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The impact and mechanisms of animal epidemics on pork prices and the mechanisms involved: Evidence from a multi-period DID model

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Abstract: This study employs the African swine fever (ASF) outbreak as a quasi-natural experiment to assess its impact on pork prices and the underlying mechanisms. Utilising panel data from 30 Chinese provinces from January 2017 to December 2022, we apply a difference-in-differences (DID) approach combined with a moderating effect model. Furthermore, through DID quantile regression models, we delve into the impact of the epidemic on price volatility under varying initial pork price growth rates and regional institutional conditions. The findings reveal that the outbreak triggered a significant increase in the pork price, which averaged approximately 6%. During this process, the hog inventory exhibited a positive moderating effect on price increases, with steeper price hikes occurring during inventory declines. The outbreak further widened regional price disparities, with more pronounced increases occurring in areas experiencing earlier and steeper initial price rises, alongside more developed agricultural economies. Consequently, governments should adopt targeted regulatory strategies tailored to the distinct characteristics of pork price fluctuations. Simultaneously, enhancing coordination across all links in the industrial chain and optimising public information platforms can mitigate the impact of sudden animal disease outbreaks on the pork market.

Keywords: African swine fever; exogenous shocks; pork price fluctuations; regional disparities

China is the world's largest producer and consumer of pork. As a vital component of domestic livestock consumption, pork constitutes one of the primary sources of meat in daily life. Fluctuations in pork prices directly impact public consumption patterns and influence residents' quality of life (Han et al. 2022; Zhang et al. 2023) In recent years, sudden outbreaks of animal diseases, particularly the spread of African swine fever, have severely disrupted China's pig farming industry, causing significant volatility in pork prices. Since the initial outbreak of African swine fever in Liaoning Province in 2018, the epidemic has rapidly spread nationwide, causing a sharp decline in the national hog inventory and a substantial reduction in hog production (Zeng and Li 2024), causing pork prices to soar to historic highs within a short period of time (Shi et al. 2023).

Currently, although several years have passed since the initial outbreak, animal epidemics represented by African swine fever remain frequent, necessitating continued vigilance in prevention and control efforts. Such outbreaks pose long-term and severe challenges to China's livestock industry and food safety system. Conducting in-depth research into the extent of the impact of ASF on pork prices and the underlying

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mechanisms involved while further analysing regional variations in epidemic effects holds significant practical value for formulating targeted policy recommendations. This study not only contributes to theoretical research on the economic impacts of public emergencies but also, more importantly, provides scientific grounds for the government and relevant departments to regulate the hog market and respond to similar animal disease shocks. Consequently, it safeguards the stability of public welfare and promotes healthy socioeconomic development.

The relationship between supply and demand in determining prices is a classic theory in economics, with numerous scholars examining various factors influencing pork price fluctuations from this perspective. Rezitis and Stavropoulos (2009) examined the dynamic relationship between pork supply and price fluctuations in Greece and found that higher pork prices encourage producers to increase supply, suggesting a significant feedback mechanism between prices and production decisions. Pang et al. (2023) employed an SVAR model to investigate the determinants of pork price fluctuations and found that supply–demand dynamics, feed costs, and epidemic shocks significantly affect market prices. Hua et al. (2024) further identified feed costs, piglet costs, and other production inputs as important drivers of pig price fluctuations, corroborating the dominant role of supply and demand in pork price formation.

Concurrently, some scholars have begun focusing on the pivotal role of cost factors in price formation. Hua et al. (2025) highlighted that feed costs, piglet costs and other production inputs are key determinants of fluctuations in the supply of live pigs. Furthermore, Rocadembosch et al. (2016) found that the degree of specialisation and the form of production organisation on pig farms have a significant impact on production efficiency and supply capacity. These findings suggest that effective monitoring of production costs and timely policy adjustments are crucial for maintaining market stability. The results indicated that supply-side changes exert a more significant effect on prices, whereas price fluctuations have weaker feedback effects on the supply side. These findings partially explain the formation mechanism of the hog cycle. With respect to market regulation measures, during periods of supply–demand shocks, frozen pork reserve interventions have been widely employed to influence pork prices, although their efficacy remains contentious. Empirical studies based on GARCH (generalised autoregressive conditional heteroskedasticity) and TARCH (threshold ARCH) models indicate that such policies can mitigate price volatility and enhance market expectation stability (Wang and Zhou 2020). As a market regulator, the reserve system can influence pork prices through strategies involving the accumulation and release of reserves. Tan and Zeng (2019) emphasise that optimising the reserve intervention mechanism is crucial for stabilising market prices and enhancing the effectiveness of government regulation. However, international experience presents a more nuanced perspective. Yu and Willis (2016) employed ARCH models and difference methods to analyse China's strategic pork reserve programme, reporting heightened short-term price volatility during implementation periods. This finding suggests that ill-timed interventions may amplify market fluctuations. Similarly, Tan and Zeng (2019) employed a reserve spider web model to conclude that government hoarding may trigger overcorrection, thereby inducing greater price instability rather than stabilising prices. These findings suggest that the stabilising effect of reserve policies largely depends on their design, timing, and coordination with broader market conditions. Additionally, factors such as environmental regulations, shifts in consumer income, competitive dynamics, and substitute supply influence pork prices.

Among the numerous factors affecting pork prices, sudden external shocks frequently trigger intense market volatility and extreme impacts. Such shocks not only diminish farmers' willingness to produce but also exacerbate consumer panic, thereby distorting market supply–demand dynamics (Yu et al. 2023). In particular, major epidemics have become among the core external risks facing the hog industry because of their suddenness, widespread impact, and persistence.

In-depth analyses of different types of epidemic shocks and their market effects have been conducted. Li et al. (2023) employed a TVP-VAR-SV (time-varying parameter vector autoregression with stochastic volatility) model to compare the impacts of African swine fever (ASF) and the star crown epidemic on the live pig market and reported that ASF had a more pronounced shock effect, primarily manifested as price increases, whereas the impact of the star crown epidemic was more evident in terms of reduced consumer demand, exerting a suppressing effect on prices. Han et al. (2022) employed an ARIMA time series model to examine the impact of sudden animal disease outbreaks on the pork market. Their findings indicate that epidemics typically disrupt market supply and demand structures by diminishing farmers' production capacity and eroding consumer confidence, thereby triggering sharp price fluctuations. Yu et al. (2023) employed

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a multi-period DID model to examine the dynamic effects of epidemics on market prices. They observed that pork prices experienced short-term sharp increases during the initial outbreak phase because of supply chain disruptions and market panic. However, as production and logistics resumed, prices gradually returned to stable levels. Duan et al. (2024) combined smoothed transition regression (STR) with SV-TVP-SVAR (time-varying parameter structural vector autoregressive models with stochastic volatility) models to examine the short- and long-term impacts of dual epidemics (African swine fever and the Xingguan outbreak) and online discourse on hog industry chain prices. The findings indicate that epidemic shocks exhibit non-linear characteristics, featuring threshold effects that evolve over time. Furthermore, online discourse exerts a stronger short-term influence on pork price fluctuations than do the epidemics themselves, although its effects prove to be transient.

Although existing research has examined the impact of epidemics on the pork market, three significant limitations remain. First, insufficient consideration of other unobservable factors during epidemics may lead to biased conclusions. Second, the focus on the potential mechanisms through which epidemics affect pork prices is inadequate. Third, while external shocks may have different effects across regions, regional heterogeneity has not been sufficiently addressed.

To address these research gaps, this study proposes three methodological improvements: first, a difference-in-differences (DID) approach that incorporates relevant disturbance variables is used to increase the robustness of the estimation results, thereby mitigating potential biases from unobservable factors; second, a moderating effect model is constructed to identify the mediating variables and explain the specific mechanisms through which epidemics influence pork prices; and, finally, a double difference quantile regression (DID-QR) model is developed to analyse the heterogeneous effects of the outbreak from the perspectives of initial pork price growth rates and agricultural environmental variables across different regions.

This study treats the African swine fever (ASF) outbreak as a quasi-natural experiment to assess its impact on pork prices and explore the underlying mechanisms involved, with a particular focus on heterogeneity across regions and market conditions. This research aims to provide insights and policy recommendations for stabilising pork prices following an epidemic shock, thereby supporting economic and social stability.

MATERIAL AND METHODS

Research hypotheses

In accordance with supply and demand theory, pork prices are determined by the interaction between supply and demand. In the absence of sudden animal disease outbreaks, equilibrium price theory indicates that pork prices ultimately tend towards the equilibrium price. However, when faced with sudden outbreaks such as African swine fever, pork prices often experience significant volatility. Specifically, such outbreaks influence market supply and demand by altering the behaviour and expectations of producers and consumers, thereby triggering price fluctuations. The following section briefly analyses the specific manifestations of epidemic shocks within China's hog industry and pork market.

On the supply side, the outbreak of African swine fever directly affected farmers' behaviour and market expectations, leading to significant changes in hog inventories and the pork supply (Shi and Hu 2023; Zhang et al. 2023). Affected by the epidemic, China's hog inventories and pork production declined sharply in the short term (Zeng and Li 2024). Under normal circumstances, pig farmers make rational production decisions under favourable market conditions, with relatively stable market expectations. However, following the outbreak, affected farmers faced risks of pig mortality or culling, whereas unaffected farmers adjusted their breeding plans because of concerns over similar risks, shifting market expectations towards pessimism. Pig deaths and culling caused substantial losses for many farmers, with some exiting the market because of their limited risk tolerance. Others reduced their production scale, further decreasing the production capacity of pig herds and pork. In the short term, some affected farmers may sell pigs (including the breeding stock) to mitigate potential losses. While doing so increases slaughter volumes, it reduces the overall herd size. In the long term, difficulties in restocking severely constrain the pig supply capacity, while the decline in breeding stock further weakens the production capabilities of the industry, undermining its stability and foundation for sustainable development. Ultimately, the epidemic has precipitated a sustained decline in hog production capacity, substantially curtailing the pork supply. While inventory management and pork imports may alleviate short-term supply pressures, long-term constraints, such as reduced stock levels and restricted interregional circulation, diminish the effectiveness of these channels. Consequently, the scope for imported pork to bridge the supply gap also narrows.

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On the demand side, outbreaks of animal diseases frequently trigger consumer panic, particularly when information is scarce or public awareness is low. Such panic typically leads to a sharp decline in pork consumption in both urban and rural areas. However, as the outbreak is brought under control and as consumer understanding deepens, demand usually recovers (Li et al. 2023). Nevertheless, the production shortfalls and supply shortages caused by the outbreak delay the recovery of demand, accelerate the depletion of inventories, and may even trigger a contraction in demand for related commodities. If the epidemic persists and production fails to fully recover, the hog market will struggle to return to pre-epidemic supply levels in the short term, perpetuating supply–demand imbalances. Given the extended growth cycle of hogs and the difficulty of rapidly replenishing herds, supply levels will remain depressed. Consequently, the pork market may face a situation where supply falls short of demand (Li et al. 2024).

From a supply–demand perspective, reductions in pork supply typically far exceed declines in demand, resulting in supply exceeding demand and consequently driving up pork prices. From a price transmission theory perspective, the severe impact of African swine fever has compelled farming entities to strengthen their disease prevention measures, leading to increased production costs due to expanded herd losses. Farmers typically pass these costs on through pork prices, thereby raising them throughout the supply chain. Based on the analysis above, the following hypotheses are proposed:

H_1: The outbreak of African swine fever leads to an increase in pork prices.

H_2: African swine fever influences pork price fluctuations through its moderating effect on hog inventory levels; a decline in the hog inventory intensifies the upward pressure on pork prices.

Econometric models

Accurately assessing the impact of African swine fever outbreaks on pork prices presents two major challenges. First, the persistent outbreaks of African swine fever alongside other external shocks imply that relying solely on a single indicator to measure the epidemic may lead to biased estimation results. Second, as epidemic prevention measures are closely intertwined with the economic environment, omitting key variables may introduce endogeneity bias. To address these issues, this paper employs a DID model, which is widely used to mitigate endogeneity problems. By establishing an experimental group and a control group, this model enables a more precise assessment of the actual impact of policy adjustments or new measures.

The outbreak of African swine fever exhibits suddenness, presenting the characteristics of a quasi-natural experiment. This study treats the epidemic as an external shock and employs the DID method to analyse its impact on pork prices. This approach circumvents the aforementioned challenges based on two logics: first, due to temporal and geographical variations in outbreak timing and differences in local government containment measures, pork prices in affected regions are more significantly impacted by the epidemic. These price differentials more clearly reflect the actual impact than those in unaffected regions do. Second, within affected regions, governmental epidemic control policies also alter the economic environment, thereby influencing pork prices. The DID method simplifies the complexity of analysing individual policies while reducing the impact of omitted variables on the estimation results. Given the temporal variation in the timing of ASF outbreaks across provinces, this study employs a multi-period DID approach for estimation, with the model specified as follows:

$$Y_{it} = \alpha + \beta ASF \times Action + \varphi_i \sum Control + \\ + \lambda_t + \mu_i + \varepsilon_{it} \tag{1}$$

where: Y_{it} – the pork price of province i in period t; *ASF* – the dummy variable for the region where the African swine fever outbreak occurred, given that outbreaks occurred sequentially across various provinces in China, a value of 1 is assigned to the dummy variable for affected regions; *Action* – the time dummy for relevant regulatory interventions, set to one for periods following policy implementation and zero for preceding periods; *ASF* × Action – the core difference-in-differences interaction treatment term; α – the model constant; β – the core coefficient measuring the net impact of policy interventions on pork prices; *Control* – a set of control variables used to eliminate potential endogeneity bias arising from trend differences between the experimental and control groups; φ_i – the corresponding regression coefficients for the control variables; λ_t – the time fixed effects; μ_i – the provincial fixed effects; ε_{it} – the random error term.

Equation (1) constructs a two-way fixed effects model for multi-period DID estimation, with the pork price as the dependent variable. The parameters for each variable are estimated.

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The time dummy variable accounts for the outbreak period, and the interaction term between *ASF* and *Action* constitutes the core treatment effect term (*ASF_DID*). The model also includes individual fixed effects to control for time-invariant factors at the individual level and time fixed effects to account for factors common across all individuals that change over time.

Variables and measurement

Explanatory variables. This paper aims to assess the impact of African swine fever outbreaks on pork prices, with pork prices used as the dependent variable. A dummy variable for African swine fever outbreaks (*ASF_DID*) is constructed as the explanatory variable to reflect the shock effect of outbreaks on pork price fluctuations.

Control variables. To control for other factors that potentially influence pork price fluctuations, several key control variables were selected based on relevant literature to ensure the robustness of the estimation results. Given that pork imports constitute only a negligible proportion of total domestic consumption and face circulation restrictions during outbreaks (Shi et al. 2023), their impact on domestic pork prices is relatively limited. Consequently, they were excluded from the control variables.

i) *Production costs.* Hog production costs constitute a pivotal determinant of pork price fluctuations. Rocadembosch et al. (2016) found that feed, labour and piglet costs constitute the main components of pig production costs; fluctuations in these costs can significantly affect farm profits and market supply, thereby influencing price levels.. Among these costs, piglet and feed costs constitute the core components, accounting for more than 80% of total expenses (Zhang et al. 2023). As a vital input during the fattening phase, compound feed influences farming profitability and reflects the transmission of cost-side factors to market prices. This study therefore analyses the impact of piglet market prices and fattening pig feed costs as core breeding cost variables on pork price fluctuations

ii) *Substitute prices.* Beef, mutton, and chicken are regarded as substitutes for pork in the meat consumption market. Gale and Dong (2023) found that the substitution effect of beef and lamb for pork is relatively limited, as their higher prices and constrained supply restrict the possibility of large-scale substitution of pork consumption. Nevertheless, as the second most consumed meat product after pork, chicken has a more pronounced influence on consumer choices, thereby affecting pork demand and prices. This study employs the market price of white-feathered chickens as a representative indicator of substitute prices to examine how competition within the meat market impacts pork price fluctuations.

Data sources and description

The primary period during which African swine fever spread and its impact waned in China spanned from August 2018 to July 2019. To encompass the critical periods before and after the outbreak while accounting for the potential impact of the COVID-19 pandemic on the pork market, this study employs panel data from 30 Chinese provinces from January 2017 to December 2022. Owing to data gaps, the Tibet, Hong Kong, Macao, and Taiwan regions are excluded from this analysis. The onset dates of African swine fever in each province were compiled based on information from the official website of the Ministry of Agriculture and Rural Affairs. Missing data were addressed via interpolation methods. To eliminate inflation and seasonal effects, the consumer price index was employed as the price deflator for monetary price variables. All price variables are presented as year-on-year growth rates to enhance the robustness and smoothness of the model. The price variable data originate from BRIC Data (2017–2022), whereas the other data are sourced from the China Animal Husbandry and Veterinary Industry Yearbook (2017–2022).

RESULTS

An empirical analysis of the impact of animal epidemic outbreaks on pork prices

Baseline regression results. To assess whether the African swine fever outbreak significantly drove up pork prices, DID model was used. Columns (1 and 2) of Table 1 report the estimation results from the ordinary least squares (OLS) regression, whereas columns (3 and 4) present the results from fixed effects (FE) regression and two-way fixed effects (TWFE) regression, respectively.

In the benchmark regression, column (1) of Table 1 indicates that without controlling for additional variables, pork prices rose by an average of 43.70% following the ASF outbreak. However, this estimate may be biased, as it disregards other potential confounding factors. To address this possibility, this study incorporates control variables, including piglet prices, feed costs for fattening pigs, and chicken meat prices. Controlling for these variables significantly moderates the estimated impact of ASF outbreaks on pork prices, indicating that these factors play a crucial role in determining pork price fluctuations. Omitting them may lead to an overestimation of the effect of the epidemic.

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Table 1. The average impact of African swine fever outbreaks on pork prices

Variable	(1) OLS	(2) OLS	(3) FE	(4) TWFE
DID	0.4370*** (0.0122)	0.0886*** (0.0094)	0.0596** (0.0250)	0.0630*** (0.0188)
Piglet price	–	yes	yes	yes
Fattening pig feed prices	–	yes	yes	yes
Chicken price	–	yes	yes	yes
Province fixed effects		–	yes	yes
Time fixed effect	–	–	–	yes
Sample size	2 160	2 160	2 160	2 160

*** and **significance at the 1% and 5% levels, respectively; standard errors are in parentheses; 'yes' indicates that the variable is included, '–' indicates that it is not included
DID – difference-in-differences; FE – fixed effect; OLS – ordinary least squares; TWFE – two-way fixed effects
Source: Authors' work

Columns (3 and 4) of Table 1 present the results of fixed effects regression and two-way fixed effects regression, respectively, after the control variables are incorporated. According to these models, the African swine fever outbreak resulted in pork price increases of 5.96% and 6.30%, respectively. These findings indicate a significant positive impact of the outbreak on pork prices, which demonstrates that after controlling for relevant variables, individual fixed effects, and time fixed effects, the outbreak shock substantially increased pork prices across all provinces nationwide, thereby validating H_1.

Robustness tests. Parallel trends testing serves as a crucial prerequisite for assessing the accuracy and validity of difference-in-differences models. Its core assumption posits that prior to policy implementation, both the experimental and control groups should exhibit similar trend changes. Specifically, had the African swine fever outbreak not occurred, pork prices in affected and unaffected regions should have exhibited comparable fluctuation patterns. Following the outbreak, however, the price trends in these areas should have markedly diverged. To test this hypothesis, in this paper, time dummy variables are constructed to examine pork price movements across regions before and after the outbreak.

As illustrated in Figure 1, no significant price disparity existed between affected and unaffected regions prior to the outbreak. Specifically, the β values remained close to zero throughout the ten months preceding the outbreak, indicating synchronised price trends between the experimental and control groups before the outbreak and thus validating the parallel trends hypothesis. Furthermore, a pronounced lag in the dynamic effect was observed after the outbreak, attributable to epidemic propagation, supply chain responses, and subsequent market and policy reactions. Stakeholders require time to formulate decisions upon receiving epidemic signals. The dynamic effect peaked in the 14^{th} month post-outbreak, when the treatment effect was strongest, before subsequently diminishing.

In summary, the parallel trends test results confirm the validity of this hypothesis, enabling the preceding empirical analysis to provide a reliable causal effect interpretation with reasonable robustness.

Second, we employed the placebo test method proposed by Bertrand et al. (2004) to construct a randomised experiment based on two treatment levels: the time and province levels. Specifically, several time points prior to the African swine fever outbreak were randomly selected, and treatment periods were randomly assigned. Subsequently, regression analysis was conducted via the method outlined in column (4) of Table 1, and the probability distribution of the estimated coefficients in the baseline regression was calculated via virtual experiments. This method serves to assess the reliability of conclusions.

To enhance the efficacy of the placebo test, this process was repeated 1 000 times, after which the distribution of the estimated coefficient for the core treatment effect term (*ASF_DID*) was plotted. This method aids in determining whether the observed effect of African swine fever outbreaks on pork prices is significantly influenced by factors other than the outbreak itself. If the distribution of the estimated coefficient of *ASF_DID* under random treatment clusters near zero, this finding indicates that the model has adequately controlled for key variables, confirming that

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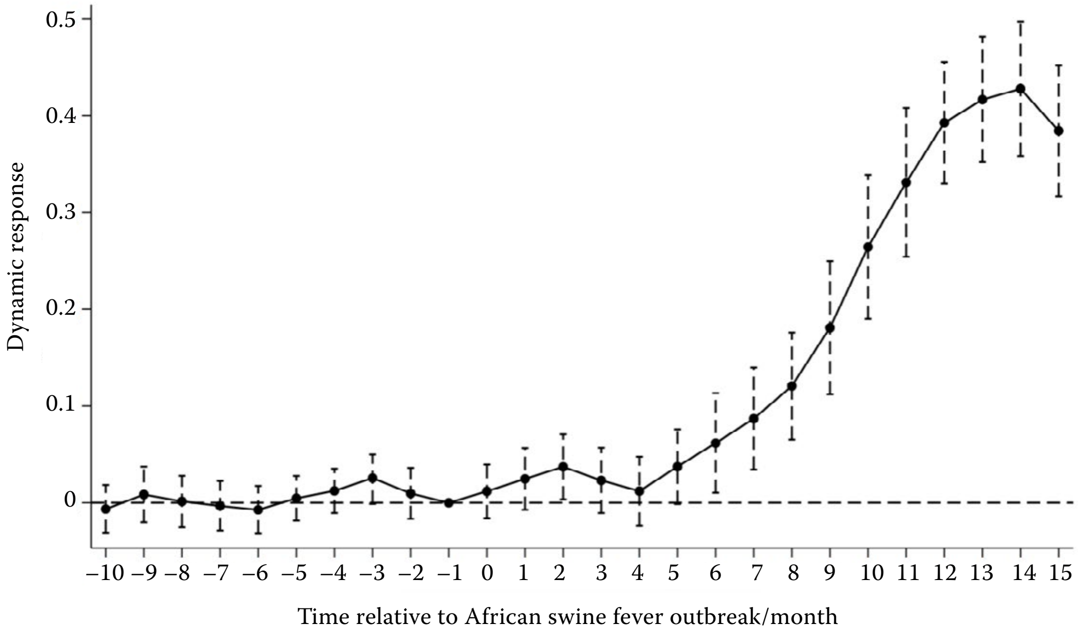

Figure 1. Parallel trends test

Source: Authors' work

the effect in the baseline analysis is indeed attributable to the African swine fever outbreak.

The distribution of the estimated coefficients shown in Figure 2 indicates that the dual difference terms of the dummy variables cluster around zero, with most *P*-values exceeding 0.1. The true policy effect value of 0.063 0 lies at the extreme end of the spurious policy effect distribution. These results suggest that no significant omitted variable issues exist in the model and that the core conclusions remain unaffected by omitted variables, random factors, or other confounding influences. Consequently, the regression results are robust.

Finally, we conduct additional robustness tests. First, we exclude other contemporaneous policy disruptions to account for the potential impact of the COVID-19 epidemic on pork price volatility. To mitigate this concern, the COVID-19 epidemic is incorporated into the baseline regression model. The regression results, presented in column (1) of Table 2, show that the coefficient of the policy variable *ASF_DID* remains significant. We subsequently perform the expected effect test. Following Malani and Reif (2015), we construct variables for the month preceding the epidemic by advancing the timing of the epidemic shock by one month. The regression results, shown in column (2) of Table 2, demonstrate that the coefficient of *ASF_DID* remains significant, suggesting that no anticipated effects from the African swine fever epidemic are present. Furthermore, we address potential endogeneity issues. Drawing on Chudik and Pesaran (2015), we lag all control variables by one period, and the resulting estimation, presented in column (3) of Table 2, shows that the coefficient of *ASF_DID* remains significantly positive. This result further supports the robustness of the findings.

Mechanism analysis. This section examines the role of the hog inventory in the impact of African swine fever on pork price volatility. To test the validity of H_2, this paper employs a moderating effect regression model to analyse the mechanisms involved. A moderating effect occurs when one variable (e.g. hog inventory) influences the relationship between another variable (e.g. African swine fever shock) and the dependent variable (e.g. pork price). By introducing an interaction term, we can assess whether hog inventory moderates the impact of African swine fever on pork prices, specifically whether the upward pressure on pork prices intensifies as the hog inventory decreases.

The mechanism testing in this paper is based on the following regression model:

$$\begin{aligned} Y_{it} &= \alpha + \beta_1 Mechanism_{it} \times ASF\_DID_{it} + \\ &+ \beta_2 ASF\_DID_{it} + \beta_3 Mechanism_{it} + \\ &+ \gamma Control + \mu_i + \lambda_t + \varepsilon_{it} \end{aligned} \quad (2)$$

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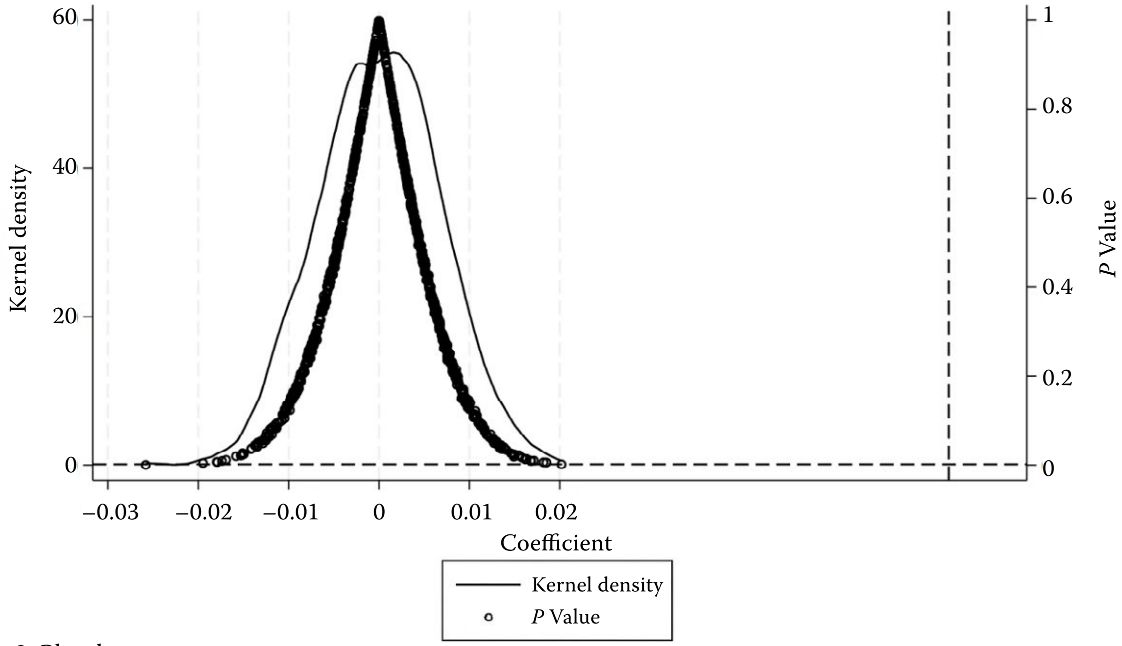

Figure 2. Placebo test

Source: Authors' work

where: *Mechanism* – the hog inventory, which is used to measure the impact of African swine fever on hog stocks. This variable allows us to test the role of the hog inventory as a mediating factor between the spread of African swine fever and changes in pork price volatility.

In Equation (2), the interaction term represents the joint effect of the hog stock and the shock of African swine fever. The core focus of this analysis is to examine how the hog stock mediates the impact of African swine fever on pork prices through this term. The coefficient of this interaction term reflects the effect of the hog inventory on changes in pork prices under the shock of African swine fever, which is the central focus of this paper. The interpretation of the remaining variables is consistent with that of the benchmark model.

If the coefficient of the interaction term is significant and positive, it indicates that a reduction in the hog inventory significantly pushes up pork prices by affecting supply, thus supporting the mediating role of the hog inventory in the mechanism through which African swine fever impacts pork prices. Conversely, if the coefficient is significant and negative, it suggests that a reduction in the hog inventory may slow the upward pressure on pork prices, possibly due to other complementary supplies or policy interventions.

Column (1) of Table 3 presents the regression results for the mechanism variable (*hog inventory*) and the policy variable. It is evident that the shock of African swine fever has a significant negative effect on the hog inventory. Column (2) of Table 3 shows the regression results for the moderating effect, where the coefficient of the interaction term is significantly positive. This result indicates that the hog inventory has a positive moderating effect on the impact of African swine fever on pork prices. As the hog inventory decreases, pork prices rise more rapidly, thus confirming the validity of H_2.

Heterogeneity analysis. Beyond the average treatment effect, understanding how the impact of ASF varied across different initial conditions and regional characteristics is important. We explore two heterogeneity dimensions that emerged from our hypothesis framework: (*i*) the initial pork price trend in a region and (*ii*) the level of agricultural development of a region. We incorporate these dimensions by extending the DID model with interaction terms and by estimating quantile treatment effects.

First, we examine whether the ASF shock had different effects in regions that initially had faster vs. slower pork price growth. Doing so addresses whether the epidemic led to a convergence, generalised uplift, or polarisation of regional prices. To test these possibilities, we employ a quantile difference-in-differences (DID-QR) framework based on Beck et al. (2010) and include an interaction term between

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Table 2. Robustness test results

Variable	Excluding the same period other policy disruptions	Expected effects test	Mitigating potential endogenous problems
	(1)	(2)	(3)
	pork_price	pork_price	pork_price
ASF_DID	0.062 8*** (0.011 7)	0.039 0** (0.016 6)	0.092 3*** (0.013 2)
COVID_DID	–0.013 1 (0.023 4)	–	–
ASF_DID_before	–	0.006 8 (0.016 2)	–
Sample size	2 160	2 100	2 130
R^2 value	0.889 5	0.963 2	0.813 9
Control variable	yes	yes	no
Control variables lagged one period	no	no	yes
Province fixed	yes	yes	yes
Fixed time	yes	yes	yes

*** and **significance at 1% and 5% levels, respectively; column (1) adds a COVID-19 period dummy; column (2) adds a one-period lead of *ASF_DID*; column (3) uses one-period-lagged control variables; *n* differs slightly when adding leads/lag reduces the sample

ASF – African swine fever; DID – difference-in-differences

Source: Authors' work

the treatment indicator and the pre-epidemic pork price growth rate (RP_i). The estimation equation is specified as follows:

$$Y_{it} = \beta_0 + \beta_1 ASF\_DID + \beta_2 ASF\_DID \times RP_i + \\ + \varphi_i \sum Control + \lambda_i + \gamma_t + \varepsilon_{2it} \quad (3)$$

where: *ASF_DID* – indicates whether region *i* at time *t* is treated (i.e. exposed to ASF); RP_i – the regional pork price growth rate prior to the epidemic.

By estimating this model across different quantiles (0.25, 0.5, and 0.75), we identify whether the impact of ASF differs depending on the initial price dynamics.

The results, reported in Table 4 [column (1)], show that the coefficients of ($ASF\_DID \times RP_i$) are significantly positive across all quantiles. Specifically, the coefficient magnitude increases with the quantile: 0.083 8 at the 25th percentile, 0.338 2 at the median, and 0.815 6 at the 75th percentile. In other words, the higher a region's pork price was rising before the outbreak, the greater the increase in the price that it experienced after the outbreak. This pattern reflects a polarisation effect rather than convergence: the ASF shock exacerbated pre-existing regional disparities in price growth. Regions that had been enjoying relatively modest price increases saw pork prices rise after ASF, but regions that were already facing rapid price growth experienced even more pronounced increases. Thus, the epidemic widened the gap in price growth across regions, contributing to market fragmentation and interregional inequality.

Next, we examine the heterogeneity in the impact of ASF based on regional agricultural development. Regions with more developed agricultural economies – characterised by larger-scale operations, better infrastructure, and more integrated markets – may be more sensitive to supply and demand shocks from an epidemic. To capture this dimension, we construct an interaction term between the treatment indicator and the institutional environment variable (IE_i), measured as the gross output value of agriculture, forestry, animal husbandry, and fishery *per capita* (averaged at the province level before the outbreak). The extended model is as follows:

$$Y_{it} = \beta_0 + \beta_1 ASF\_DID + \beta_2 ASF\_DID \times IE_i + \\ + \varphi_i \sum Control + \lambda_i + \gamma_t + \varepsilon_{3it} \quad (4)$$

As shown in Table 4 [column (2)], the interaction term ($ASF\_DID \times IE_i$) is significantly positive across the 0.25, 0.5, and 0.75 quantiles, with coefficients of 0.092 7, 0.318 4, and 0.817 4, respectively. These findings suggest

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Table 3. Mechanism test results (the hog inventory as a moderator)

Variable	(1) *Mechanism*	(2) Y_{it}
DID	–0.056 2** (0.021 5)	0.015 0*** (0.005 6)
Mechanism × *DID*	–	0.028 2* (0.016 6)
Mechanism	–	–0.071 8*** (0.011 5)
Province fixed effects	yes	yes
Time fixed effect	yes	yes
Sample size	2 160	2 160

***, ** and *significance at the 1%, 5% and 10% levels, respectively; the dependent variable in column (1) is the annual growth in the hog inventory, the dependent variable in column (2) is pork price growth; the hog inventory is measured as the number of pigs (the breeding sow and hog stock)

DID – difference-in-differences

Source: Authors' work

that the ASF epidemic had a stronger effect on pork price growth in regions with higher levels of agricultural development. One possible explanation is that in more developed regions, where the pork supply chain is more highly integrated, disruptions due to farm culling, transportation restrictions, and supply shortages propagate more rapidly and extensively through the production and distribution systems. While integration typically brings efficiency, it also heightens systemic vulnerability during shocks. In contrast, less developed regions with more fragmented or localised markets may experience milder and more contained price effects.

In summary, the heterogeneity analysis revealed two key findings:

i) The initial conditions proved critical: regions experiencing higher pork price increases prior to the outbreak suffered disproportionately greater impacts. This finding indicates that African swine fever did not eliminate regional disparities; rather, it amplified them, creating a 'rich get richer' effect within price inflation.

ii) The market structure matters: Regions with more developed agricultural economies experienced more severe impacts, suggesting that industrial integration amplifies the shocks triggered by the epidemic.

Table 4. Heterogeneity test results

Variable	(1)	Variable	(2)
$ASF\_DID \times RP_{0.2}$	0.083 8*** (0.031 2)	$ASF\_DID \times IE_{1(0.25)}$	0.092 7*** (0.012 9)
$ASF\_DID \times RP_{0.5}$	0.338 2*** (0.055 9)	$ASF\_DID \times IE_{1(0.5)}$	0.318 4*** (0.036 0)
$ASF\_DID \times RP_{0.7}$	0.815 6*** (0.051 8)	$ASF\_DID \times IE_{1(0.75)}$	0.817 4*** (0.022 0)
Control	yes	yes	yes
Province fixed effects	yes	yes	yes
Time fixed effect	yes	yes	yes
Sample size	2 160	2 160	2 160

***significance at the 1% level; standard errors are in parentheses; 'yes' indicates that the variable is included

Column (1) investigates heterogeneous effects grouped by the variable RP. Column (2) carries out heterogeneity tests based on the indicator IE.

Source: Authors' work

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These findings underscore the importance of tailoring policy responses to local conditions, as one-size-fits-all interventions may fail to address the asymmetry of epidemic impacts.

DISCUSSION

This empirical study reveals that animal epidemics, as exemplified by ASF, exert significant upward pressure on pork prices in China. Employing a DID framework, we find that even after controlling for numerous variables and fixed effects, ASF continues to drive up pork prices. This finding further corroborates the view that epidemic shocks impose substantial pressure on agricultural commodity markets.

A key finding lies in the mediating role of hog inventory levels in the transmission of the ASF shock to market prices. ASF reduces the hog supply through culling and contagion, with this supply contraction directly translating into upward price pressure. These findings revalidate classical supply shock theory from an epidemiological perspective.

This research also reveals pronounced regional disparities. In areas experiencing rapid increases in pork prices prior to the outbreak, the impact of ASF was particularly pronounced. This pattern likely stems from pre-existing market tensions – where elevated prices reflected supply–demand imbalances – with the epidemic shock exacerbating supply concerns and altering market expectations, thereby amplifying price volatility. Concurrently, despite possessing greater breeding capacity, agriculturally advanced regions proved more vulnerable to the epidemic because of highly concentrated hog supply chains. Moreover, greater government intervention in these areas often precipitated more pronounced price reactions. Collectively, market fundamentals and structural characteristics amplified the exogenous ASF shock, generating heterogeneous regional impacts.

Unlike prior research, this study deepens the understanding of the impact of ASF by integrating mechanism analysis with heterogeneity analysis. Building upon existing research focusing on average treatment effects, our findings align with those of Salling (2025), confirming that ASF caused significant pork price increases. However, this study reveals more nuanced economic mechanisms and regional variations in the market impact of ASF.

Notably, the peak of the dynamic treatment effect emerged after a 14-month lag following the outbreak. This delay likely stems from sluggish stakeholder responses, policy implementation lags, and incremental market adjustments. Future epidemic response strategies and forecasting models should explicitly incorporate such temporal lags.

A key limitation of this study lies in its reliance on observational data – despite the use of rigorous econometric methods, unobserved confounding factors may still influence the results. Furthermore, the proxy indicators used to measure regional development levels and inventory stocks may inadequately capture the complexity of agricultural infrastructure and informal market dynamics.

Nevertheless, our findings have significant theoretical and policy implications. Policymakers should tailor intervention strategies to regional market structures and prevailing price dynamics. For instance, price stabilisation mechanisms and strategic reserves may prove particularly crucial in regions experiencing rapid price surges or high market integration. From a research perspective, these findings warrant further exploration of supply chain resilience and the impact of market expectations on agricultural price dynamics.

In summary, the African swine fever outbreak significantly increased Chinese pork prices by reducing hog inventories and amplifying regional market characteristics. These findings underscore the necessity of incorporating structural determinants into epidemic-related price analyses and advocate for targeted strategies to enhance market resilience during future animal health crises.

CONCLUSION

In conclusion, this study examines the impact of African swine fever outbreaks on Chinese pork prices and the underlying mechanisms involved. Employing a rigorous DID approach supplemented by moderating effect and quantile regression analyses, we find that African swine fever outbreaks lead to significant increases in pork prices. Analysis confirms that the price surge primarily stems from a supply shock caused by reduced hog inventories, with more pronounced effects in specific regions (those with higher initial price increases and developed agricultural markets). By simultaneously addressing endogeneity issues, revealing supply intermediation mechanisms, and exploring heterogeneous effects, this study fills a significant gap in the understanding of market shocks triggered by epidemics.

The findings have practical implications for managing agricultural market shocks. Policymakers should

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strengthen epidemic prevention systems to minimise livestock losses and to provide timely support to producers during outbreaks to stabilise supply. Market intervention tools (strategic reserves, trade adjustments, and information dissemination) require regionally differentiated strategies to prevent excessive price surges and to protect consumer interests. By enhancing the resilience of the pig supply chain and implementing region-specific interventions, governments can effectively mitigate the economic repercussions of animal epidemics.

This empirical analysis of the disruptive market impacts of severe animal disease outbreaks and mitigation pathways provides significant contributions to the literature on food price volatility and agricultural risk management. China's African swine fever control experience offers valuable reference points for nations to refine agricultural policies and emergency response mechanisms, thereby enhancing food market stability during animal health crises.

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