



The SEM-PLS Model of Post-FMD Farmer Welfare in Indonesia: Integration of Social, Economic, and Psychological Factors

Ananta Winendra Surya Kusuma

Department of Livestock Socio-Economics, Faculty of Animal Science,
Brawijaya University

Jaisy Aghniarahim Putritamara

Department of Livestock Socio-Economics, Faculty of Animal Science,
Brawijaya University

Rofiatin Annisa'

Department of Livestock Socio-Economics, Faculty of Animal Science,
Brawijaya University

Address: Jl. Veteran, Ketawanggede, Lowokwaru District, Malang City, East Java
Corresponding author: jaisyap@ub.ac.id

Abstract. *The Foot-and-Mouth Disease (FMD) outbreak has inflicted severe multidimensional disruptions on dairy farming communities, yet limited research has systematically examined how social, economic, and psychological impacts collectively shape farmer welfare in post-outbreak contexts, particularly in developing countries. This study aims to investigate the simultaneous effects of social, economic, and psychological impacts on the welfare of dairy farmers following the FMD outbreak in Indonesia, and to extend theoretical frameworks of welfare and resilience to the context of livestock disease crises. A quantitative survey was conducted with 150 dairy farmers in Pujon District, Malang Regency—one of the areas most severely affected by the 2022 FMD outbreak. Data were collected using structured questionnaires and analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS 4. The measurement model results was assessed for reliability and validity, while the structural model tested the hypothesized relationships. All three impact dimensions demonstrated significant positive effects on farmer welfare: social impact ($\beta = 0.640$, $t = 4.431$, $p < 0.001$), economic impact ($\beta = 0.635$, $t = 4.487$, $p < 0.001$), and psychological impact ($\beta = 0.647$, $t = 4.143$, $p < 0.001$). The model explained 95.5% of the variance in farmer welfare (R^2 adjusted = 0.955), indicating exceptional explanatory power. Factor loadings revealed that mutual assistance (0.990), loss of assets (0.986), and business insecurity (0.981) were the strongest indicators of social, economic, and psychological impacts, respectively. Farmer welfare in post-FMD contexts emerges from the synergistic interplay of social solidarity, economic pragmatism, and psychological resilience. The findings extend welfare utility and post-traumatic growth theories to livestock disease settings and provide evidence-based foundations for integrated post-disaster interventions targeting smallholder farmers in developing countries.*

Keywords: *Dairy farmer welfare, Multidimensional impacts, Farmer resilience, Foot-and-Mouth Disease (FMD), Indonesia*

INTRODUCTION

The Foot-and-Mouth Disease (FMD) outbreak that has hit various regions and countries such as Nigeria, Japan, Ethiopia, and Indonesia (Brito et al., 2017) has had a significant impact on the welfare of dairy farmers, both socially, economically, and psychologically. Globally, as in Nigeria, Japan, and Ethiopia, economic losses due to FMD are estimated to reach USD 6.5–21 billion per year, including lost production and vaccination costs (Knight-Jones & Rushton, 2013). In Indonesia, the average loss per farmer reached around 46 million rupiah one year after the FMD outbreak, and production decreased by around 39.75% or fell to 18.31 liters per day (Salsabilah et al., 2024). In developing countries such as Nigeria and Mongolia, the impact of FMD on farmers is very significant, ranging from a decline in milk production, increased medical costs, to being forced to sell livestock below market prices to meet their daily needs (Zewdie et al., 2023). This decline in income and disruption to the fulfillment of farmers' basic needs is relevant to the theory of welfare utility and perceived losses in livestock investment (Govindaraj et al., 2017; McElwain & Thumbi, 2017).

In social terms, the FMD outbreak resulted in restrictions on livestock movement and reduced interaction with the farming community, which was also felt by farmers in Nigeria (Alhaji et al., 2020). There has been a decline in production, obstacles to livestock sales, and food security or food needs have also been felt by dairy farmers affected by the FMD outbreak (van Andel et al., 2020). FMD also triggers disruption of social interaction and a sense of loss of social ties (Cleaveland et al., 2001). One tangible consequence is the loss of trust in authorities and even fellow farmers, a phenomenon that persists for up to 18 months after an outbreak (Cleaveland et al., 2001). This results in a decline in solidarity and mutual assistance, such as cooperation in caring for farmers or restoring livestock businesses (Crimes & Enticott, 2019).

Psychologically, in Ethiopia, farmers experience stress, depression, even divorce and the risk of suicide due to the economic and social impacts caused by the FMD outbreak (Zewdie et al., 2023). A study in the Netherlands, which surveyed 661 farmers over a period of 6-8 months using the Impact of Event Scale (IES), showed that around 50% of farmers experienced symptoms of post-traumatic stress disorder (PTSD) such as intrusion and avoidance (Olf et al., 2005). (Elhai et al., 2004), as well as stress and depression due to mass culling policies (Van Haaften et al., 2004). Similar findings were also reported in the United Kingdom, with psychological morbidity rates reaching 73% (Mort et al., 2005). In Kenya, the FMD outbreak caused a 16.1% decline in milk production, an increase in the incidence of mastitis from 5.4% to 21.5%, and an increase in livestock culling from 0.59%

to 3.8% (Lewis et al., 2023). In Japan, farmers experienced mental stress due to livestock loss (Hibi et al., 2015). FMD caused deep emotional distress among farmers, who were concerned about the condition of their livestock (Putra et al., 2024).

LITERATURE REVIEW

Foot-and-Mouth Disease (FMD) is a highly contagious transboundary animal disease that significantly disrupts livestock production systems and farmer livelihoods worldwide. The disease affects cloven-hoofed animals and leads to severe productivity losses, particularly in dairy farming systems where milk production is a primary income source. Globally, FMD has been reported in various countries such as Nigeria, Japan, Ethiopia, and Indonesia, with economic losses estimated at USD 6.5–21 billion annually due to decreased production, control measures, and vaccination costs (Knight-Jones & Rushton, 2013; Brito et al., 2017). In Indonesia, the 2022 FMD outbreak caused substantial financial losses among dairy farmers, including decreased milk production and increased operational costs, thereby directly affecting farmer welfare .

Farmer welfare is a multidimensional concept encompassing economic stability, social well-being, and psychological conditions. From an economic perspective, FMD leads to decreased income, increased veterinary expenses, livestock mortality, and forced sales of animals at lower prices (Govindaraj et al., 2017). These economic shocks reduce farmers' ability to meet basic needs and threaten the sustainability of their farming enterprises. Studies have shown that declines in milk production and increased disease management costs are key determinants of financial vulnerability among dairy farmers affected by FMD outbreaks .

Social impacts of FMD are equally significant, as disease outbreaks often result in movement restrictions, reduced market access, and disruptions in farmer networks. These conditions weaken social cohesion and reduce cooperation among farmers, which is crucial for collective action in livestock management (Cleaveland et al., 2001; Crimes & Enticott, 2019). Reduced trust among farmers and between farmers and authorities has also been observed, leading to long-term declines in social capital and community resilience. In affected regions, diminished mutual

assistance and farmer group activity hinder recovery processes and limit the effectiveness of collective disease control strategies .

Psychologically, FMD outbreaks impose considerable stress on farmers due to uncertainty, financial loss, and emotional attachment to livestock. Previous studies have documented increased levels of stress, anxiety, depression, and even post-traumatic stress disorder (PTSD) among farmers following disease outbreaks (Olf et al., 2005; Van Haaften et al., 2004). In severe cases, prolonged psychological distress has been linked to social problems such as family conflict and reduced quality of life. Emotional responses to livestock loss and business instability further exacerbate mental health challenges, particularly in smallholder farming systems where livestock represents both economic and cultural assets .

Theoretical frameworks such as welfare utility theory and resilience theory provide important lenses for understanding how farmers respond to multidimensional shocks. Welfare utility theory emphasizes how perceived losses and changes in income affect subjective well-being, while resilience theory highlights the capacity of individuals and communities to adapt and recover from disturbances. In the context of livestock disease outbreaks, farmer welfare is not solely determined by economic recovery but also by the ability to maintain social support networks and psychological stability.

Despite extensive studies on the economic, social, and psychological impacts of FMD, most previous research has examined these dimensions separately. Limited studies have integrated these factors into a comprehensive analytical framework that explains their simultaneous influence on farmer welfare. Recent approaches using Structural Equation Modeling (SEM), particularly Partial Least Squares (PLS-SEM), allow for the analysis of complex relationships among latent variables and provide a more holistic understanding of welfare dynamics (Hair et al., 2014). However, empirical applications of such integrative models in the context of post-FMD recovery, especially in developing countries like Indonesia, remain scarce.

Therefore, there is a critical research gap in understanding how social, economic, and psychological impacts interact synergistically to shape farmer welfare in post-outbreak conditions. A more comprehensive evaluation that

simultaneously incorporates these multidimensional factors is needed to capture the complexity of farmer responses and to inform more effective, integrated policy interventions. This study addresses this gap by employing a PLS-SEM approach to analyze the combined effects of social solidarity, economic adaptation, and psychological resilience on the welfare of dairy farmers affected by FMD in Indonesia

RESEARCH METHODS

This study was conducted in Pujon District, Malang Regency, East Java. The location was deliberately chosen because Pujon is one of the main dairy cattle centers in Indonesia, with a large livestock population. Pujon District was chosen as the research location because it is one of the areas with a high number of FMD cases in East Java. In 2022, 7,322 dairy cows were exposed to FMD and 373 dairy cows died from FMD (BPS, 2024). This study used the multistage random sampling technique, which was conducted by randomly and gradually sampling the population by grouping it into several groups, then randomly selecting samples from each group (Singh et al., 2019). The study sampled 150 farmers from 1,450 farmers affected by PMK (BPS, 2024). This study was conducted from July to October 2025..

The analysis method used in this study is quantitative analysis, with data in the form of numbers calculated statistically based on questionnaire responses from the sample taken, and using the SEM-PLS method (Structural Equation Modeling–Partial Least Squares) because this data analysis approach covers a number of latent constructs with complex indicators and simultaneous direct interactions (Hair et al., 2014).

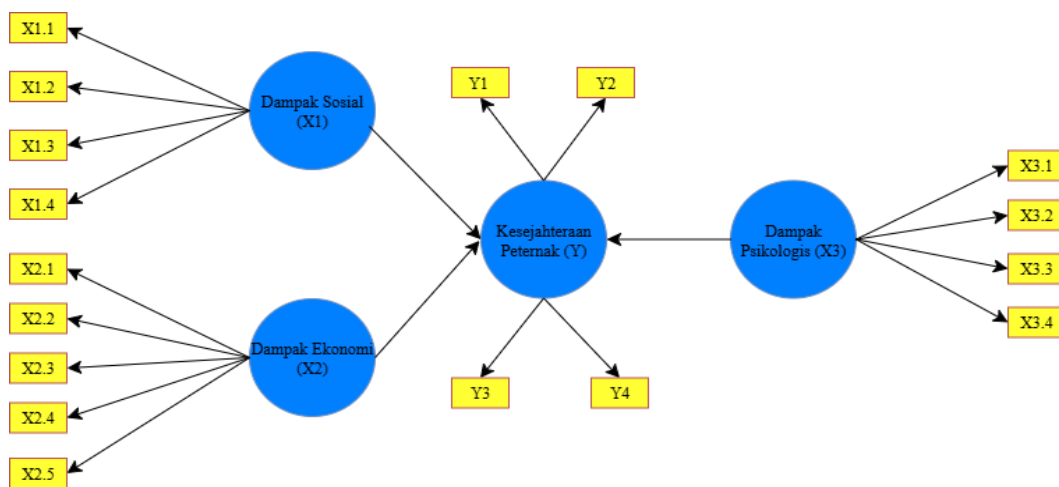


Figure 1. Research Data Analysis Model

Table 1. Analysis Model Description

Variable	Indicator Code	Indicator
Social Impact (X1)	X1.1	Farmers helping each other
	X1.2	Active farmer community
	X1.3	Trust among fellow farmers
	X1.4	Care for fellow farmers
Economic Impact (X2)	X2.1	Decrease in income
	X2.2	Increase in medical costs
	X2.3	Decrease in milk production
	X2.4	Loss of assets
	X2.5	Difficult economic recovery
Psychological Impact (X3)	X3.1	Farmers' stress levels
	X3.2	Farmers' anxiety
	X3.3	Decline in farmers' quality of life
	X3.4	Farmers' insecurity about their business
Kesejahteraan Peternak (Y1)	Y1.1	Satisfaction with current conditions
	Y1.2	Fulfilment of farmers' needs
	Y1.3	Stable income
	Y1.4	Hope and optimism about the business

RESULTS AND DISCUSSION

1. Measurement Model for Independent Variables

Variable measurement models are used to determine the contribution of each indicator to each variable.

a. Social Impact Variable Measurement Model

The data model for measuring social impact variables can be seen in Table 2.

Table 2. Outer Model Measurement Model of Social Impact Variables

Indicator	<i>Loading Faktor</i>
X1.1	0.990
X1.2	0.965
X1.3	0.979
X1.4	0.968

The social impact model obtained results based on the value of each indicator. (Shrestha, 2021) emphasizes that the minimum acceptable factor loading value is 0.5. The measurement model above shows that mutual assistance (X1) contributes

99.0% to measuring social impact, community activity (X2) contributes 96.5%, trust (X3) contributes 97.9%, and concern (X4) contributes 96.8%.

b. Economic Impact Variable Measurement Model

The data model for measuring social impact variables can be seen in Table 3.

Table 3. Outer Model Measurement Model of Economic Impact Variables

Indicator	Loading Faktor
X2.1	0.987
X2.2	0.941
X2.3	0.956
X2.4	0.986
X2.5	0.975

The economic impact model yields results based on the values of each indicator. (Shrestha, 2021) asserts that the minimum acceptable factor loading value is 0.5. The measurement model above shows that a decrease in income (X1) contributes 98.7% to measuring the economic impact, an increase in medical costs (X2) contributes 94.1%, a decrease in milk production (X3) affects the economic impact by 95.6%, loss of assets (X4) affects the economic impact by 98.6%, and difficult economic recovery (X5).

c. Psychological Impact Variable Measurement Model

The data model for measuring social impact variables can be seen in Table 4.

Table 4. Outer Model Measurement Model of Psychological Impact Variables

Indicator	Loading Faktor
X3.1	0.980
X3.2	0.919
X3.3	0.976
X3.4	0.981

The psychological impact model yields results based on the values of each indicator. (Shrestha, 2021) asserts that the minimum acceptable factor loading value is 0.5. The measurement model above shows that stress levels (X1) contribute 98.0% to measuring psychological impact, anxiety (X2) contributes 91.9%,

decreased quality of life (X3) influences psychological impact by 97.6%, and business insecurity (X4) influences psychological impact by 98.1%.

d. Measurement Model of Livestock Farmer Welfare Variables

The data model for measuring social impact variables can be seen in Table 5.

Table 5. Outer Model Measurement Model of Livestock Welfare Variables

Indicator	Loading Faktor
Y1.1	0.970
Y1.2	0.990
Y1.3	0.977
Y1.4	0.985

The measurement model for the livestock farmer welfare variable yields results based on the values of each indicator. (Shrestha, 2021) asserts that the minimum acceptable factor loading value is 0.5. The measurement model above shows that satisfaction (Y1) contributes 97.0% to livestock farmer welfare, fulfillment of needs (Y2) contributes 99.0% to livestock farmer welfare, stable income (Y3) contributes 97.7% to livestock farmer welfare, and optimism toward business (Y4) contributes 98.5% to livestock farmer welfare.

2. Validity and Reliability Testing

Validity and reliability testing aims to ensure that the measurement instrument used is reliable and accurate in measuring the intended construct. The measurement model for validity and reliability testing can be seen in Table 6.

Table 6. Measurement Model for Validity and Reliability Testing

Variable	CA	CR	AVE
Social Impact (X1)	0.983	0.983	0.952
Economic Impact (X2)	0.984	0.985	0.939
Psychological Impact (X3)	0.975	0.975	0.930
Livestock Welfare (Y)	0.987	0.987	0.962

Based on the data processing results table, the AVE value for all variables is >0.5. Therefore, it can be concluded that each instrument from the indicators in the research variables is valid and can proceed to the next stage.

In the evaluation of composite reliability and Cronbach's alpha measurements, the value must be greater than 0.7 for confirmatory research, and a value in the range of 0.6 - 0.7 is still acceptable for exploratory research (Fauzi, 2022).

3. Structural Measurement Model (*Inner Model*)

R-Square Adjusted can be seen in the Table 7:

Table 7. *R-Square Adjusted* Test Result

R-Square	0.956
R-Square Adjusted	0.955

Based on the table above, the adjusted R-square value of the livestock breeder welfare variable is 0.955, which means that the Social Impact, Economic Impact, and Psychological Impact variables have an influence on the livestock breeder welfare variable of 95.5%. The remaining 4.5% is influenced by variables outside the research model. The Fit Model can be seen in the Table 8.

Table 8. *Fit* Model Test Result

	Saturated Model	Estimated Model
SRMR	0.032	0.032
NFI	0.878	0.878

The results above indicate that the SRMR value found was 0.032. (Sathyanarayana & Mohanasundaram, 2024) stated that the SRMR value meets the requirements if it is <0.10. The NFI in SmartPLS is in the range of 0-1 and has a high fit if the resulting value is close to 1 (not less than 0.80), then an NFI showing a number of 0.878 is considered fit. The structural model of the research can be seen in Figure 2.

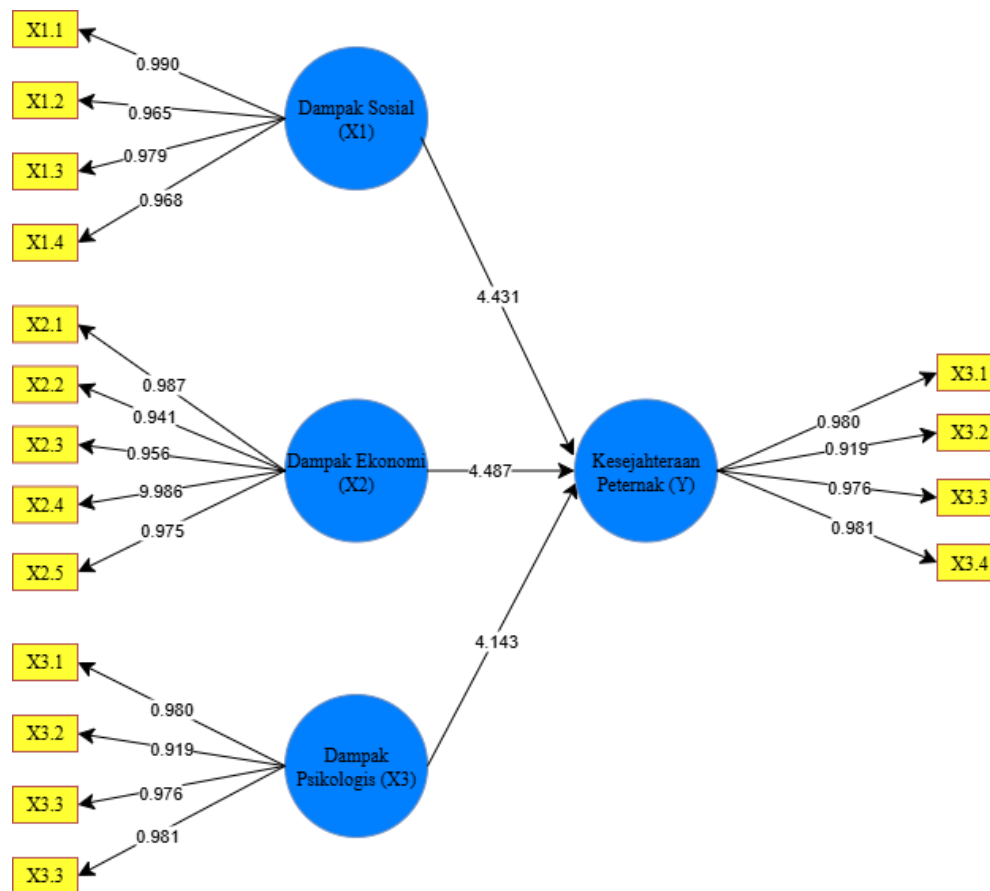


Figure 2. Research Structural Model

The results of the hypothesis test can be seen in Table 9:

Table 9. Hypothesis Test Results

Hypothesis	Variable	Original Sample	T Statistics	P Values	Decision
H1	Social Impact > Livestock Welfare	0.640	4.431	0.000	Accepted
H2	Economic Impact > Livestock Welfare	0.635	4.487	0.000	Accepted
H3	Psychological Impact > Livestock Welfare	0.647	4.143	0.000	Accepted

Noted: ** Has a significant effect at 5% or 0.05 significance**

From Table 9 it can be seen that:

- 1) There is a positive influence between social impacts and livestock farmer welfare. Table 9 shows a t-statistic of $4.431 > 1.96$ and a p-value of $0.000 < 0.05$. Therefore, the hypothesis is accepted.

- 2) There is a positive influence between economic impacts and livestock farmer welfare. Table 9 shows a t-statistic of $4.487 > 1.96$ and a p-value of $0.000 < 0.05$. Therefore, the hypothesis is accepted.
- 3) There is a positive influence between psychological impacts and livestock farmer welfare. Table 9 shows a t-statistic of $4.143 > 1.96$ and a p-value of $0.000 < 0.05$. Therefore, the hypothesis is accepted.

CONCLUSION

The social, economic, and psychological impacts have a positive effect on the welfare of livestock farmers because solidarity and social concern encourage cooperation and communal responsibility, understanding the economic pressures caused by the FMD outbreak makes livestock farmers more pragmatic in increasing business efficiency and profitability, and psychological pressures such as insomnia, stress, and anxiety encourage livestock farmers to strengthen mental resilience and build social support networks as an effort to reduce burnout and maintain welfare.

REFERENCES

- Brito, B. P., Rodriguez, L. L., Hammond, J. M., Pinto, J., & Perez, A. M. (2017). Review of the global distribution of foot-and-mouth disease virus from 2007 to 2014. *Transboundary and emerging diseases*, 64(2), 316-332. <https://doi.org/10.1111/tbed.12373>
- Cleaveland, S., Laurenson, M. K., & Taylor, L. H. (2001). Diseases of humans and their domestic mammals: Pathogen characteristics, host range and the risk of emergence. *70 Philosophical Transactions of the Royal Society B: Biological Sciences*, 356(1411), 991–999. <https://doi.org/10.1098/rstb.2001.0889>
- Crimes, D., & Enticott, G. (2019). Assessing the social and psychological impacts of endemic animal disease amongst farmers. *Frontiers in Veterinary science*, 6, 342. <https://doi.org/10.3389/fvets.2019.00342>
- Govindaraj, G., Ganeshkumar, B., Nethrayini, K. R., Shalini, R., Balamurugan, V., Pattnaik, B., & Rahman, H. (2017). Farm Community Impacts of Foot-and-Mouth Disease Outbreaks in Cattle and Buffaloes in Karnataka State, India. *Transboundary and Emerging Diseases*, 64(3), 849–860. <https://doi.org/10.1111/tbed.12450>
- Hair, J. F., Sarstedt, M., Hopkins, L., & Kuppelwieser, V. G. (2014). Partial least squares structural equation modeling (PLS-SEM): An emerging tool in business research. In *European Business Review* (Vol. 26, Issue 2, pp. 106–121). Emerald Group Publishing Ltd. <https://doi.org/10.1108/EBR-10-2013-0128>

- Hibi, J., Kurosawa, A., Watanabe, T., Kadowaki, H., Watari, M., & Makita, K. (2015). Post-traumatic stress disorder in participants of foot-and-mouth disease epidemic control in Miyazaki, Japan, in 2010. *Journal of Veterinary Medical Science*, 77(8), 953–959. <https://doi.org/10.1292/jvms.14-0512>
- Knight-Jones, T. J. D., & Rushton, J. (2013a). The economic impacts of foot and mouth disease - What are they, how big are they and where do they occur? In *Preventive Veterinary Medicine* (161–173). Elsevier B.V. <https://doi.org/10.1016/j.prevetmed.2013.07.013>
- Olf, M., Koeter, M. W. J., Van Haaften, E. H., Kersten, P. H., & Gersons, B. P. R. (2005). Impact of a foot and mouth disease crisis on post-traumatic stress symptoms in farmers. *British Journal of Psychiatry*, 186(FEB.), 165–166. <https://doi.org/10.1192/bjp.186.2.165>
- Putra, D. W., Kusumastuti, T. A., Andarwati, S., Panjono, & Guntoro, B. (2024). Perceptions and Economic Losses of Foot and Mouth Disease to Beef Cattle Farmers in Bantul Regency, Yogyakarta. *Tropical Animal Science Journal*, 47(4), 529–537. <https://doi.org/10.5398/TASJ.2024.47.4.529>
- Salsabilah, K. N., Firman, A., & Nurlina, L. (2024). Impact of foot and mouth disease (FMD) outbreak on financial performance of Koperasi Peternakan Bandung Selatan (KPBS) Pangalengan. *Advances in Animal and Veterinary Sciences*, 12(9), 1740-1751. DOI <https://dx.doi.org/10.17582/journal.aavs/2024/12.9.1740.1751>
- Sathyanarayana, S., & Mohanasundaram, T. (2024). Fit indices in structural equation modeling and confirmatory faktor analysis: reporting guidelines. *Asian Journal of Economics, Business and Accounting*, 24(7), 561-577. <https://doi.org/10.9734/ajeba/2024/v24i71430>
- Shrestha, N. (2021). Faktor analysis as a tool for survey analysis. *American journal of Applied Mathematics and statistiks*, 9(1), 4-11. <https://doi.org/10.12691/ajams-9-1-2>
- Singh, R. K., Sharma, G. K., Mahajan, S., Dhama, K., Basagoudanavar, S. H., Hosamani, M., Sreenivasa, B. P., Chaicumpa, W., Gupta, V. K., & Sanyal, A. (2019). Foot-and-mouth disease virus: Immunobiology advances in vaccines and vaccination strategies addressing vaccine failures—An Indian perspective. In *Vaccines* (Vol. 7, Issue 3). MDPI AG. <https://doi.org/10.3390/vaccines7030090>
- van An del, M., Jones, G., Buckle, K., Phiri, B., McFadden, A., Dacre, I., ... & Gates, M. C. (2020). Estimating foot-and-mouth disease (FMD) prevalence in central 78 Myanmar: Comparison of village headman and farmer disease reports with serological findings. *Transboundary and emerging diseases*, 67(2), 778-791. <https://doi.org/10.1111/tbed.13397>
- Van Haaften, E. H., Olf, M., & Kersten, P. H. (2004). The psychological impact of the Foot and Mouth Disease crisis on Dutch dairy farmers. *NJAS - Wageningen Journal of Life Sciences*, 51(4), 339–349. [https://doi.org/10.1016/S1573-5214\(04\)80001-0](https://doi.org/10.1016/S1573-5214(04)80001-0)
- Zewdie, G., Akalu, M., Tolossa, W., Belay, H., Deresse, G., Zekarias, M., & Tesfaye, Y. (2023). A review of foot-and-mouth disease in Ethiopia: epidemiological aspects, economic implications, and control strategies. In *Virology Journal* (Vol. 20, Issue 1). BioMed Central Ltd. <https://doi.org/10.1186/s12985-023-02263-0>