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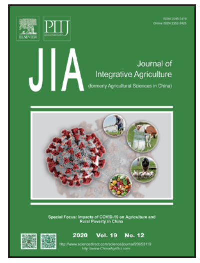

RESEARCH ARTICLE

The short- and long-term impacts of the COVID-19 pandemic on family farms in China — Evidence from a survey of 2 324 farms

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Abstract

Family farms are considered the most desirable form of Chinese agriculture. Studies on the risk management of family farms are rare, while the COVID-19 pandemic provides an opportunity to explore how family farms respond to risks. Based on an online survey of 2 324 family crop farms, we examine for the first time the short-term impact (immediate impact or short-term fluctuation, and farms' instantaneous response) and long-term impact (on farms' future or long-term production) of the COVID-19 pandemic on family farms' production and operation in rural China. By using factor analysis and dummy variable regression, we find that the severity of the pandemic, the lockdown of the village, and farmers' knowledge of the pandemic contribute significantly to the short-term impact, but not on the long-term impact. Farmers' characteristics such as gender, age, and education are not related to the short-term impact, but family farms with male owners or owners with high school education or below are more likely to be diversified and large-scale. The number of years the farm has existed for and agricultural insurance affect both short-term and long-term impacts. We suggest that the government needs to pay more attention to stability-enhancing policies, the market environment, vocational training and the agricultural insurance market.

Keywords: family farms, COVID-19, agricultural risk, China

1. Introduction

Compared to other types of agricultural operators, such as smallholder farmers, cooperatives and leading agricultural enterprises, family farms are the most suitable and desirable form of agricultural production and management in China (Du 2018a). First, family farms are larger than traditional smallholder farms, which makes family farms more capable of coping with risks. Second, family farms connect smallholder farmers, cooperatives and leading agricultural enterprises. Unlike cooperatives and leading enterprises, family farmers stay at the forefront of the agricultural supply chain, mainly working on primary agricultural products. Multiple family farms can jointly establish cooperatives, and cooperatives are the main form of agricultural cooperation. Family farms can also get technical services, processing services and marketing services from leading agricultural enterprises. Therefore, family farms have great importance

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to China's agricultural and rural development[1].

A large and growing body of literature has investigated family farms' behaviors of production and management in China, including functions (Du and Liu 2017; Du 2018b), land use and transfer (Gao 2020), hiring of labor (Gao *et al*. 2020), green production (Cai and Du 2016; Xia *et al*. 2019), and the impact of policy (Liu *et al*. 2018). Family farmers face market risks, natural risks, policy risks, social risks, management risks, and technical risks (He 2018; Liu *et al*. 2019). So far, however, there has been little discussion about family farms' risk response and risk behaviors, especially in the context of huge and unexpected disasters.

The COVID-19 pandemic, which started in early 2020, poses huge risks for agricultural production. It provides a natural experiment for evaluating risk responses among family farms. Unlike other kinds of risks, the COVID-19 pandemic does not affect family farms directly. It is the side effects caused by anti-pandemic measures that influence family farms' behaviors. For example, the COVID-19 pandemic may create uncertainty for the global food market, which may lead to fluctuations in food supply and price.

Family farms in China play an important role in achieving China's agricultural policy goals. Among different types of family farms, family crop farms (family farms that focus on planting crops) are expected to ensure the supply of grain, oil, cotton, and other primary agricultural products. Family crop farms are essential to food security in China. Therefore, the study of the risk response and behaviors of family crop farms is of great theoretical and practical significance.

Based on an online survey of family farms in February 2020, we examine the short- and long-term impacts of the COVID-19 pandemic on family farms in China. The "short-term impact" refers to the immediate shocks caused by the anti-pandemic measures and the immediate responses of family farms. This includes impacts on daily production and operation, spring tillage and planting, agricultural inputs, sales, and costs, as well as behavioral responses such as whether emergency measures taken. The "long-term impact" refers to future or long-term production plans or ideas, including planting structure adjustment, land-scale adjustment, and willingness to participate in various agricultural insurance programs. We find that mechanisms for short- and long-term effects are different. We suggest that the government needs to provide vocational education and training for family farm owners, create a policy and market environment that suits the long-term and stable operation of family farms, and improve the agricultural insurance market.

The novelty of this paper is twofold. First, we expand research on family farms by examining both the short- and long-term impacts of the COVID-19 pandemic. As far as we know, this is the first investigation on the impact of the COVID-19 pandemic on family farms in China. Second, since China has the largest number of family farms of any country and family farm is the core agricultural production and management entity, this paper contributes to the research on the COVID-19 pandemic globally.

The remaining parts of the paper proceed as follows: the second section introduces data and methods; the third section first describes the short- and long-term impacts of the COVID-19 pandemic on family farms, then presents the common factors and their scores, and the results of regressions; the fourth section discusses the determinants of the short- and long-term impacts of COVID-19 on family farms; and the last section concludes with policy implications.

2. Data and methods

2.1. Data

The data used in the paper are from a nationwide online survey conducted between February 9th and 13th, 2020. The online survey was initiated and designed by the Family Farms Monitoring and Research Team (FFMRT) at the Rural Development Institute, Chinese Academy of Social Science[2]. The survey aimed to examine the short- and long-term impacts of the COVID-19 pandemic on family farms. The questionnaires were publicized and distributed *via* WeChat by members of FFMRT and governmental officials who are in charge of family farms affairs. Due to the limitations of the online survey, we were not able to select samples randomly. A total of 9 527 family farms were involved in the online survey, covering 29 provinces, municipalities

[1] By the end of 2018, nearly 600 thousand family farms were registered with the Ministry of Agriculture and Rural Affairs of China (MARA). Among these registered family farms, 83 thousand farms were selected as model family farms at the county level or above. The total operating land area of family farms in China was 162 million mu (10.8 million hectares) in 2018, accounting for 8.01% of the national cultivated area. The total value of agricultural products sold by family farms reached 194.62 billion CNY, with an average of 324 thousand CNY per family farm. Data from MARA: http://www.zcggs.moa.gov.cn/gzdt/202003/t20200327_6340082.htm

[2] The team was set up in 2013 to undertake monitoring and research on family farms as entrusted by the formely Ministry of Agriculture (MOA). Professor Du Zhixiong from the Rural Development Institute, Chinese Academy of Social Sciences is the team leader. The team is working closely with MOA/MARA and has jointly published the annual development report on family farms since 2014.

and autonomous regions in mainland China[3]. According to MOARA, there were about 800 thousand family farms in the monitoring system in 2019. Therefore, more than 1% of total registered family farms were involved in our survey. The high coverage of our survey (in terms of locations and number of cases) provides an excellent dataset with rich information on family farms, and also helps to alleviate the issue of non-random sample selection.

We exclude cases with missing values and those that are outliners in terms of key variables. After this, we are left with 6 704 family farms that focus on planting (2 324), animal husbandry (315), or both (4 065). Given the importance of family crop farms and the different mechanisms of operation among different types of family farms, this paper restricts the sample to the family crop farms, which gives us 2 324 cases for the analysis.

2.2. Sample characteristics

We show the characteristics of family crop farm owners in Table 1 and the operation characteristics of family crop farm owners in Table 2.

According to Table 1, (1) the majority owners of family crop farms were male, accounting for 82.23%; (2) in terms of age, more than 70% of family farm owners are over 40 years old, while less than 30% are under 40; (3) most of the owners' are educated at the high school level or below. Only 25.39% of family farm owners have a college education or above; (4) most family farm owners are familiar with the COVID-19 pandemic; less than 1% of farmers report that they know the COVID-19 pandemic very little; (5) in terms of the duration of family crop farms, more than 80% of family crop farms last over two years, and 17.05% of family crop farms have been operated for two years or less.

According to Table 2, (1) the proportion of family crop farms with a scale of 100 mu (1 mu=1/15 ha) or less, more than 100 mu and less than or equal to 200 mu, more than 200 mu and less than or equal to 400 mu, and more than 400 mu accounted for 27.02, 24.05, 23.97 and 24.96% of the sample respectively; (2) nearly 39% of family crop farms were engaged in contract farming. Thus, about 1/3 of family crop farms signed an agricultural products sales contract before the COVID-19 pandemic. About 2/3 of family crop farms did not sign one; (3) more than 40% of family crop farms purchased agricultural insurance before the COVID-19 pandemic. Nearly 60% of family crop farms were not covered by agricultural insurance; (4) due to the COVID-19 pandemic, 95% of the villages of family crop farms enforced a lockdown.

2.3. Methods

We adopt the principal-component factor analysis (PCF) and the dummy variable regression to carry out the quantitative analysis. Specifically, we use PCF to get common factors and their scores by reducing ten indictors of the short-term impact and three indictors of the long-term impact. The scores of common factors for the short- and long-term impacts are used as the explained variables in the dummy variable regression, in which we examine the effect of the severity of the COVID-19 pandemic, characteristics of farmers, and characteristics of farm management on the

Table 1 The characteristics of family crop farm owners

Variables	Labels/Values	Observations	Percent (%)
Male	Female	413	17.77
	Male	1 911	82.23
Age (Years)	≤30	125	5.38
	(30, 40]	555	23.88
	(40, 50]	987	42.47
	(50, 60]	609	26.20
	>60	48	2.07
Education	High school or below	1 734	74.61
	College or above	590	25.39
Knowledge of COVID-19	Very little	15	0.65
	A little	957	41.17
	Much	1 352	58.18
Duration of the farm (years)	≤2	396	17.05
	(2, 4]	645	27.75
	(4, 6]	790	33.99
	>6	493	21.21

[3] Although we would like to include samples from all regions in mainland China, there were no respondents from Tibet or Xinjiang.

Table 2 The operation characteristics of family crop farms

Variables	Labels/Values	Observations	Percent (%)
Farm scale (mu)[1)]	≤100	628	27.02
	(100, 200]	559	24.05
	(200, 400]	557	23.97
	>400	580	24.96
Contract farming	No	1 424	61.27
	Yes	900	38.73
Agricultural insurance	No	1 281	55.12
	Yes	1 043	44.88
Village in lockdown	No	116	4.99
	Yes	2 208	95.01

[1)] 1 mu=1/15 ha.

short- and long-term impacts of the COVID-19 pandemic on family farms.

Data reduction by factor analysis Indicators for the short- and long-term impacts of the COVID-19 pandemic on family farms are multi-dimensional. These indicators are not independent of each other. It is difficult to calculate and compare the overall short- or long-term impacts of the COVID-19 pandemic on family farms by looking at these indicators directly. According to Cattell (1978) and StataCorp (2019), since some indicators have common characteristics that may be correlated in some respect, we can reduce the number of variables by using the PCF method. Since PCF can help us to find common factors that are more easily interpreted, PCF is widely used as a statistical technique for data reduction (Barrett *et al*. 1974; Bai and Ng 2002; Ingram and Neumann 2006; Pukthuanthong and Roll 2009). From those common factors, we can create a single index that captures the overall short- or long-term impacts. Those indices can be used as explained variables in regressions. We use ten indicators to measure the short-term impact and three indicators to measure the long-term impact, as shown in Table 3.

Model We use the following model to explore the determinants of the short- and long-term impact of the COVID-19 pandemic on family crop farms:

$$Y_i^a=\alpha_0+\beta M_i+\sum_{k=1}^{k=5}\lambda_k Z_{ki}+\sum_{m=1}^{m=5}\varphi_m W_{mi}+\delta D_i+\varepsilon_i \quad (1)$$

where Y_i^a refers to the impact of the COVID-19 pandemic on the farm *i*. We let Y_i^a equal the component score of F_1, F_2, F_3 or F when examining the short-term impact. We let Y_i^a equal the component score of M_1 when considering the long-term impact.

α_0, β, λ_k, φ_m, and δ are the parameters to be estimated. ε_i is the random error. When the coefficient of β, λ_k, φ_m or δ is greater than zero, the short-term adverse impact on family farms is more serious and family farms are more likely to diversify and scale up in the long-term. When the coefficient of β, λ_k, φ_m or δ is less than zero, it is the opposite.

M_i is the incidence rate, the number of COVID-19 cases per 10 000 people, in the province where the farm *i* is located. Since the online survey was launched on February 9th, 2020, we use the number of COVID-19 cases in each province by February 9th, 2020. The resident population in each province is taken from the *China Statistic Yearbook 2019* (NBSC 2020), which provides statistical data at the end of 2018. The incidence rate represents the severity of the COVID-19 pandemic in each province at the time of the online survey. From the coefficient of M_i and its significance level, we can see how the severity of the pandemic influences short- and long-term impacts on family farms.

Z_{ki} is a set of variables that reflect the characteristics of family farm owners, including owners' knowledge of the COVID-19 pandemic, age, gender, education, and the number of years the farm has existed for.

W_{mi} is a set of variables related to the characteristics of family farms, including land area and its square, whether the village was in lockdown during the pandemic, whether the farm was engaged in contract farming before the pandemic, and whether the farm purchased agricultural insurance before the pandemic.

D_i indicates whether farm *i* is located in a national key poverty-stricken county.

Potential endogeneity For the model in eq. (1), there may be potential endogeneity problems from omitted variables. For example, the family farmers' abilities, which are not included in the model, can affect both farm operation and responses to COVID-19. Local economic conditions and government capacities are also related to the extent to which COVID-19 was controlled.

The OLS model in the paper does not have serious endogeneity problems because of the nature of the variables used in the model. The explained variables, the short- and long-term impacts of COVID-19 (F, F_1, F_2, F_3, and M_1), reflect judgments and decisions of family farms after the pandemic. Meanwhile, most of the explanatory variables are facts that occurred before the pandemic. The incidence rate, with which this paper is concerned, is an exogenous shock.

To better address the omitted variables and to obtain a

Table 3 Indicators to measure the short- and long-term impacts of the COVID-19 pandemic

Types	Indicators	Values/Labels/Units
Short-term impact	Sales revenue (X_1)	1=Increase by 60% or more
		2=Increase by 40–60%
		3=Increase by 20–40%
		4=Increase by less than 20%
		5=No change
		6=Decrease by less than 20%
		7=Decrease by 20–40%
		8=Decrease by 40–60%
		9=Decrease by 60% or more
	Sales volume (X_2)	1=Increase by 20% or more
		2=Increase by less than 20%
		3=No change
		4=Decrease by less than 20%
		5=Decrease by 20–40%
		6=Decrease by 40% or more
	Cost increased (X_3)	%
	Spring tillage and spring planting (X_4)	1=No impact
		2=Small impact
		3=Medium impact
		4=Large impact
		5=Huge impact
	Purchase of agricultural materials (X_5)	1=No impact
		2=Can purchase 60–80% of needed
		3=Can purchase 40–60% of needed
		4=Can purchase 20–40% of needed
		5=Can purchase less than 20% of needed
		6=Cannot purchase any
	labor hiring (X_6)	1=No impact
		2=Can hire 60–80% of needed
		3=Can hire 40–60% of needed
		4=Can hire 20–40% of needed
		5=Can hire less than 20% of needed
		6=Cannot hire any
	Can perform daily activities (X_7)	0=Yes
		1=No
	Land transfer (X_8)	1=Increase by 20% or more
		2=Increase by less than 20%
		3=No impact
		4=Decrease by less than 20%
		5=Decrease by 20% or more
		6=No plan of land transfer
	Help, support, or guidance from high level organizations	0=No
	(e.g., associations of farms, cooperatives) (X_9)	1=Yes
	Number of emergency measures (X_{10})	Number
Long-term impact	Planting structure in the future (D_1)	1=Decrease species
		2=No changes
		3=Increase species
	Farm scale in the future (D_2)	1=Decrease scale
		2=No change
		3=Increase scale
	Willing to buy agricultural insurance in the future (D_3)	0=No
		1=Yes

consistent estimate like a "fixed effect" model, we employ a dummy variable regression and control county dummies in regressions. According to Wooldridge (2016), we should control each farm as a dummy variable in the dummy variable regression. A common risk of putting too many individual dummies into regressions is that software like Stata will not produce the result because of matrix problems. Instead of using dummies at the farm level, here we use dummies at the county level. First, we have 2 324 family farms in 538 counties. On average, each county has 4.3 family farms. Thus, county dummies are a suitable replacement of individual farm dummies in reality. Second, 223 counties only have one family farm. This 10% of cases presents no problems for the dummy variable regression.

There are another 83 counties that have only two family farms. Together there are fewer than eight farms in 469 counties, which cover 57% of the sample. The distribution of family farms in counties ensures that models with county dummies can produce approximate "fixed effect" estimation results.

3. Results

3.1. Descriptions of the impact of the COVID-19 pandemic on family crop farms

When faced with the unexpected COVID-19 pandemic, family farms instinctively formulated a short-term response strategy to reduce the immediate impact of the pandemic. Besides the preliminary impact, the pandemic had a profound impact on family farms' perceptions and attitudes towards risks, as well as their long-term production and management strategies. In this section, we distinguish the short- and long-term impacts of the COVID-19 pandemic on family crop farms. "Short-term impact" refers to immediate shocks caused by anti-pandemic measures and the immediate responses of family farms. "Long-term impact" refers to how the future or long-term production plans or ideas are affected by the COVID-19 pandemic; these effects may have a more significant long-term impact on China's agriculture and deserve more attention.

The short-term impact of the COVID-19 pandemic on family crop farms The short-term impact of the COVID-19 pandemic on family crop farms includes impact on daily production and operation, spring tillage and planting, agricultural inputs, sales income, and emergency responses.

First, family crop farms' daily production, operation, spring tillage and planting have been greatly affected by the COVID-19 pandemic. Table 4 shows that nearly 70% of family crop farms were unable to carry out daily production and operation activities due to the pandemic. Since the pandemic occurred during the spring season, only 13% of family crop farms reported no impacts from the pandemic on spring tillage and spring planting. In contrast, nearly half of family crop farms said the pandemic had a large or huge impact on their spring tillage and spring planting.

Second, the COVID-19 pandemic had a large effect on agricultural inputs. During the pandemic, governments imposed restrictions on the movement of people and vehicles. Most villages implemented traffic control and closed roads in and out of villages. Those anti-pandemic measures affected the availability of agricultural inputs, including agricultural materials, labor and land transfer. According to Table 5, (1) more than one-third of family crop farms were unable to purchase any agricultural materials. Only about one quarter of family crop farms indicated that their purchase of agricultural materials was not affected; (2) although it was not the season for high labor demand, hiring of labor on farms was seriously affected by the COVID-19 pandemic. About 36% of farms could not hire any labor because of the pandemic, whereas only 17% of farms reported that their hiring was not affected by the pandemic; and (3) land transfer was partly affected by the COVID-19 pandemic. In our sample, 19% of farms did not have any plan for land transfer. Nearly 70% of farms have plans for land transfer, and their plans are not affected by the COVID-19 pandemic. Nearly 10% of farms would reduce land transfer, while only 1.5% of farms would increase land transfer. Compared with effects on agricultural materials and labor, the demand for land is much less affected by the pandemic. The reason for the small impact of the COVID-19 pandemic on land transfer is that land transfer usually occurs during autumn and was thus largely completed before the pandemic. Demands and purchases of agricultural materials and labor, however, are made during the pandemic.

Third, 80% of family crop farms have adopted emergency measures to deal with the pandemic. Table 6 shows that multiple emergency measures may be implemented at the same time. For example, 46% of farms made labor arrangements in advance; 44% of farms carried out agricultural operations such as seeding in advance; 22% of the farms purchased seeds, fertilizers, pesticides and other materials in advance; 21% of farms purchased agricultural machinery services in advance; 14.94% of farms sold inventory products in advance or speeded up the sale; 18.71% of farms negotiated land leases in advance. Among different emergency measures, the majority are labor-related. The dominance of labor-related measures

Table 4 The short-term impacts of the COVID-19 pandemic on production, operation, spring tillage and planting

Variables	Labels/Values	Observations	Percent (%)
Daily production and operation	Cannot perform daily activities	1 594	68.59
	Can perform daily activities	730	31.41
Spring tillage and planting	No impact	302	12.99
	Small impact	489	21.04
	Medium impact	418	17.99
	Large impact	731	31.45
	Huge impact	384	16.53

Table 5 The short-term impacts of the COVID-19 pandemic on agricultural inputs

Variables	Labels/Values	Observations	Percent (%)
Impact on the purchase of agricultural materials	No impact	606	26.08
	Can purchase 60–80% of requirements	274	11.79
	Can purchase 40–60% of requirements	232	9.98
	Can purchase 20–40% of requirements	194	8.35
	Can purchase less than 20% of requirements	149	6.41
	Cannot purchase any requirements	869	37.39
Impact on labor hiring	No impact	384	16.52
	Can hire 60–80% of amount needed	262	11.27
	Can hire 40–60% of amount needed	285	12.26
	Can hire 20–40% of amount needed	199	8.56
	Can hire less than 20% of amount needed	352	15.15
	Cannot hire any labor	842	36.24
Impact on areas of land transferred	Increase by 20% or more	14	0.60
	Increase by less than 20%	21	0.90
	No impact	1 620	69.71
	Decrease by less than 20%	109	4.69
	Decrease by 20% or more	121	5.21
	Not applicable (no plan of land transfer)	439	18.89

Table 6 Emergency measures adopted by family crop farms

Variables	Labels/Values	Observations	Percent (%)
Emergency measures	No	437	18.80
	Yes	1 887	81.20
Types of emergency measures	Arrange labor in advance	864	45.79
	Carry out agricultural operations in advance	829	43.93
	Buy seeds, fertilizers, pesticides and other materials in advance	410	21.73
	Buy machinery services in advance	400	21.20
	Negotiate land leases in advance	353	18.71
	Sell inventory products in advance or speed up the sale	282	14.94

indicates that labor shortage may still be a problem for family farms even though it is now common for machines to have replaced labor in many agricultural tasks.

Fourth, for most of the family farms, sales volume and sales revenue are expected to fall, while costs are expected to rise. The falling sales and rising operating costs have an adverse effect on the income growth of family crop farms. According to Table 7, (1) nearly two-thirds of farms reported a decrease in their sales volume. One-fifth of farms expected to reduce sales volume by 40 percentage points or more. Nearly one-third of farms expected to hold their sales volume. Only 2.54% of farms expected an increase in sales volume; (2) more than 80% of farms reported a decrease in their sales revenue. Nearly one-quarter of farms expected to reduce sales revenue by 40 percentage points or more. And 17% of farms expected to hold their sales revenue. Only 2.79% of farms expected an increase on sale revenue; and (3) over 70% of farms reported that their operating costs would rise by 20–40 percentage points; while 7.5 and 21.5% of farms expected that their cooperating costs would increase by more than 40 percentage points and less than 20 percentage points, respectively.

The long-term impact of the COVID-19 pandemic on family crop farms "Long-term impact" refers to effects on the future or long-term production plans or ideas, including planting structure adjustment, scale adjustment, and willingness to purchase agricultural insurance, as shown in Table 8.

First, 47% of family crop farms reported that they would adjust their future planting structure: 17% of farms will increase the number of species they plant and 29% will reduce the number of species. As suggested in other studies (Valdivia *et al*. 1996; Dercon 1996; Zhang and Liu 2016; Zou *et al*. 2019), planting structure adjustment is a traditional method of managing risks. Large-scale agricultural operators like family farms can use planting structure adjustment more flexibly to deal with risks.

Second, 24% of farms reported that they would reduce their current scale, while 9% of farms reported that they would increase their current scale. Together, 33% of farms wish to adjust their scale to manage risks. The remaining 67% of farms, however, will hold their current scale.

Third, 84% of farms said that they are willing to buy agricultural insurance in the future. The high level of

Table 7 The short-term impacts of the COVID-19 pandemic on sales volume, sales revenue and operating costs

Variables	Labels/Values	Observations	Percent (%)
Impact on sales volume	Increase by 20% or more	35	1.51
	Increase by less than 20%	24	1.03
	No change	750	32.28
	Decrease by less than 20%	546	23.49
	Decrease by 20–40%	509	21.90
	Decrease by 40% or more	460	19.79
Impact on sales revenue	Increase by 20% or more	24	1.03
	Increase by less than 20%	41	1.76
	No change	397	17.08
	Decrease by less than 20%	659	28.36
	Decrease by 20–40%	625	26.89
	Decrease by 40–60%	348	14.98
	Decrease by 60% or more	230	9.90
Impact on costs	Increase by less than 20%	499	21.47
	Increase by 20–40%	1 651	71.04
	Increase by 40% or more	174	7.49

Table 8 The long-term impacts of the COVID-19 pandemic on family crop farms

Variables	Labels/Values	Observations	Percent (%)
Planting structure in the future	Decrease species	674	29.00
	No changes	1 246	53.61
	Increase species	404	17.39
Farm scale in the future	Decrease scale	552	23.75
	No change	1 565	67.34
	Increase scale	207	8.91
Willing to buy agricultural insurance in the future	No	370	15.92
	Yes	1 954	84.08

willingness to purchase agricultural insurance indicates that family crop farms have realized the importance of agricultural insurance after experiencing a pandemic that has generated real risks.

3.2. Common factors and their scores

First, we check whether our data is suitable for factor analysis. The Kaiser-Meyer-Olkin (KMO) test value for the ten indicators of short-term impact is 0.810, which indicates the proportion of variance in those ten indicators may be caused by underlying factors. The The Bartlett's Test of Sphericity Chi-square value for the ten indicators of short-term impact is 3 768 and is statistically significant at 0.001 which suggests that the ten indicators are related and therefore suitable for structure detection. As to the three indicators of long-term impact, the KMO test value is 0.506 and Bartlett's test value is 321 and is statistically significant at 0.001. Both validity tests show that the ten indicators of short-term impact and the three indicators of long-term impact are suitable for factor analysis.

Second, we select three common factors (F_1, F_2 and F_3) for the short-term impact and one common factor (M_1) for the long-term impact, depending on whether the eigenvalue is larger than 1. Table 9 shows that percentages of explained variance for F_1, F_2 and F_3 are 21.37, 19.11 and 11.84, respectively. The accumulated percentage of explained variance for F_1, F_2 and F_3 is 52.32. The percentage of explained variance for M_1 is 45.56.

Third, we use the rotated component matrix to determine what the common factors represent. Table 10 shows that the common factor F_1 is most highly correlated with X_1, X_2, X_3 and X_4, which suggests that F_1 mainly represents the operational efficiency of family farms. The common factor F_2 is most highly correlated with X_5, X_6, X_7 and X_8, which indicates that F_2 mainly represents resource allocations of family farms. The common factor F_3 is most highly correlated with X_9 and X_{10}, which means that F_3 mainly represents risk perceptions and responses of family farms. As to the common factor M_1 for the long-term impact in Table 11, M_1 is most highly correlated with D_1 and D_2, which implies that M_1 mainly represents adjustments to planting structure and scale in the future.

Fourth, we use the component score coefficient matrix

Table 9 Explained variance after rotating

Types	Common factors	Percentages (%)	Accumulated percentage (%)
Short-term impact (*F*)	F_1	21.37	21.37
	F_2	19.11	40.48
	F_3	11.84	52.32
Long-term impact (*M*)	M_1	45.56	45.56

Table 10 The rotated component matrix and component score coefficient matrix of the common factors for short-term impact (F_1, F_2 and F_3)

Indicators of short-term impact	Rotated component matrix			Component score coefficient matrix		
	F_1	F_2	F_3	F_1	F_2	F_3
Sales revenue (X_1)	0.8230	0.0999	–0.0002	0.4671	–0.1818	0.0080
Sales volume (X_2)	0.7762	0.1845	–0.0346	0.4131	–0.1124	–0.0152
Cost increase (X_3)	0.6208	0.1303	–0.0247	0.3356	–0.1014	–0.0109
Spring tillage and spring planting (X_4)	0.5749	0.4875	0.0342	0.1995	0.1606	0.0659
Purchase of agricultural materials (X_5)	0.1239	0.7658	–0.0483	–0.1577	0.4813	0.0154
labor hiring (X_6)	0.2550	0.7266	–0.0313	–0.0665	0.4160	0.0272
Can perform daily activities (X_7)	0.2126	0.5676	–0.1451	–0.0440	0.3120	–0.0819
Land transfer (X_8)	–0.0446	0.4066	0.0879	–0.1503	0.2974	0.1052
Help, support, or guidance from high level organizations (e.g., associations of farms, cooperatives) (X_9)	–0.0921	0.0129	0.7633	–0.0589	0.0933	0.6537
Number of emergency measures (X_{10})	0.0747	–0.1023	0.7524	0.0769	–0.0368	0.6360

(as shown in Tables 10 and 11) to calculate the component scores for each common factor. The scores of individual common factors and overall common factors are calculated as follows:

$$F_1=0.4671X_1+0.4131X_2+0.3356X_3+0.1995X_4–0.1577X_5–0.0665X_6–0.0440X_7–0.1503X_8–0.0589X_9+0.0769X_{10}$$

$$F_2=0.4671X_1+0.4131X_2+0.3356X_3+0.1995X_4–0.1577X_5–0.0665X_6–0.0440X_7–0.1503X_8–0.0589X_9+0.0769X_{10}$$

$$F_3=0.0080X_1–0.0152X_2–0.0109X_3+0.0659X_4+0.0154X_5+0.0272X_6–0.0819X_7+0.1052X_8+0.6537X_9+0.6360X_{10}$$

$$F=(21.37/52.32)F_1+(19.11/52.32)F_2+(11.84/52.32)F_3$$

$$M_1=0.5962D_1+0.5949D_2+0.1491D_3$$

For the short-term impact, the higher the values of the ten indicators, the more adverse the effects of the COVID-19 pandemic on family farms. Accordingly, the higher the values of the component scores, the more adverse the effects of the COVID-19 pandemic on family farms. For example, the higher the value of the common score of F_1, the more adverse the effects of the COVID-19 pandemic on family farms' operational efficiencies, such as sales volume, sales revenue and costs. By aggregating the common scores of F_1, F_2 and F_3 with weights of explained variance, we can get an overall common score (*F*). Similarly, the higher the value of *F*, the more adverse the effects of the COVID-19 pandemic on family farms.

For the long-term impact, the higher the values of the three indicators, the more likely family farms are to be diversified, large-scale, and have insurance. Since the common factor M_1 is more related to D_1 and D_2, the higher the value of M_1, the more diversified and large-scale family farms are.

The scores and distributions of *F*, F_1, F_2, F_3, and M_1 are shown in Table 12.

First, the incidence rate, lockdown of the village, knowledge of COVID-19 and contract farming are positively correlated with short-term impact, but there is a negative correlation between agricultural insurance and short-term impact. According to Table 12, (1) the higher the value of the incidence rate, the larger the scores of *F* and F_1; (2) the scores of *F*, F_1, F_2 and F_3 for family farms with "lockdown of the village" are larger than those without "lockdown of the village". This means that lockdown of the village has a large negative impact on family farms in the short-term; (3) the scores of *F*, F_1, F_2 and F_3 for those who report a lot of knowledge of COVID-19 are larger than the scores of those with little or very little knowledge of COVID-19; (4) the score of *F* for family farms with contract farming is larger than the score for family farms without contract farming; and (5) the scores of *F*, F_1 and F_2 for the family farms with agricultural insurance are smaller than the scores for family farms without agricultural insurance.

Second, incidence rate and education level are negatively correlated with long-term impact, but having a male owner, contract farming and agricultural insurance are positively correlated with long-term impact. According to Table 12, (1) the higher the value of the incidence rate, the smaller the score for M_1. This means that family farms that experienced a more severe pandemic tended to be less diversified

Table 11 The rotated component matrix and component score coefficient matrix of the common factors for long-term impact (M_1)

Indicators of long-term impact	Rotated component matrix	Component score coefficient matrix
	M_1	M_1
Planting structure in the future (D_1)	0.8150	0.5962
Farm scale in the future (D_2)	0.8132	0.5949
Willing to buy agricultural insurance in the future (D_3)	0.2038	0.1491

Table 12 The mean scores of common factors (F_1, F_2 and F_3) and overall common factors (F and M_1)

Variables	Labels/Values	F	F_1	F_2	F_3	M_1
Overall		0.0000	–0.0000	0.0000	0.0000	0.0000
Incidence rate (number of COVID-19 cases per 10000)	≤0.04	–0.1548	–0.2829	0.0224	–0.2097	0.1156
	(0.04, 0.05]	–0.0399	0.0139	–0.1555	0.0497	0.0847
	(0.05, 0.12]	0.0619	0.0409	0.1052	0.0297	–0.0501
	>0.12	0.0834	0.1348	0.0358	0.0672	–0.1056
Village lockdown	0=No	–0.2614	–0.1390	–0.5254	–0.0565	–0.1091
	1=Yes	0.0137	0.0073	0.0276	0.0030	0.0057
Knowledge of COVID-19	1=Very little	–0.2403	–0.1365	–0.2551	–0.4040	–0.0010
	2=A little	–0.0401	–0.0167	–0.0300	–0.0986	0.0057
	3=Much	0.0310	0.0133	0.0241	0.0743	–0.0040
Male	0=Female	0.0294	0.0035	0.0839	–0.0119	–0.0866
	1=Male	–0.0063	–0.0008	–0.0181	0.0026	0.0187
Age (years)	≤30	–0.0306	0.0038	–0.1872	0.1599	–0.0697
	(30, 40]	0.0385	0.1238	–0.0024	–0.0492	0.0017
	(40, 50]	–0.0060	–0.0343	0.0070	0.0239	0.0182
	(50, 60]	–0.0108	–0.0555	0.0404	–0.0127	–0.0218
	>60	–0.1049	–0.0318	–0.1414	–0.1782	0.0638
Education	0=High school or below	–0.0149	–0.0513	0.0306	–0.0229	0.0425
	1=College or above	0.0439	0.1507	–0.0900	0.0672	–0.1248
Farm scale (mu)[1)]	≤100	0.0180	0.1577	–0.0712	–0.0900	–0.0020
	(100, 200]	0.0146	–0.0082	0.0424	0.0111	0.0265
	(200, 400]	–0.0092	–0.0144	0.0054	–0.0234	–0.0252
	>400	–0.0248	–0.1490	0.0311	0.1092	0.0008
Duration of farm (years)	≤2	0.0222	0.0004	0.0575	0.0045	0.0972
	(2, 4]	0.0428	0.0611	0.0914	–0.0686	–0.0363
	(4, 6]	–0.0291	–0.0403	–0.0291	–0.0091	0.0264
	>6	–0.0271	–0.0157	–0.1190	0.1006	–0.0729
Contract farming	0=No	–0.0351	–0.0151	0.0324	–0.1799	–0.0260
	1=Yes	0.0555	0.0239	–0.0512	0.2846	0.0411
Agricultural insurance	0=No	0.1009	0.2230	0.0649	–0.0616	–0.0596
	1=Yes	–0.1239	–0.2739	–0.0797	0.0756	0.0733
Poor county	0=No	–0.0056	–0.0015	–0.0141	0.0007	–0.0054
	1=Yes	0.0672	0.0177	0.1697	–0.0088	0.0649

[1)] 1 mu=1/15 ha.

and large-scale; (2) compared to owners with high school education or below, the M_1 score for owners with college education or above is smaller; (3) the M_1 score for family farms with male owners is larger than it is for family farms with female owners; and (4) compared to family farms without contract farming or agricultural insurance, the M_1 score for family farms with contract farming or agricultural insurance is larger.

3.3. Regression results

Scores of common factors (F_1, F_2 and F_3) and overall common factors (F and M_1) are used as the explained variables in the dummy variable regression. Descriptive statistics of explaining variables are shown in Table 13.

We estimate the model of the overall short-term impact (F) in column 1 in Table 14 and the model of the overall long impact (M_1) in column 2. We also estimate models of the three common factors of the short-term impact (F_1, F_2 and F_3) in columns 3, 4 and 5, respectively. The F-statistics of the five models (row 17) are all statistically significant at the level of 0.0000 (row 18), which indicates good fits for the regressions. Values of R^2 for five models (row 16) are nearly 0.3 or above.

4. Discussion

4.1. The determinants of the short-term impact of COVID-19 on family farms

From columns 1, 3, 4 and 5 in Table 14, we have the following main results related to the short-term impact of the COVID-19 pandemic on family farms.

First, the more severe the pandemic, the greater the short-term impact on family farms. For example, the figure in row 1, column 1 is positive and statistically significant, which means the incidence rate of COVID-19 is positively

Table 13 Descriptive statistics of variables

Variables	Labels/Values/Units	Mean	SD	Min	Max
Incidence rate (number of COVID-19 cases per 10000 people)	Person	0.3845	1.1419	0.0213	4.5800
Village lockdown	1=Yes, 0=No	0.9501	0.2178	0	1
Knowledge of COVID-19	1=Very little, 2=A little, 3=Much	2.5753	0.5073	1	3
Male	1=Male, 0=Female	0.8223	0.3824	0	1
Age	Years	45.22	8.50	21	78
Education	0=High school or below, 1=Junior college or above	0.2539	0.4353	0	1
Farm scale (area of land)	mu[1)]	336.70	412.51	10	3000
Duration of farm	Years	5.02	3.16	1	34
Contract farming	1=Yes, 0=No	0.3873	0.4872	0	1
Agricultural insurance	1=Yes, 0=No	0.4488	0.4975	0	1
Poor county	1=Yes, 0=No	0.0766	0.2660	0	1

[1)] 1 mu=1/15 ha.

Table 14 The determinants of the short- and long-term impacts of COVID-19 on family farms

Variables	F	M_1	F_1	F_2	F_3
	(1)	(2)	(3)	(4)	(5)
1. Incidence rate of COVID-19	0.1021***	–0.0735	0.0993*	0.2024***	–0.0548
	(0.0361)	(0.0627)	(0.0598)	(0.0607)	(0.0620)
2. Village lockdown	0.2460***	–0.0317	0.1745*	0.4279***	0.0814
	(0.0624)	(0.1084)	(0.1033)	(0.1049)	(0.1072)
3. Knowledge of COVID-19	0.0723***	–0.0160	0.0218	0.0777*	0.1548***
	(0.0261)	(0.0453)	(0.0432)	(0.0439)	(0.0448)
4. Male	–0.0013	0.1392**	0.0884	–0.1194**	0.0277
	(0.0356)	(0.0618)	(0.0589)	(0.0598)	(0.0611)
5. Age	–0.0001	0.0000	–0.0036	0.0033	0.0008
	(0.0017)	(0.0029)	(0.0028)	(0.0028)	(0.0029)
6. Education	0.0105	–0.2147***	0.1115**	–0.0697	–0.0424
	(0.0332)	(0.0576)	(0.0549)	(0.0557)	(0.0569)
7. Farm scale (area of land)	0.0000	0.0001	–0.0001	0.0002	0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
8. Farm scale squared	–0.0000	–0.0000	0.0000	–0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
9. Years of duration of farm	–0.0044	–0.0176**	–0.0007	–0.0093	–0.0031
	(0.0044)	(0.0076)	(0.0073)	(0.0074)	(0.0076)
10. Contract farming	0.0871***	0.1192**	0.0729	–0.0852*	0.3908***
	(0.0285)	(0.0495)	(0.0472)	(0.0479)	(0.0489)
11. Agricultural insurance	–0.1625***	0.2416***	–0.3523***	–0.0922*	0.0667
	(0.0314)	(0.0546)	(0.0520)	(0.0528)	(0.0540)
12. Poor county	–0.0222	0.8012	–0.8770*	0.8086	0.1795
	(0.3085)	(0.5354)	(0.5105)	(0.5182)	(0.5296)
13. County dummies	Yes	Yes	Yes	Yes	Yes
14. Constant	–0.5883	–0.6518	–0.1150	–1.2720*	–0.3391
	(0.4006)	(0.6953)	(0.6629)	(0.6729)	(0.6877)
15. N	2324	2324	2324	2324	2324
16. R^2	0.3386	0.2999	0.3636	0.3442	0.3150
17. F	1.6540	1.3840	1.8465	1.6960	1.4860
18. Prob>F	0.0000	0.0000	0.0000	0.0000	0.0000

Standard errors in parentheses; ***, P<0.01; **, P<0.05; *, P<0.1.

related with the overall short-term impact *F*. Specifically, the incidence rate has adverse effects on family farms' efficiency (figure in row 1, column 3) and resource allocations (figure in row 1, column 4).

Second, the lockdown of the village significantly increased the short-term impact of the COVID-19 pandemic on family farms, as shown by the figure in row 2, column 1. Since the lockdown of the village is mainly affecting transportation, the coefficient in row 2, column 4, is much bigger than other coefficients in column 1. The lockdown of the village makes it hard to buy agricultural materials, hire laborers and perform daily operations.

Third, the knowledge of the COVID-19 increased the short-term impact of the COVID-19 pandemic on family farms, as shown by the figure in row 3, column 1. This may be because the more farm owners understand the COVID-19 pandemic, it indicates that the short-term behavior of their farm production and operation is more affected by the pandemic and more timely emergency measures are taken.

Fourth, family farm owners' personal characteristics have no significant effect on the overall short-term impact of the COVID-19 pandemic on family farms. The coefficients of age, gender and education for the model of *F* in column 1 are not statistically significant. Female owners, however, received more shocks to resource allocations than male owners, as shown by the figure in row 4, column 4.

Fifth, the scale and the duration of the farm have no significant effect on the short-term impact of the COVID-19 pandemic on family farms. All the coefficients related to scale and duration in columns 1, 3, 4, and 5 are not statistically significant.

Sixth, contract farming has mixed effects on the short-term impact of the COVID-19 pandemic on family farms. Compared to farms without contract farming, farms with contract farming have a larger overall short-term impact (row 10, column 1), greater response to the pandemic (row 10, column 5), and fewer shocks to resource allocations (row 10, column 4). The advantages of resource allocation for farms with contract farming may come from two sides. One is that farms with contract farming may have more reserves of agricultural materials with which to fulfill the contract. Another is that partners of contract farmers, such as cooperatives and leading agricultural enterprises, are more likely to be able to provide agricultural materials to farms with contracts. Leading agricultural enterprises and cooperatives play a role in ensuring the supply of important production materials to family farms. Therefore, compared to farms without contract farming, farms with contract farming do not have to directly face the market risks of agricultural materials and other production factors.

Seventh, agricultural insurance can reduce the short-term impact of the COVID-19 pandemic on family farms. Farms with agricultural insurance before the pandemic have lower overall short-term impact (row 11, column 1), and less adverse effects on efficiency (row 11, column 3) and resource allocations (row 11, column 4). As to the response to the pandemic (row 11, column 5), however, the immediate reaction of farms with agricultural insurance is stronger than farms without agricultural insurance.

Eighth, family farms in poor counties are not less affected by the COVID-19 pandemic in the short-term than farms in other regions. Before and after the pandemic, poor counties received a certain degree of special treatment in terms of industrial policies. Although the coefficient of poor county is negative, this effect is not statistically significant (row 12, column 1). Farms in poor counties have less adverse effects on efficiency (row 12, column 3). This may be because many areas have used "consumption poverty alleviation" and other methods to treat agricultural products in poor counties with special treatment.

4.2. The determinants of the long-term impact of COVID-19 on family farms

From column 2 in Table 14, we have the following main results related to the long-term impact of the COVID-19 pandemic on family farms.

First, the severity of the pandemic, the lockdown of the village, and knowledge of the pandemic are not significantly related to the long-term impact of the pandemic on family farms. This suggests that long-term behaviors like adjustment of planting structure and scale are not affected by the pandemic, after controlling other variables.

Second, farm owners' personal characteristics such as gender and education have significant effects on the long-term impact of the COVID-19 pandemic on family farms. Family farms with male owners tend to be more diversified and large-scale than those with female owners. Compared to owners with high school education or below, owners with college education or above are less likely to be diversified and large-scale. Owners with higher education may have made arrangements in terms of diversification and scale during their daily operations. They do not have to wait for huge risks like the COVID-19 pandemic to make adjustments.

Third, the scale of the farm is not significantly related to the long-term impact of the COVID-19 pandemic, but the duration of the farm is. Compared to farms with short duration, farms with a long duration may have more experience and are more mature in terms of dealing with risks. Old farms may implement measures related to risk during daily operations, so they do not have to revise their long-term strategies as dramatically as young farms.

Fourth, contract farming has a positive effect on the long-term impact of the COVID-19 pandemic on family farms. Compared to farms without contract farming, farms with contract farming face the constraints of the contract; that is, they must fulfill the contract at a given time. This constraint has become a burden in case of risks. In order to better balance the pros and cons of the contract, farms with contract farming may have to make adjustments to long-term strategies. Thus, the long-term impact of the COVID-19 pandemic is larger for farms with contract farming.

Fifth, agricultural insurance increases the long-term impact of the COVID-19 pandemic on family farms. Farms with agricultural insurance before the pandemic may be more sensitive to risks and more willing to adjust long-term strategies.

5. Conclusion and policy implications

The COVID-19 pandemic and anti-pandemic measures have changed the supply and demand side of the agricultural industry in China. However, there has been very little empirical study of the impact of the COVID-19 pandemic on family farms. Using an online survey that includes 2 324 family farms, this paper examines for the first time the short- and long-term impacts of the COVID-19 pandemic on family crop farms in China.

Descriptive analysis shows that the impacts of the COVID-19 pandemic on family farms is multi-dimensional. In terms of the short-term impact of the COVID-19 pandemic, farms' daily production, operation, spring tillage and planting, agricultural inputs are greatly affected. Most farms have adopted emergency measures to deal with the pandemic. Most farms' sales volume and sales revenue are expected to fall, whereas their costs are expected to rise. As to the long-term impact of the COVID-19 pandemic on family farms, nearly half of the farms are going to adjust planting structure and one-third of farms are going to change the scale of the farm. More than 80% of farms intend to buy agricultural insurance in the future.

Regressions show that determinants of the short- and long-term impacts of the COVID-19 pandemic on family farms are different. As a specific and real risk, the COVID-19 pandemic affected family farms mainly through anti-pandemic measures. Those measures, however, are temporary and only affect farms in short-term ways. In the long run, those measures have no significant effect on farms. What matters in the long run are human capital related factors, such as education and experience. Those factors exist regardless of the pandemic and determine the long-term path of farm operations. That is why regressions show that personal characteristics are not significantly related to the short-term impact, but affect the long-term impact of the COVID-19 pandemic on family farms.

As to contract farming, it is a double-edged sword. Under normal circumstances, contract farming brings a stable market and reduces risks of sale. When it comes to risks like the COVID-19 pandemic, however, the breach of contract is like a sharp ax that may hit the head of the family farm at any time. Therefore, contract farming is both positive and statistically significant to the short- and long-term impacts of the COVID-19 pandemic on family farms.

Agricultural insurance reduces the short-term impact of the COVID-19 pandemic on family farms, but increases the long-term impact. Family farm owners who had agricultural insurance before the pandemic are a special group of people who are more sensitive to risks. They are more active in both their short-term and long-term responses to the pandemic.

Based on the above results, we suggest policies should focus on three aspects. First, the government needs to continue to provide vocational education and training for family farm owners. By improving the human capital of family farm owners, vocational education and training will increase family farm owners' capacities to handle risks. Second, the government needs to create a policy and market environment that supports the long-term, stable operation of family farms. Stable operators with long duration are capable of dealing with risks. Third, the government needs to improve the agricultural insurance market. The agricultural insurance market should be more open to different agents.

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