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How economic policy uncertainty affect the scale-up of hog breeding in China?

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Abstract: In recent years, China has promoted large-scale hog farming through various approaches. However, this scale-up process may be affected by economic policy uncertainty. This paper empirically examines the impact of policy uncertainty on hog farming scale-up using provincial panel data from 2016–2022 and a fixed-effects model. Our results indicate that economic policy uncertainty significantly inhibits hog farming scale-up, and this effect remains significant even when we increase the criteria for recognising scale-up, alternative estimation methods include two-stage least squares (2SLS), dynamic panel model and panel Poisson model. Mechanism analysis reveals that economic policy uncertainty not only exacerbates the impact of labour and capital factor prices on scale-up hog farming but also exacerbates the volatility of hog prices, which further raises the risks faced by hog farming and inhibits scale-up hog farming. Heterogeneity analysis reveals that the effect of economic policy uncertainty on hog farming scale-up decreases as farm size increases. Higher-level economic policy uncertainty can inhibit scale-up hog farming, while lower-level economic policy uncertainty can instead promote scale-up hog farming. Economic policy uncertainty has a more obvious inhibitory effect on scale-up hog farming in major development areas. These findings have important implications for the promotion of large-scale hog farming and related policy regulation.

Keywords: capital price; frequent policy adjustment; hog farming; hog price fluctuation; labour price; large-scale hog farming

China is a large producer and consumer of pork (Xiong et al. 2017; Zhu et al. 2022). According to data released by the National Bureau of Statistics, China produced 92.27 million tons of meat in 2022, of which 55.41 million tons were pork, accounting for 60.05%. China is the world's largest producer and consumer of pork. In China, pork is the staple animal protein for Chinese households (Ortega et al. 2015; Wang et al. 2020).

In China, the number of small farmers accounts for the vast majority of farmers. According to data published in the China Animal Husbandry Yearbook in 2022 (China Agricultural Press 2022), the number of small farms with fewer than 500 hogs reached 19 925 093, accounting for 99.12% of the total number of farm households. Small-scale farming is also known as the backyard farming model (Qiao et al. 2016). The

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large number of small-scale farmers constrains the stable development of the hog industry. Limited to information asymmetry, small-scale hog farmers in China usually formed price expectations based on neighbours or social networks (Xiong et al. 2023). In this context, small-scale farmers frequently enter and leave the farming industry (Cai et al. 2023), resulting in cyclical fluctuations in hog prices. Against this background, the Chinese government aims to achieve stability in the hog industry by guiding large-scale hog farming.

In recent years, the Chinese government has promoted large-scale hog farming through various measures, including incentive and restriction policies. In terms of incentive policies, since 2012, the Ministry of Finance issued incentive measures for large counties that transfer hogs out, guiding large-scale hog farming through financial subsidies. In terms of constraint policies, in 2013, the Ministry of Agriculture issued regulations on pollution prevention in animal husbandry farming, raising the threshold for hog farming. This indirectly promoted scale-up hog farming. Through a series of policy measures, China's hog industry is now experiencing an important transition from backyard, household-based production to large-scale production (Qiao et al. 2016). Realistically, according to the data released by the China Veterinary Yearbook of Animal Husbandry (China Agricultural Press 2010, 2022), the number of hog farmers within 500 heads in 2022 was 19 925 093, a decrease of 47 149 033 compared to 2010, a drop of 70.29%. At the same time, the number of hogs slaughtered by large-scale hog farmers is increasing. According to the data released by the Ministry of Agriculture and Rural Affairs, the scale-up of hog farming reached 60% in 2021, which means that more than half of the hogs are raised by large-scale farmers. However, although China's policy of large-scale hog farming has achieved fairly good results. The number of small-scale farmers is still overwhelmingly large. As mentioned above, the number of small farmers is still 19 925 093, accounting for more than 99%. The scale-up of hog breeding still needs to be promoted continuously.

The development of scale-up hog farming in China may be affected by economic policy uncertainty. Economic policy uncertainty in China has been on the rise in recent years due to factors such as intensifying economic and trade frictions, trade protectionism, the outbreak of COVID-19, and the Russia-Ukraine war. From a domestic perspective, according to the data released by the National Bureau of Statistics, the unemployment rate in China has recently shown an upward trend. The Chinese government must take comprehensive measures to address these problems. However, policy changes create an uncertainty bias that is contrary to the original intention (Lagerkvist 2005; Mittenzwei et al. 2017). As economic policy changes frequently, the business environment will become turbulent and complicated (Zheng and Wen 2023), which impacts the gross margin of farmers and can stimulate investment decisions (Schauberger et al. 2022), ultimately affecting scale-up hog farming.

Scholars have studied the impact of economic policy uncertainty from several perspectives. From a macro perspective, economic policy uncertainty has reduced the peak of total investment (Baker et al. 2016) and slowed economic growth (Jiang et al. 2019). Policy uncertainty caused by elections leads to uncertainty in financial markets (Goodell et al. 2020) and reduced foreign direct investment (Chen et al. 2019). From a micro perspective, economic policy uncertainty affects the cost of debt financing through two mechanisms: information asymmetry and default risk (Tran 2021). Economic policy uncertainty reduces enterprise innovation investment (Qi et al. 2022; Zhang et al. 2022) and capital factor input (Feng et al. 2023). Meanwhile, economic policy uncertainty increases the number of cash holdings (Li 2019). In the field of agriculture, scholars have focused on the impact of policy uncertainty on agricultural production and agricultural commodity prices. In terms of agricultural production, the study finds that economic policy uncertainty discourages agricultural investment (Lagerkvist 2005). Government intervention in the market leads to great uncertainty that affects the production plans of merchants (Brummer et al. 2009). In terms of agricultural prices, government intervention in the market leads to a high degree of uncertainty and has an impact on the spread of wheat and flour prices (Brummer et al. 2009), it will also have a significant impact on China's grain price (Hua et al. 2022) and futures prices (Xiao et al. 2019).

The literature review has found that few papers discuss the impact of economic policy uncertainty on industry development, especially scale-up hog farming. This paper examines the impact of economic policy uncertainty on scale-up hog farming. Compared to the literature on economic policy uncertainty, the main contributions of this paper may lie in the following three areas. First, this paper extends the study of economic policy uncertainty to the field of animal husbandry development, providing a reference for animal husbandry policy making. Second, this paper discusses the mechanisms by which economic policy uncertainty affects hog scale-up in terms of the external environ-

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ment. Specifically, economic policy uncertainty not only exacerbates the impact of labour and capital factor prices on scale-up hog farming but also raises the risks faced by hog farming and inhibits scale-up hog farming. Third, we examine the impact of economic policy uncertainty on scale-up hog farming in different farm sizes, economic policy uncertainty levels, and regions, providing empirical support for the government to develop different policies.

MATERIAL AND METHODS

Hypothesis development

According to the existing studies, scholars have a lot of discussion about the impact of economic policy uncertainty (Brandon and Youngsuk 2012; Zheng and Wen 2023), among which the impact of economic policy uncertainty on investment is an aspect that scholars pay more attention to (Aizenman and Marion 1993; Chen et al. 2019). From a macro perspective, economic policy uncertainty has a significant impact on macro investment (Aizenman and Marion 1993), private investment (Rodrik 1991), and foreign direct investment (Chen et al. 2019; Zhang et al. 2023). From a micro perspective, economic policy uncertainty also has a significant impact on financial investment (Durnev 2010) and corporate investment (Brandon and Youngsuk 2012; Gulen and Ion 2016). Some scholars have further extended the concept of investment (Chu and Fang 2021; Zheng and Wen 2023). For example, they discussed the impact of economic policy uncertainty on enterprise innovation (Zheng and Wen 2023), labour input (Chu and Fang 2021), and bank loans (Chi and Li 2017; Francis et al. 2014). Research on the impact of policy uncertainty on investment has become richer.

The scale-up of hog farming is essentially a derivative concept of investment. After making large-scale hog breeding decisions, farmers first need to build production factories and prepare other inputs related to hog production, such as piglets, feed, and labour (Jia and Li 2021). Therefore, large-scale hog breeding is a kind of investment behaviour. From an investment perspective, we can analyse the impact of economic policy uncertainty on large-scale hog farming using the theoretical framework of real options. According to the real options theory, if a farmer has the option to delay scale-up, it will make that scale-up investment only when its net present value is higher than the value of the option to delay. The value of the deferred real option increases with the uncertainty associated with the value of the asset increases. Hence, higher uncertainty implies investments need to meet a higher threshold before they are undertaken. When analysing the impact of policy uncertainty on large-scale hog farming based on the theory of real options, the main factor to consider is the reversibility of assets formed by scale-up. A firm with completely irreversible investments would have a lot more to gain from waiting until some of the uncertainty is reduced since they have more to lose if the project proves unprofitable (Gulen and Ion 2016). Corporate investment is often irreversible (Hartman 1972). For hog farmers, although most of the assets formed by scale-up are transferable among producers, they may still experience losses when converting assets in high-risk situations, such as when hog prices decrease, and the hog production scale is reduced.

In addition, economic policy uncertainty raises the market risk faced by hog farming, further inhibiting large-scale hog farming. The studies have found that economic policy uncertainty significantly exacerbates food price volatility (Brummer et al. 2009; Xiao et al. 2019; Hua et al. 2022). In this empirical perspective, economic policy uncertainty may also exacerbate hog price volatility, increase the market risk faced by hog farming, and inhibit farmers' willingness to expand their farming scale, thus negatively affecting hog farming scale-up.

According to the analysis above, we propose the following hypothesis:

H_1: Economic policy uncertainty has a negative impact on scale-up hog farming.

Economic policy uncertainty inhibits hog farming scale-up through pathways that amplify the impact of factor prices and exacerbate hog price volatility.

Large-scale hog farming requires capital investment (Qiao et al. 2016) and labour investment (Jia and Li 2021). Therefore, scale-up hog farming is influenced by the prices of capital and labour factors. Economic policy uncertainty may increase the impact of capital and labour prices on large-scale hog farming.

Economic policy uncertainty has increased the difficulty of financing for hog farmers. Farmers raise funds for large-scale hog farming through both endogenous and exogenous sources. In terms of endogenous financing, rising economic policy uncertainty increases the business risk and cash flow uncertainty for enterprises (Baum et al. 2010), and enterprises tend to hold cash assets (Ashraf 2020) to improve their ability to cope with risks. At this time, it is difficult for farmers to access funds for scale-up from endogenous sources, which will be detrimental to large-scale hog farming. In terms of exogenous financing, economic policy uncertainty

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suppresses the expansion of credit (Jiang et al. 2019). The reason is that economic policy uncertainty raises banks' passive risk-taking (Chi and Li 2017; Karadima and Louri 2021) and banks need to increase bank liquidity reserves (Ashraf 2020) to cope with possible risks. At the same time, economic policy uncertainty may lead to tighter credit conditions and increase reluctance from financial institutions to provide loans for agricultural investment. In the context of economic policy uncertainty, banks will intensify their loan scrutiny (Francis et al. 2014) and reduce lending to farmers. The tightening of loan conditions will be detrimental to hog farms' access to capital, thus inhibiting large-scale hog farming.

Economic policy uncertainty amplifies the impact of labour factor prices on hog farming scale-up. Rising labour prices have raised production costs for farmers (Jia and Li 2021). Against the backdrop of rising labour prices, the cost of hog farming has increased, and farmers' willingness to expand the scale of hog farming has decreased, thus inhibiting large-scale hog farming. To cope with the negative impact of rising labour prices, farmers tend to use mechanical equipment instead of manual inputs (Liu et al. 2014) to improve production efficiency. However, purchasing machinery and equipment requires large capital investment, which is difficult for farmers to access in an environment of policy uncertainty (Francis et al. 2014). In other words, rising labour costs will inhibit hog scale-up. Superimposed on the economic policy uncertainty, the difficulty of substituting factors of production for farmers will increase, and large-scale hog farming will be further inhibited.

In addition, economic policy uncertainty exacerbates hog price volatility, raises the market risk faced by hog farming, and is not conducive to large-scale hog farming. Economic policy uncertainty affects farmers' hog farming decisions, which in turn affects hog supply and ultimately leads to hog price volatility. In terms of China's reality, around 2016, China's environmental constraints tightened, and local governments practised a one-size-fits-all stringent environmental policy, ignoring the time required to dispose of hog farming assets. Against this backdrop, when there is a shortage of hog supply and the government encourages farmers to engage in hog farming, farmers will develop a sense of distrust towards the government, affecting farmers' willingness to expand production (Li and Wang 2020). At this time, the supply and demand of hogs will be further imbalanced, thus exacerbating the fluctuation of hog prices. Hog price volatility directly increases the market risk faced by hog farming, thus inhibiting hog farming scale-up.

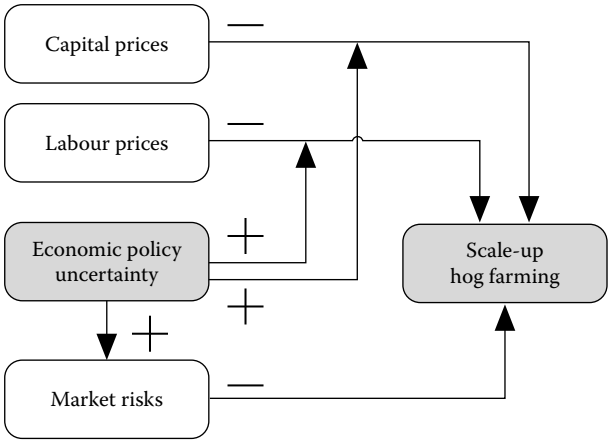

Figure 1. The analysis framework

Source: Author's own elaboration

The analysis framework for the impact of economic policy uncertainty on scale-up hog farming is shown in Figure 1.

According to the analysis above, we propose the following hypotheses:

H_2: Economic policy uncertainty inhibits hog farming scale-up through pathways that amplify the impact of factor prices and exacerbate hog price volatility.

H_{2a}: Economic policy uncertainty amplifies the impact of capital prices on scale-up hog farming.

H_{2b}: Economic policy uncertainty amplifies the impact of labour prices on scale-up hog farming.

H_{2c}: Economic policy uncertainty exacerbates hog price volatility and raises the risks faced by hog farming, thereby inhibiting scale-up hog farming.

Variables and data source

To test the effect of economic policy uncertainty on hog farming scale-up, we set the following variables.

Dependent variable: Number of newly registered scale hog farms (SHF). Since there is a lack of continuous tracking survey data from micro subjects, this study measures the scale-up of hog farming based on the number of newly registered large-scale farms. In terms of the reality of China's hog industry, China's total pork consumption is relatively stable and the self-sufficiency rate of pork is more than 93% year-round. Against the above background, an increase in the number of large-scale farms will be accompanied by a decrease in the number of small-scale farmers. Therefore, any increase in the number of large-scale farmers, regardless of whether such an increase is brought about by the transformation of small-scale farmers into large-scale farmers or the entry of new large-scale farming en-

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tities into the hog farming market, will lead to a decrease in the number of small-scale farmers. Therefore, the increase in the number of large-scale farmers can, to a certain extent, reflect the process of scale-up farming in China's hog industry. In other words, there is a high degree of correlation between the increase in the number of large-scale farms and the scale-up of hog farming. Therefore, it is reasonable to use the number of newly registered large-scale farms to indicate the scale-up of hog farming.

In this article, we use QiChaCha (https://www.qcc.com/) to get the business information of hog farmers in each province. QiChaCha is an enterprise information search tool designed to provide users with quick access to enterprise business information, court decisions, and other services. QiChaCha can show the registered capital, registered place, enterprise name, and other business information of enterprises. However, QiChaCha does not mark whether the farmer is a large-scale farmer. We need to establish a standard to count the number of large-scale farmers registered in each province. According to the National Hog Production Development Plan (2016–2020) issued by the Ministry of Agriculture and Rural Affairs, farmers with an annual output of 500 head or more are considered to be large-scale farmers. This study follows this criterion and considers farmers with an annual slaughtering capacity of 500 head or more as large-scale farmers. To meet the large-scale standard, the farm needs to maintain a stock of 250 live hogs. According to information released by the Government (Peoples Government of Jining city 2024), the initial input cost of a live hog is approximately USD 243.94, based on this, the cost of running a large-scale hog farm is USD 62 985.92. Considering that a new farm also requires fixed assets and other related inputs, USD 70 422.54 is needed to reach the scale-up criteria. Therefore, we counted the number of hog farmers with a registered capital of USD 70 422.54 or more and used it as the explanatory variable.

Through the query, we obtained a total of 419 294 hog farmers' registration information. Among them, there are 89 881 hog farmers with registration amounts above USD 70 422.54, accounting for 2.14%. This is in line with the structural characteristics of the number of Chinese farmers.

Independent variable

Economic policy uncertainty (*EPU*) is our primary independent variable. Economic policy uncertainty refers to the ambiguity of policy objectives due to frequent adjustments in economic policy or changes in government (Bhattacharya et al. 2017; Liu and Zhang 2020). There are two mainstream indicators for measuring China's economic policy uncertainty, constructed by Baker et al. (2016) and Davis et al. (2019), respectively. Baker et al. (2016) developed an EPU index for China utilising the English-language newspaper the 'South China Morning Post' as the primary study object. This index is currently the most extensively used proxy for *EPU*. However, it has obvious flaws. First, it relies on textual data from the 'South China Morning Post', a more subjective source when it comes to assessing China's economic position and policy changes, making it impossible to gauge China's economic policy uncertainties. Second, because English keywords tend to have simpler interpretations than Chinese keywords when used for screening and indexing, the index cannot capture all the words that signify uncertainty in economic policy (Wu et al. 2022). Given these reasons, based on the method according to Baker et al. (2016), Davis et al. (2019) quantified uncertainty-related concepts using two mainland Chinese newspapers: the Renmin Daily and the Guangming Daily. Therefore, this article uses the *EPU* index constructed by Davis et al. (2019) to better describe China's economic policy uncertainty.

Mechanism variable

Hog price fluctuation (HPF). This study sets the *HPF* variable based on the absolute value of the hog price change rate to examine the market risk path of economic policy uncertainty affecting scale-up hog farming.

Control variables

Hog price affects hog production (Rezitis and Stavropoulos 2012) and may have an impact on hog farming scale-up. Therefore, this paper introduces the hog price variable (*price*) in the empirical model. Scaled-up hog farms need to employ labour (Qiao et al. 2016) and wage is a cost item (Onaran and Yentürk 2001; Cheng et al. 2020), which may have an impact on hog scale-up. Therefore, this paper uses income as a proxy variable for wage (*wage*) to control for the effect of wage. The price of capital is an issue that needs to be considered by newly established enterprises (Igwe et al. 2018; Cheng et al. 2020). In this paper, we control for the effect of price changes of capital factors (*R*) on hog scale-up. Since interest rates are controlled by the central government, there is less regional heterogeneity in interest rates. Therefore, we use the level of interest rates at the national level as a control variable. In addition, the business environment is an obstacle to the operation of the enterprise (Igwe et al. 2018). The

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amount of primary industry investment can represent the business environment in which hog farmers operate. We introduced the variable primary industry investment (*PII*) in our model to control the effect of the business environment on the scale-up of hog farming. The degree of scale-up hog farming may be affected by the level of economic development of the region. Therefore, referring to existing studies (Bhattacharya et al. 2017), we introduce the gross domestic product (*GDP)* variable in the empirical model. The data for the control variables in this paper were obtained from the National Bureau of Statistics (National Bureau of Statistics 2022) Descriptive statistics of the main variables are shown in Table 1.

Model construction

Fixed-effects models are mostly used to analyse panel data (Kang et al. 2014; Gulen and Ion 2016; Drobetz et al. 2018; Liu and Zhang 2020). Referring to existing studies, this paper uses a fixed-effects model to analyse the effect of economic policy uncertainty on scale-up hog farming. Setting up the model requires consideration of omitted variables as well as two-way causality, both of which may lead to endogeneity problems that reduce the reliability of the estimation results. First, in China, there are differences in hog production planning in different provinces. To avoid the endogeneity problem caused by the omission of provincial differences in the model, individual effects are added to the empirical model in this paper. Second, the hog industry is vulnerable to external contingencies. Hog farming scale-up may be affected by factors that change over time. To avoid the omission of time-varying variables affecting the estimation results, this paper adds time effects to the empirical model. Third, there may be a two-way causal relationship between policy uncertainty and scale-up. To reduce the endogenous problem of *EPU*, the *EPU* variable is lagged by one period.

To estimate the impact of policy uncertainty on the scale of hog farming, we set the following empirical model:

$$SHF_{it} = \alpha EPU_{t-1} + \beta X_{it} + \lambda_t + u_i + \varepsilon_{it} \quad (1)$$

where: SHF_{it} – number of newly registered scale hog farms of the province; *i* in the period *t*; *EPU* – variable of economic policy uncertainty; X_{it} – control variables; ε_{it} – random disturbance term; α and β – parameters to be estimated, respectively; λ and *u* – time effects and individual effects, respectively.

To verify that policy uncertainty amplifies the impact of capital and labour prices on scale-up hog farming, we set up the following empirical model:

$$SHF_{it} = \alpha EPU_{t-1} + \delta EPU_{t-1} \times R_t + \beta X_{it} + \lambda_t + u_i + \varepsilon_{it} \quad (2)$$

$$SHF_{it} = \alpha EPU_{t-1} + \delta EPU_{t-1} \times wage_t + \beta X_{it} + \lambda_t + u_i + \varepsilon_{it} \quad (3)$$

Table 1. Descriptive statistics of variables

Variable	Variable description	Obs.	Mean	SD	Min	Max
SHF	number of large-scale farms by province	2 480	14.96	22.22	0.00	404.00
EPU	economic policy uncertainty index	2 480	278.65	116.80	106.81	661.83
HPF	fluctuations in hog prices calculated based on hog prices	2 449	7.21	6.55	0.07	32.61
Price	hog prices by province	2 480	20.06	7.72	11.06	36.62
R	price of capital	2 480	3.15	0.68	1.64	4.91
Wage	income of the population by province (log)	2 418	10.02	0.49	9.13	10.77
PII	investment in the primary sector by province (log)	2 263	8.80	0.90	6.32	10.02
GDP	level of gross domestic product by province (log)	2 418	9.26	1.13	5.47	11.73

SHF – scale hog farms; *EPU* – economic policy uncertainty; *HPF* – hog price fluctuation; *R* – control variable; *PII* – primary industry investment; *GDP* – gross domestic product; SD – standard deviation; Obs. – observations

Source: Author's own processing

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where: *R* – capital price; *wage* – labour price; δ – parameter to be estimated. The other variables remain consistent with the Equation (1).

This study sets up the following empirical model to test the pathways through which policy uncertainty affects hog price volatility and thus scale-up hog farming.

$$HPF_{it} = \alpha EPU_{t-1} + \beta X_{it} + \lambda_t + u_i + \varepsilon_{it} \quad (4)$$

where: *HPF* – hog price fluctuation. The other variables remain consistent with the Equation (1).

RESULTS AND DISCUSSION

Benchmark regression analysis

There are inter-provincial differences in the layout of China's hog farming industry, and there may be heteroscedasticity issues in the data. To avoid the problem of heteroscedasticity causing a decrease in the credibility of the estimation results, we use robust standard error for estimation. The benchmark regression results are shown in Table 2.

This paper uses ordinary least squares (OLS) regression to initially test the effect of economic policy uncertainty on hog farming scale-up. According to the empirical results of Model 1 and Model 2, economic policy uncertainty significantly inhibits hog farming scale-up. This effect is reduced by adding control variables to the model.

To avoid the unobserved individual effects and time effects from affecting the estimation results, we add individual effects and time effects in the empirical model one by one. According to the empirical results of Model 3, the effect of economic policy uncertainty on hog farming scale-up does not change much after considering the individual effect. After considering the individual and time effects together, according to the empirical results of Model 4, the effect of economic policy uncertainty on the scale-up of hog farming de-

Table 2. Benchmark regression results of economic policy uncertainty affecting hog farming scale-up

Variable	Model 1	Model 2	Model 3	Model 4
	OLS (SHF)	OLS (SHF)	FE (SHF)	FE (SHF)
EPU	–0.040***	–0.017***	–0.0180***	–0.006**
	(0.000)	(0.000)	(0.000)	(0.000)
Price	–	0.084	0.051	–0.297***
	–	(0.140)	(0.110)	(0.100)
R	–	–2.787*	–2.899**	–2.807***
	–	(1.430)	(1.080)	(0.760)
Wage	–	–33.135***	–10.116	–2.668
	–	(2.370)	(8.470)	(7.250)
PII	–	13.114***	13.519***	7.168***
	–	(0.940)	(2.780)	(1.530)
GDP	–	6.512***	–13.288	–9.260
	–	(0.350)	(8.560)	(6.680)
Constant	25.976***	178.305***	127.807***	75.416***
	(1.220)	(15.150)	(27.040)	(19.840)
Province FE	–	–	yes	yes
Year FE	–	–	no	yes
Observations	2 449	2 201	2 201	2 201
R-squared	0.045	0.166	0.150	0.232

***significance at the level of 1%, respectively; robust standard errors in parentheses; OLS – ordinary least squares; FE – fixed effect; *SHF* – scale hog farms; *EPU* – economic policy uncertainty; *R* – goodness of fit; *PII* – primary industry investment; *GDP* – gross domestic product

Source: Author's own processing

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creases and the model's *R*-squared improves. Obviously, OLS and fixed-effects models that only consider individual effects overestimate the effect of economic policy uncertainty on hog farming scale-up. According to the empirical results of Model 4, the *EPU* variable is negative at the 5% significance level, indicating that economic policy uncertainty significantly inhibits scale-up hog farming. The coefficient of the *EPU* variable is 0.06, indicating that each unit increase in economic policy uncertainty leads to a 0.006 unit decrease in hog farming scale-up. Hypothesis H_1 is verified. The significance of the control variables is in line with theoretical expectations.

Endogenous discussion and robustness test

This paper is based on large sample estimation, which circumvents the endogeneity problem caused by sample selection bias. Therefore, this paper discusses the possible endogeneity problems in terms of measurement bias, bi-directional causality, and omitted variables, and conducts robustness tests to ensure the reliability of the conclusions.

First, regarding measurement bias. The calculation criteria of hog scale-up may affect the estimation results. To avoid this issue, we raised the threshold for determining the scale of hog farming and counted the number of hog farmers with registered capital over USD 140 845.07. We re-ran the empirical model using the newly calculated number of hog scale farmers. Model 5 in Table 3 presents the robustness test results considering the variable calculation threshold. According to the empirical results, the coefficient of the *EPU* variable is negative at the 1% level of significance, indicating that economic policy uncertainty inhibits hog farming scale-up.

Second, regarding bi-directional causality. To reduce the effect of bidirectional causality, this paper uses lagged one-period core explanatory variables for the regressions. Further, referring to existing studies (Nunn and Qian 2014), we use the lagged terms of the core explanatory variables as instrumental variables for two-stage least squares (2SLS) regression to further weaken the endogeneity problem. The empirical results are shown in Model 6 in Table 3. According to the empirical results, the coefficient of the *EPU* variable is negative at the 5% significance level, indicating that economic policy uncertainty inhibits hog farming scale-up.

Third, regarding omitted variables. To reduce the effect of omitted variables, this paper controls for both individual effects and year effects to reduce the endogeneity problem caused by omitted variables. Further, since this study is based on panel data, which may be affected by dynamic panels (i.e. the level of scale farming in the current period is affected by scale farming in the previous period), thus generating endogeneity problems due to omitted variables, this study further uses a dynamic panel model for generalised method of mo-

Table 3. Robustness test results of economic policy uncertainty affecting hog farming scale-up

Variable	Model 5	Model 6	Model 7	Model 8
	FE (SHF)	2SLS (SHF)	GMM (SHF)	Poisson (SHF)
EPU	–0.005***	–0.038**	–0.007***	–0.001***
	(0.000)	(0.020)	(0.000)	(0.000)
Constant	49.088***	141.031***	–	–
	(11.510)	(29.080)	–	–
Control variables	yes	yes	yes	yes
Province Fe	yes	yes	–	yes
Year FE	yes	yes	–	yes
Observations	2 201	2 201	2 201	2 201
R-squared	0.227	0.208	–	–
AR(1)	–	–	0.036	–
AR(2)	–	–	0.180	–
Hansen test	–	0.309	0.355	–
Wald *F*	–	19.164	–	–

***, **, *significance at the level of 1%, 5%, and 10%, respectively; robust standard errors in parentheses; FE – fixed effects; 2SLS – two-stage least squares; GMM – generalised method of moments; SHF – scale hog farms; *EPU* – economic policy uncertainty; AR – arellano-Bond test

Source: Author's own processing

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ments GMM estimation, and the empirical results are shown in Model 7 in Table 3. According to the empirical results, the coefficient of the *EPU* variable is negative at the 1% significance level, indicating that economic policy uncertainty inhibits hog farming scale-up.

In addition, since the explanatory variable in this paper is a count variable, regression bias may arise based on OLS regression. Therefore, we further conduct a robustness test based on panel Poisson regression, and the results are shown in Model 8 in Table 3. According to the empirical results, after using panel Poisson regression, the coefficient of the economic policy uncertainty variable is still negative at the 1% significance level, indicating that economic policy uncertainty significantly inhibits hog farming scale-up.

The above results indicate the reliability of the basic findings of this study.

Mechanism analysis

As previously discussed, economic policy uncertainty may amplify the effects of labour and capital factor prices on scale-up hog farming. To test this hypothesis, we introduce interaction terms between economic policy uncertainty and labour and capital prices in our model. The results are presented in Table 4. According to Model 9, the interaction coefficient between *EPU* and *R* is significantly negative at a 5% level and consistent with the direction of *R*, suggesting that the impact of economic policy uncertainty on hog farming scale-up increases as the capital price rises. The empirical results of Model 9 suggest that economic policy uncertainty exacerbates the impact of capital prices on scale-up hog farming. Hypothesis H_{2a} is verified. Similarly, Model 10 shows that the interaction coefficient between *EPU* and wage is significantly negative at a 5% level and consistent with the direction of wage, suggesting that the impact of economic policy uncertainty on hog farming scale-up increases as the labour price rises. The empirical results of Model 10 indicate that economic policy uncertainty exacerbates the impact of capital prices on scale-up hog farming. Hypothesis H_{2b} is verified.

As previously discussed, economic policy uncertainty has exacerbated hog price volatility, which has raised the risks faced by hog farming. This, in turn, has reduced the willingness of farmers to expand their farming scale, thus inhibiting hog scale-up. To test this hypothesis, we take hog price fluctuation as an explanatory variable for the empirical test, and the empirical results are shown in Model 11 in Table 4. According to the empirical results, the coefficient of the *EPU* variable is negative at the 1% significance level, suggesting that economic policy uncertainty significantly exacerbates hog price volatility, which can inhibit hog farming scale-up. Hypothesis H_{2c} is verified.

Heterogeneity analysis

Heterogeneity of scale. As the size of enterprises increases, their financing channels tend to be enriched (Schiantarelli 1996), which can affect their risk-taking capacity (Schiantarelli 1996; Gulen and Ion 2016). We divided our sample into three groups based on registered capital: medium-scale (MS) farmers with registered capital between USD 70 422.54 and USD 704 225.35; large-scale (LS) farmers with registered capital between USD 704 225.35 and USD 1 408 450.70; and super-scale (SS) farmers with registered capital exceeding USD 1 408 450.70. On this basis, we conduct empirical tests on the three subsamples above separately. Model 12–Model 14 in Table 5 report the effect of economic policy uncertainty on the scale-up of hog farming for different-

Table 4. Mechanism verification results of economic policy uncertainty affecting hog farming scale-up

Variable	Model 9	Model 10	Model 11
	SHF	SHF	HPF
EPU	–0.006**	–0.002	0.001***
	(0.000)	(0.000)	(0.000)
EPU×R	–0.008**	–	–
	(0.000)	–	–
EPU×wage	–	–0.014**	–
	–	(0.010)	–
R	–2.923***	–2.826***	0.175***
	(0.760)	(0.760)	(0.000)
Wage	–2.638	–2.721	–6.978***
	(7.260)	(7.230)	(0.420)
Constant	75.328***	79.908***	35.748***
	(19.870)	(20.100)	(0.930)
Control variables	yes	yes	yes
Province FE	yes	yes	yes
Year FE	yes	yes	yes
Observations	2 201	2 201	2 201
R-squared	0.232	0.233	0.377

***, **, *significance at the level of 1%, 5%, and 10%, respectively; SHF – scale hog farms; HPF – hog price fluctuation; *EPU* – economic policy uncertainty; *R* – goodness of fit; FE – fixed effect

Source: Author's own processing

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sized farmers. According to the empirical results, the coefficients of the *EPU* variables are all negative at a 1% significance level for different scales of hog farming scale-up, indicating that economic policy uncertainty has a negative impact on different scales of hog farming scale-up. In terms of coefficient magnitude, the coefficients of *EPU* variables in MS, LS, and SS groups are –0.005, –0.002 and –0.001, respectively, indicating that the impact of economic policy uncertainty on hog farming scale-up decreases as the scale of farmers increases.

Heterogeneity of economic policy uncertainty level. Economic policy uncertainty does not always inhibit large-scale hog farming. The study has found that industrial policy can also have a positive impact on the hog industry (Wang et al. 2022; Li et al. 2024). Under this perspective, the lower level of policy uncertainty generated when the government moderately intervenes in the hog industry may promote scale-up hog farming. To test the above heterogeneity, this study divides the sample into a low economic policy uncertainty level group (LEPU) and a high economic policy uncertainty level group (HEPU) based on the 25% quartile of the policy uncertainty level. On this basis, we empirically test the above two subsamples separately, and the empirical results are shown in Model 15 and Model 16 in Table 5. The empirical results show that, for the LEPU group, the coefficient of the *EPU* variable is positive at the 1% significant level, indicating that lower economic policy uncertainty can significantly promote scale-up hog farming. For the HEPU group, the coefficient of the *EPU* variable is negative at the 5% significant level, indicating that higher economic policy uncertainty can significantly inhibit scale-up hog farming. In terms of the magnitude of the coefficients, the coefficients of the *EPU* variable for the LEPU and HEPU groups are 0.090 and –0.008, respectively, indicating that economic policy uncertainty promotes more than inhibits scale-up hog farming.

Heterogeneity of region. In April 2016, the Ministry of Agriculture and Rural Affairs issued the 'National Hog Production Development Plan (2016–2020)', which categorises hog breeding areas into four types: Main Development Areas (MADA), Constrained Development Areas (CODA), Potential Growth Areas (PODA), and Moderate Development Areas (MODA). Table 6 presents China's regional plan for hog breeding development.

There are three main tasks for the main development areas. First, relying on the existing development foundation accelerates the transformation and upgrading of the hog industry, and improves the level of scale, standardisation, industrialisation, and information technology. The second is to promote the green development of the hog industry. Third, use local breed resources to develop special hog breeding. There are two main tasks of the constrained development area.

Table 5. Heterogeneity empirical results of economic policy uncertainty affecting hog farming scale-up on different scales and economic policy uncertainty level

Variable	Model 12	Model 13	Model 14	Model 15	Model 16
	different scale			different economic policy uncertainty level	
	MS	LS	SS	LEPU	HEPU
EPU	–0.005***	–0.002***	–0.001***	0.090***	–0.008**
	(0.000)	(0.000)	(0.000)	(0.020)	(0.000)
Constant	63.790***	22.502***	3.712**	155.129***	58.269**
	(12.660)	(5.070)	(1.500)	(32.530)	(24.640)
Control variables	yes	yes	yes	yes	yes
Province FE	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes
Observations	2 201	2 201	2 201	589	1 612
R-squared	0.218	0.173	0.132	0.267	0.181

***, **, *significance at the level of 1%, 5%, and 10%, respectively; MS – medium scale farmers; LS – large scale farmers; SS – super scale farmers; LEPU – low economic policy uncertainty group; HEPU – high economic policy uncertainty level group; *EPU* – economic policy uncertainty; FE – fixed effect; *R* – goodness of fit

Source: Author's own processing

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Table 6. Regional plan for hog farming development in China

PODA	MODA	MADA	CODA
Liaoning	Shanxi	Hebei	Beijing
Jilin	Shaanxi	Shandong	Tianjin
Heilongjiang	Gansu	Henan	Shanghai
Neimenggu	Xinjiang	Chongqing	Jiangsu
Yunnan	Xizang	Guangxi	Zhejiang
Guizhou	Qinghai	Sichuan	Fujian
–	Ningxia	Hainan	Anhui
–	–	–	Jiangxi
–	–	–	Hubei
–	–	–	Hunan
–	–	–	Guangdong

PODA – potential growth areas; MODA – moderate development areas; MADA – main development areas; CODA – constrained development areas

Source: The Ministry of Agriculture and Rural Affairs (2016)

One is to promote the green development of the hog industry, and the other is to develop the modern hog industry. There are three main tasks in the potential growth area. The first is to expand the scale of production and increase production and efficiency. The second is to promote the green development of the hog industry. The third is to promote the infrastructure construction of the hog industry. The main tasks of the moderate development area are three. First, actively guide large enterprise groups to build breeding bases and improve production levels. Second, promote the green development of the hog industry. The third is to develop a regional special hog industry according to local hog breeds.

Due to the different development objectives of the hog industry, there are differences in the impact of economic policy uncertainty on the scale-up of hog farming in different regions. We conduct empirical tests on the subsamples of different regions separately, and the empirical results are shown in Table 7. According to the empirical results, for the MADA group, the coefficient of *EPU* is negative at the 5% level of significance, indicating that economic policy uncertainty significantly inhibits scale-up hog farming in the MADA region. The coefficients of the *EPU* variable in the other groups are not significant, indicating that economic policy uncertainty does not affect scale-up hog farming in CODA, PODA, and MODA regions.

Table 7. Heterogeneity empirical results of economic policy uncertainty affecting hog farming scale-up in different regions

Variable	Model 17	Model 18	Model 19	Model 20
	MADA	CODA	PODA	MODA
EPU	–0.010**	–0.003	–0.000	–0.003
	(0.000)	(0.000)	(0.000)	(0.000)
Constant	33.890	60.758***	41.689*	44.803
	(43.850)	(10.480)	(18.980)	(28.500)
Control variables	yes	yes	yes	yes
Province FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
Observations	497	781	426	497
R-squared	0.422	0.172	0.396	0.238

***, **, *significance at the level of 1%, 5%, and 10%, respectively; MADA – main development areas; CODA – constrained development areas; PODA – potential growth areas; MODA – moderate development areas; *EPU* – economic policy uncertainty; FE – fixed effect; *R* – goodnees of fit

Source: Author's own processing

CONCLUSION AND DISCUSSION

Using panel data from 2016–2022 and a fixed-effects model, this paper empirically examines the impact of economic policy uncertainty on scale-up hog farming. Our results indicate that economic policy uncertainty significantly inhibits the scale-up of hog farming. The basic conclusions continue to hold after we conduct robustness tests by the alternative threshold for calculating scale-up, using the 2SLS model, using a dynamic panel model, and using a panel Poisson regression model. The mechanism analysis has found that, on the one hand, the economic policy uncertainty amplifies the effects of labour and capital prices on scale-up. On the other hand, economic policy uncertainty raises the market risk faced by hog farming, further inhibiting farmers' willingness to expand hog farming. Heterogeneity analysis reveals that, first, the impact of economic policy uncertainty on hog farming scale-up decreases as the scale of farmers increases. Second, only when economic policy uncertainty is at a high level, economic policy uncertainty will have an inhibitory effect on scale-up hog farming. When economic policy uncertainty is at a low level, economic policy uncertainty instead promotes scale-up hog farming, and the

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promotion effect is greater than the inhibition effect. Third, economic policy uncertainty has had a dampening effect on scale-up farming in the main hog-producing areas, and an insignificant dampening effect on scale-up hog farming in other areas.

Although the research in this paper is based on macroscopic indicators of economic policy uncertainty, the findings have implications for government policy formulation and implementation in the hog industry. The hog industry in China is highly influenced by policy interventions. First, when there is a shortage of pork supply, government departments intervene in the hog industry to promote hog production. For example, when the hog industry is affected by external emergencies such as severe acute respiratory syndrome (SARS), avian influenza, and African swine fever, to stabilise the production of livestock products, the government takes measures to stabilise production. Second, the government intervenes in the hog farming industry to protect the environment and improve land use efficiency. For instance, the Ministry of Agriculture issued the 'National Hog Production Development Plan (2016–2020)' (The Ministry of Agriculture and Rural Affairs 2016), which provides regional adjustments for hog farming. In addition, the government also intervenes in pork prices through the central reserve meat policy. When pork prices fall within a certain warning range, the government may purchase or sell pork to stabilise prices. The government's 'decide as occasion demands' adjustment policy is intended to correct market failure, inadvertently improving the policy uncertainty.

Policy implications

Based on the research conclusions, we get the following policy implications:

i) The government should reduce its intervention in hog farming to avoid creating large economic policy uncertainty, particularly in the main hog development areas. These areas are responsible for ensuring the national pork supply. To minimise the negative impact of policy uncertainty on these areas, government departments should engage in long-term planning for the industry.

ii) Comprehensive measures should be taken to reduce the impact of policy uncertainty on hog farming scale-up. One approach could be to use financial subsidies or low-interest rates to promote hog farming scale-up, as the hog industry is highly susceptible to policy changes and carries significant risks. Additionally, since the impact of policy uncertainty on hog farming scale-up decreases as the size of farmers increases, the government could implement graduated financial subsidies based on the size of hog farmers. This approach could not only promote hog farming scale-up but also improve the efficiency of financial fund usage.

iii) A compensation mechanism for policy changes should be established. This would help mitigate the impact of policy changes on hog farmers. For example, when implementing restriction or prohibition policies, the government should consider the time needed for farmers to exit the market and dispose of their assets rather than adopting a 'one size fits all' approach. Compensation should be provided for new investments made before the introduction of restriction policies to protect the interests of hog-breeding farmers.

iv) A fault-tolerant and corrective mechanism should be established. Due to the subjectivity of policy implementation, there may be deviations in the process, such as designating forbidden areas beyond the intended scope or constructing 'no hog cities' or 'no hog counties' in the name of environmental protection, which can harm the scale-up intentions of hog farmers. To address these issues, higher-level departments should strengthen their supervision of policy implementation and regularly evaluate its effectiveness.

Limitations

There are some limitations in our study:

i) Our analysis focuses on the impact of macroeconomic policy uncertainty on hog farming scale-up. In future research, the concept of policy uncertainty could be extended to examine the impact of hog industry policy uncertainty on hog farming scale-up.

ii) Our study does not differentiate between different types of economic policy uncertainty. As such, we do not analyse the impact of different types of policy uncertainty on hog farming scale-up. Future research could refine the analysis by considering different policy types and examining the impact of various types of policy uncertainty on hog farming scale-up.

iii) Limited by data availability, we discuss the response of hog farming scale-up to economic policy uncertainty in terms of the number of large-scale farming entities. Although this approach can answer the questions we raise to a certain extent, it would further enrich the established research findings if we could discuss the impact of policy uncertainty on hog farming scale-up from the perspective of micro-individual size change. Therefore, future studies also need to obtain data in micro-individuals to further expand the existing research.

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