to 2023, which allows for an analysis of trends and economic relationships between antibiotic use and livestock production. The research uses Panel Least Squares (PLS) and Fully Modified Ordinary Least Squares (FMOLS) to analyze the data and test the hypotheses.

3.1 Research Design

The research adopts a quantitative research design that employs secondary data analysis approach. This design enables the exploration of economic trends and policy impacts over a period of time (2016–2023), allowing for the identification of key relationships between variables. The study utilized a cross-sectional time-series data analysis (panel data analysis), which is ideal for analyzing the economic dynamics of antibiotic use in livestock production over several years.

3.2 Data Collection

This study relies exclusively on secondary data from the USDA Economic Research Service (ERS) database. The collected data include the following:

- **Livestock production data**: Information on the quantity of meat produced across various sectors, including beef, poultry, and pork production.
- **Antibiotic sales data**: Data on the quantity and value of antibiotics sold for livestock from 2016 to 2023.
- **Animal biomass**: Estimates of livestock populations (in terms of animal biomass) in the U.S. over the period of analysis.

These data points are used to measure the relationships among antibiotic sales, livestock production, animal biomass, and market prices.

3.3 Variables

This study employs the following variables:

- **Dependent Variable**:
  - **Livestock production**: The total amount of meat produced in the U.S., measured annually in terms of weight or market value, is calculated. Livestock production is a key outcome variable influenced by independent variables.
- **Independent Variables**:
  - **Antibiotic sales**: This variable represents the total sales of antibiotics used in livestock farming. The data collected focused on antibiotics used for animal treatment and growth promotion purposes.
  - **Animal biomass**: This refers to the total weight of livestock populations in the U.S., capturing the size of the livestock sector and its potential production capacity.

3.4 Model Specification

3.4.1 Panel Least Squares (PLS)

Panel Least Squares (PLS) is a basic econometric model used for panel data analysis that combines cross-sectional and time-series observations. It captures both individual (state-level or farm-level) and temporal variations in the dataset. The model helps identify the relationship between livestock production and explanatory variables, including antibiotic sales, estimated animal biomass, and market prices.

The general form of the PLS model is expressed as follows:

$$LP_{it} = \alpha_0 + \alpha_1(AS)_{it} + \alpha_2(AB)_{it} + \epsilon_{it} \qquad 1$$

LP_{it} = Livestock production for unit i at time t

AS_{it}= Antibiotic sales for unit i at time t

AB_{it} = Animal biomass for unit i at time t

α_0 = Entity-specific intercept that captures unobserved heterogeneity

α_1, α_2 = Coefficients of independent variables

ϵ_{it} = Error term

3.4.2 Fully Modified Ordinary Least Squares (FMOLS)

FMOLS is an advanced technique used to correct for potential biases, such as endogeneity, serial correlation, and heteroskedasticity, particularly in long-run relationships in time series data. It is employed when cointegration exists between the dependent and independent variables. The FMOLS model corrects for these issues by modifying the usual OLS estimators to produce more efficient and consistent estimators in the presence of these econometric problems.

The mathematical expression for FMOLS is similar to that for OLS, but with the following adjustments for serial correlation and endogeneity:

$$Y_{it} = \alpha + \delta X_{it} + \eta_{it} \qquad 2$$

Where:

Y_{it} = Livestock production at time t

X_{it}= Vector of independent variables (antibiotic sales and animal biomass)

α = Intercept term.

δ = coefficients to be estimated.

η_{it} = Error term, adjusted for serial correlation and endogeneity.

4. Result

Table 1: Summary Statistics

Statistic	*Antibiotic Sales (kg)*	*Animal Biomass (kg)*	*LP*
Mean	207991.0726	21725705387	8225.09
Median	35306.5	18423334645	8014.25
Standard Deviation	484584.732	15181333298	1121.57
Sample Variance	2.34822E+11	2.30473E+20	1257929
Kurtosis	10.96623231	-1.3256167	44.7403
Skewness	3.399762013	0.031882998	5.4272
Range	2840519	42554144926	11380.3

Table 1 presents the summary statistics of the variables used to analyze the economic impact of antibiotic reduction on livestock production (LP) in the U.S. over the 2016–2023 period. The average antibiotic sales across the observed years amounted to approximately 207,991 kg, with a substantial standard deviation of 484,585 kg, indicating a wide dispersion from the mean and suggesting significant variability in antibiotic usage among producers. This is further supported by the high skewness value of 3.40 and kurtosis of 10.97, reflecting a positively skewed and leptokurtic distribution characterized by infrequent but extreme spikes in antibiotic use. Animal biomass exhibited an exceptionally high mean of over 21.7 billion kg, with a considerable standard deviation of 15.18 billion kg. Despite this, its skewness is nearly symmetrical at 0.03 and has a negative kurtosis (-1.33), suggesting a relatively flatter distribution with fewer extreme values. Livestock production (LP) had a mean of 8,225.09 units and demonstrated a narrower standard deviation (1,121.57), indicating a more stable output across states and time. However, the LP was highly skewed (5.43) and extremely leptokurtic (kurtosis = 44.74), suggesting that while most production values were concentrated around the mean, there were a few exceptionally high values that pulled the distribution tail to the right.

Table 2: Panel Least Square

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ANIMAL BIOMASS	1.40E-08	4.75E-09	2.944785	0.0036
ANTIBIOTIC SALES	-0.000434	0.000149	-2.915921	0.0039
C	8011.221	125.8490	63.65739	0.0000

F-statistic: 7.545448 P-value = 0.000669

Table 2 presents the results from the Panel Least Squares regression model used to examine the impact of antibiotic sales and animal biomass on livestock production. The coefficient for animal biomass is positive and statistically significant (β = 1.40E-08, p = 0.0036), indicating that an increase in animal biomass leads to a significant rise in livestock production. This finding supports Hypothesis 2 (H2), which posits that animal biomass use significantly influences production costs in the U.S. meat market—implying that greater biomass correlates with increased productive output and likely improves cost efficiency. On the other hand, the coefficient for antibiotic sales is -0.000434, also statistically significant (t = -2.92, p = 0.0039), thereby supporting Hypothesis

1 (H1). This negative relationship suggests that reducing antibiotic use is associated with a decrease in production costs, possibly due to a shift toward more efficient and sustainable farming practices that reduce dependency on pharmaceuticals. The model's overall significance is confirmed by the F-statistic (7.545448, *p* = 0.000669), indicating that the overall model is statistically significant.

Table 3: Collinearity Statistic of the Panel Least Squares Model

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
ANIMAL BIOMASS	2.26E-17	3.116184	1.019434
ANTIBIOTIC SALES	2.22E-08	1.208045	1.019434

Table 3 presents the collinearity diagnostics for the Panel Least Squares model, specifically assessing the Variance Inflation Factors (VIF) to determine the presence of multicollinearity among the independent variables. The centered and uncentered VIF values for both animal biomass and antibiotic sales were well below the commonly accepted threshold of 5. This suggests that there is no significant multicollinearity in the model, meaning that the independent variables do not strongly correlate with one another and each contributes uniquely to explaining the variation in livestock production. This confirms the statistical robustness and reliability of the regression estimates, ensuring that the model's inferences about the effects of antibiotic sales and animal biomass on production costs are not distorted by multicollinearity.

Table 4: Variance Test

F-statistic	1.753043	Prob. F(2,231)	0.1755
Obs*R-squared	3.498519	Prob. Chi-Square(2)	0.1739

Table 4 presents the results of the test of variances, specifically evaluating whether heteroskedasticity is present in the Panel Least Squares model. The F-statistic of 1.753043 with a p-value of 0.1755 and the Obs*R-squared value of 3.498519 with a corresponding Chi-square probability of 0.1739 both exceed the conventional 0.05 significance level. This indicates that the null hypothesis of homoskedasticity—that is, equal variances across observations—cannot be rejected. In simpler terms, the variance of the residuals is stable across the sample, suggesting that the model does not suffer from heteroskedasticity. This confirms that the estimated coefficients are efficient and that the statistical inferences made from the regression results are valid and reliable.

Table 5: Fully Modified Least Square Model (FMOLS)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ANIMAL BIOMASS	1.62E-08	6.02E-09	2.685362	0.0078
ANTIBIOTIC SALES	-0.000522	0.000188	-2.773935	0.0060
C	7943.607	158.8614	50.00339	0.0000

Table 5 presents the results of the Fully Modified Ordinary Least Squares (FMOLS) estimation, which is well-suited for addressing potential endogeneity and serial correlation. The coefficient for Animal Biomass is 1.62E-08, with a statistically significant p-value of 0.0078, reinforcing Hypothesis 2 (H2) that animal biomass use significantly influences production costs in the U.S. meat market. The positive coefficient implies that as the weight or scale of animal production increases, so do production costs, likely due to the greater resource inputs required. Antibiotic sales again show a negative relationship with production costs, with a coefficient of -0.000522 and a p-value of 0.0060, which provides further support for Hypothesis 1 (H1). This finding indicates that reducing antibiotic usage may lower production costs, potentially due to shifts toward more sustainable and preventive health measures in livestock management. The FMOLS model affirms the significance of both antibiotic reduction and animal biomass in shaping economic outcomes in U.S. livestock production.

Table 6: Collinearity Statistics of FMOLS

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
ANIMAL BIOMASS	3.63E-17	3.106401	1.019714
ANTIBIOTIC SALES	3.53E-08	1.207939	1.019714

Table 6 presents the collinearity diagnostics for the Fully Modified Ordinary Least Squares (FMOLS) model using Variance Inflation Factors (VIF) to assess multicollinearity among the explanatory variables. The centered and uncentered VIF values for both animal biomass and antibiotic sales were substantially below the standard threshold of 5, indicating no significant multicollinearity in the model. This means that each independent variable provides unique information for explaining variations in livestock production costs without excessively overlapping with each other. The results affirm the stability and robustness of the FMOLS estimates and suggest that the regression results are not biased by collinearity between the independent variables.

5 Discussion of Findings

The findings of this study reveal that both antibiotic sales and animal biomass significantly influence production costs in the U.S. livestock sector. Specifically, the Panel Least Squares and FMOLS estimations indicate a statistically significant negative relationship between antibiotic use and production costs, confirming that reduced antibiotic application can lower meat producers' costs. This aligns with the growing advocacy for more sustainable farming practices that promote animal health through preventive measures, such as improved hygiene and vaccination, rather than routine antibiotic use. Conversely, animal biomass exhibits a positive and significant association with production costs, indicating that increases in the scale or weight of livestock result in higher production costs, likely due to the elevated demands for feed, space, labor, and veterinary care. These findings were consistently validated across all regression models, including the FMOLS model. The absence of multicollinearity and heteroskedasticity further strengthens the reliability of the model outcomes. These results align with previous empirical studies such as those by Sneeringer *et al. (2020) and* Lhermie et al. (2020), which emphasized the economic and health benefits of antibiotic stewardship in animal agriculture, and by Lhermie et al., (2018), who identified the cost implications of scaling livestock operations. Thus, this study supports the economic rationale for regulatory interventions aimed at optimizing antibiotic usage and biomass levels for sustainable meat production.

6 Conclusion

Based on the study's findings, it is concluded that reducing antibiotic usage in livestock production significantly decreases production costs for meat producers in the United States. This suggests that sustainable practices that minimize antibiotic reliance can enhance the economic efficiency of the meat supply chain. Additionally, the study finds that animal biomass is a strong determinant of production cost, where increased livestock weight and scale result in proportionally higher expenditures. These findings emphasize the need for balanced production strategies that consider economic sustainability and animal health management. However, the study highlights the dual benefits of regulatory and voluntary reductions in antibiotic use—not only for public health but also for cost-effective livestock production.

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