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How Do Logistics Disruptions Affect Rural Households? Evidence from COVID-19 in China

Nan Li [1,†], Muzi Chen [2,†] and Difang Huang [3,*,†]

[1] Business School, Shandong Normal University, Jinan 250061, China
[2] School of Management Science and Engineering, Central University of Finance and Economics, Beijing 100081, China
[3] Faculty of Business and Economics, The University of Hong Kong, Hong Kong, China
* Correspondence: difang.huang@outlook.com
† These authors contributed equally to this work.

Abstract: Using a comprehensive survey of rural households during the early stage of the COVID-19 pandemic in China, we find that logistics disruptions due to the lockdown have resulted in severe economic losses for rural households. Insufficient production inputs and perishable outputs can aggravate the impact of logistics disruptions on losses, while the purchase of agriculture insurance and higher regional GDP can mitigate this effect. We further examine the mechanisms by which logistics disruptions affect rural households, including both sales and production channels in agricultural supply chains. The former includes changes in product prices and reduced sales, while the latter includes changes in input prices and shortages of raw materials, capital, and labor. Of these channels, logistics has the most severe impact on sales. Opening up the logistics of sales channels is the primary policy choice. More storage warehouses and insurance are also important preemptive measures. Building stable and sustainable agricultural supply chains can ensure rural household viability during the pandemic.

Keywords: COVID-19; logistics disruptions; supply chain; rural households; income

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1. Introduction

The COVID-19 pandemic has been the most serious global health crisis in recent years. More than 630.6 million confirmed cases and over 6.5 million deaths of COVID-19 were reported to WHO globally by 10 November 2022. During the early period of the COVID-19 pandemic, countries around the world responded in various ways to reduce transmission, including use of social quarantine, traffic control, city lockdown, and other measures to restrict the movement of people. These measures effectively reduced the possibility of the virus spreading [1,2], but also severely impacted countries' economies [3–8].

China adopted rigorous traffic control measures in the early stage of the epidemic to contain the spread of the virus. Between January and March 2020, when COVID-19 was under control, almost all urban and rural communities were in lockdown, and inter-provincial and intra-provincial public transport was strictly restricted. The lockdown measures have seriously impacted China's agricultural production [9–12]. In the agricultural products market, in terms of demand, traditional offline agricultural product sales markets and stores were closed, and purchase demand was reduced due to the lockdown policy; in terms of supply, agricultural products could not be transported and sold due to logistics obstructions. The barrier affecting the sales channel transferred the sales pressure to the production department, resulting in many unsalable agricultural products. With the movement of people severely restricted, the lack of labor makes agricultural production less efficient, affecting output. Data from the Ministry of Agriculture and Rural Affairs show that, as of 10 March 2020, seed sales have decreased by 10–30% compared to the previous year. Rural households' living and economic conditions are also of concern, as

they represent the most vulnerable population [13–15]. A survey of 1733 rural households in China in February 2020 showed that, among those who were recently out of poverty, 23% reported that they might fall back into poverty due to the COVID-19 pandemic [8,16,17].

The most important reason for the significant economic losses caused by COVID-19 is that lockdown measures have severely hampered logistics and disrupted normal supply chains [18–20]. Therefore, after the outbreak of COVID-19, the management of logistics and supply chains has become an important new issue [21–23]. The nature of supply-chain disruptions and their economic impact is a primary research direction. Disruption of the logistics network, a sharp drop in logistics demand, and shortage of transportation capacity are the main impacts of COVID-19 on the logistics industry [24,25]. The labor supply shock to the supply chain is also an important aspect of the impact of the lockdown [10,16,26]. The extent to which logistics are disrupted and the characteristics of the supply chain determine the economic losses experienced [27–29]. As for supply-chain management, resilience and sustainability are key issues [30–33]. Logistics disruptions continue to affect agriculture, small and medium-sized enterprises, and cross-border supply [8,16,34–36]. Recognizing the specific difficulties and corresponding management strategies is an important part of post-epidemic logistics management [20,21].

Some studies have examined the impact of logistics disruptions on the supply chain of agricultural products. Vegetable supply-chain disruptions are a driver of price increases and sales reductions [5,37,38]. Disruptions to hog transportation immediately impact both price and consumption [39,40]. Lockdowns have impacted the entire agricultural production system, blocking agricultural product input and output channels [9,16,41,42], leading to food supply shortages and price increases [3,43–45]. The extent of the impact of the lockdown on agriculture is related to both market infrastructure and COVID-19 policies [18,36,46,47]. Further, lockdowns also harmed household production and income, including rural household production and sales [48–50] and caused household economic losses [6,17,51–57].

For a country like China, where a low income rural population is in the majority, the losses suffered by rural households during the pandemic are of great concern. This is of great significance to the country's economic development and social stability. Rural household losses are often closely related to logistics and supply chain conditions. Therefore, considering the logistics and supply chains in the study of rural household losses, exploring the impact channels of logistics disruption on the loss, and comparing the differences among different channels are important for the formulation of relevant policies and the recovery of agricultural supply chains.

Although the existing literature includes extensive studies on rural household economic losses and the agricultural supply chain during COVID-19, there are still some gaps. First, there is a lack of quantitative empirical research on rural household losses caused by farmer-specific logistics situations based on rural household survey data. Most of the literature concerns investigations of the production or economic status of rural households in the context of lockdown and has not addressed the relationship between logistics obstruction and rural household losses through econometric models. Secondly, the literature includes studies of the impact of micro- and macro-factors on rural household losses under lockdown, but has not yet examined the role of these factors in rural household losses caused by logistics obstruction. Third, rural household losses in the early stage of COVID-19 are mostly related to the disruption of agricultural supply chains, but there are no studies that consider multiple links in agricultural supply chains as part of a framework for understanding the impact of logistics disruptions on rural household losses.

The purpose of this paper is not only to understand the extent of losses caused by logistics obstruction to rural households, but, more importantly, to explore the mechanisms underpinning the impact. What is the impact of logistics disruption on rural household losses? What product features and external measures in the production process can reduce the impact of logistics disruptions? Through which supply chain channels do logistics obstructions cause the loss of rural households, and what are the different impacts of

the various channels? Research on these issues will help to build sustainable logistics systems, enhance the resilience of supply chains, and, ultimately, improve the resilience of rural households. In the early stages of the COVID-19 outbreak in 2020, we collected survey data on 2408 rural households in 17 provinces in China. The data included basic characteristics, types of operations, multiple logistics and production-related variables, and different dimensions of loss. Based on this data, we employed a quantitative approach to investigate the impact of logistics disruption on rural household losses.

Our study makes a number of contributions. First, based on a sample of diverse types of rural households, we examine the relationship between logistics disruption and rural household losses. We use a rural household logistics disruption variable to reflect the real logistics situation of each rural household under lockdown. We also use three loss measures to comprehensively assess rural household losses during the period of the most stringent lockdowns. Moreover, our sample types are diverse, including a variety of industries and operation scales and, hence, compared with use of a single type of sample [37], the conclusions derived are more general. Second, we consider the heterogeneity of household responses to logistics disruptions, taking into account product characteristics, insurance purchased, and macroeconomics. This should enable rural households and policymakers to adopt targeted mitigation measures based on heterogeneity when dealing with logistics disruptions. Third, we incorporate the impact of logistics disruptions on multiple parts of the agricultural supply chain into a theoretical framework, reflecting the impact mechanisms of logistics disruptions on rural household losses. The channels include sales and production, which have six dimensions. In the literature, the influence channels of COVID-19 on rural households and agricultural production have mostly been analysed qualitatively [9]; however, this paper quantifies the impact of logistics on these channels. In addition, based on a comparison of multiple channels, we are able to determine the degree of impact of logistics disruptions on different channels, so that policymakers can prioritize solutions to the most serious supply-chain problems.

The remainder of this paper is organized as follows: Section 2 discusses the research hypothesis. Section 3 describes the data used and outlines the methodology. Section 4 discusses the main results of the paper. Section 5 reports the discussion, and Section 6 presents the conclusions.

2. Hypothesis

2.1. The Impact of Logistics Disruption on Rural Household Losses

At the beginning of the COVID-19 outbreak, most countries implemented lockdown policies. This policy impedes normal logistics between regions. Logistics obstruction causes rural households' to experience sales and production difficulties, resulting in losses. On the one hand, rural household products cannot be transported to the sales market in time, resulting in overstocking of agricultural products or even damage [58], causing direct economic losses to rural households. On the other hand, production materials in stock are limited and cannot be replenished in a timely way [49], and scarcity of labor [37,38] results in a substantial increase in production costs, or even production stagnation, generating indirect economic losses for rural households. Therefore, the following research hypothesis is proposed:

H1. *Logistics disruption increases the losses of rural households.*

2.2. Potential Factors

Many factors play a role in affecting the impact that logistics disruption has on rural household losses, enhancing or weakening the degree of impact, resulting in heterogenous impacts of logistics disruption on rural household losses.

At the micro level, rural household production characteristics are directly related to the degree of influence of logistics. On the supply side, logistics disruptions prevent the timely arrival of production materials to rural households, so, sufficient and long-

term storage of production materials can alleviate supply shortages. In contrast, difficult-to-store production materials can increase rural household losses. On the output side, logistics obstacles prevent products from being promptly transported to the sales market or distributors. Therefore, perishable outputs are more sensitive to logistics disruptions, increasing economic losses [59–61]. In addition, whether to buy agricultural insurance is also closely related to losses. Although different types of agricultural insurance cover different risk situations, agricultural insurance can compensate for agricultural production losses caused by logistics disruption only to a certain extent.

At the macro level, the economic situation of the region in which a rural household is located can play a positive role in mitigating the impact of logistics on losses. In poverty-stricken regions of China, the damage caused by logistics disruptions to the stocking of agricultural products is particularly severe [58]. Generally, rural households in developed areas have stronger management ability and better income status, and greater ability to resist external risks. Governments with higher fiscal revenues can provide additional means of production, subsidies, and other assistance to help rural households address production problems. Financial institutions in developed regions have better operating profits and more accessible loan facilities, so are likely to provide more loans or extend loans to rural households to help relieve economic pressure. The following research hypothesis is proposed:

H2. *Insufficient production inputs and perishable outputs aggravate the impact of logistics disruption on rural household losses. Purchases of agriculture insurance and higher regional GDP reduce this impact.*

2.3. Economic Mechanism

Logistics disruption may cause rural households economic losses through sales and production channels, as shown in Figure 1. Relevant studies are listed in Table A2. The sales channel includes sales volume and price. In the early days of COVID-19, inter-city logistical arrangements sought to ensure that medical needs were addressed first, with the sale of goods reduced in priority. Both theoretically and investigation-based studies suggested that, due to the disruption of logistics, a large number of agricultural products could not be transported to the trading market, resulting in overstocked products and a significant reduction in sales [9,37,38,49,52,58]. According to supply and demand theory, the equilibrium market price of agricultural products is determined by supply and demand. Based on survey, the price changes have been found to be different for different regions, markets, and products [62]. The lockdown measures impose very stringent restrictions on transportation from producers to the markets and from one market to another. A reduction in supply has led to a rise in selling prices, while shortages of labor and production materials have contributed to a rise in prices by reducing output. In addition, on the demand side, consumers are likely to hoard food due to the COVID-19 panic, which also pushes up prices [37]. However, it has been hypothesized that there is a substitution effect between perishables and non-perishables and that a decrease in demand for certain perishables will lead to a decrease in their price. Most available studies have concluded that the prices of agricultural products rose in the early stages of COVID-19. Compared with surveys of prices based on the retail market or the wholesale market that are presented in the existing literature [37,62], we investigate the sales situation at the rural household level, focusing on the impact of logistics disruption on the rural household. On the one hand, an increase in the retail or wholesale market price due to strong demand may affect the sales price of rural households, driving an increase in the selling price of rural households. On the other hand, the decrease in production directly raises the selling price of rural households. However, it is also possible that logistics disruptions have led to fewer wholesalers and lower prices. Generally speaking, for most rural households, logistics disruptions have led to higher selling prices. The increased output price would help mitigate the economic loss.

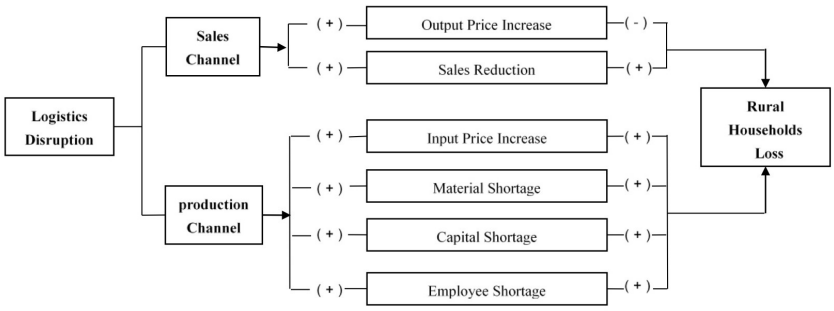

Figure 1. The economic mechanism map.

The production channel includes input price and shortage of various means of production. Firstly, logistics disruption increases the input price. Disrupted logistics hinder necessary production inputs. When supply decreases and demand is stable, the equilibrium price will go up. The rising price of inputs increases the cost of production and, thus, amplifies the losses of rural households [49]. Secondly, logistics disruption leads to a shortage of raw materials. For example, only 36% of rural households had direct access to fertilizers by 4 March 2020 in China. The planting industry and the breeding industry are all facing a shortage of basic means of production. The closure of stores selling feed and veterinary drugs and the disruption of logistics prevent replenishment of these supplies, resulting in the deaths of poultry and livestock and the economic loss of rural households. Thirdly, logistics disruption triggers a shortage of capital. As the product is difficult to get on the market, rural households cannot achieve profits. However, the operating costs still exist, which causes a mismatch between cash inflow and outflow, resulting in a shortage of capital. The shortage of capital further exacerbates the production difficulties and further aggravates the losses [17,63]. Existing studies pay more attention to the prices and sales of agricultural products in the context of lockdown, but less attention to capital. The capital shortage variable used in this paper can effectively measure rural households' demand for capital, which is helpful to the government and financial institutions when formulating policy. Finally, logistics disruption exacerbates the shortage of employees. Logistics and transportation are disrupted and migrant rural households cannot reach their work destinations, creating a labor shortage for employers [9,37,38,48]. The increasing cost of hiring and lower productivity make rural households suffer more losses. However, if the employees come mainly from areas near to the workplace, rather than from across cities, logistics disruption may not have a significant impact on employee shortages.

Although existing studies include detailed discussion of the performance of the agricultural supply chain in the context of logistics obstruction caused by lockdown, most of these studies only focus on certain issues in the supply chain, such as price, and fail to comprehensively measure multiple linkages and factors in the supply chain. This paper considers the impact channels influencing logistics disruptions that affect rural household losses, integrates multiple links in the agricultural supply chain into a unified framework, and compares the degree of impact of logistics on each channel in this framework, filling a gap in the existing literature. The following research hypothesis is proposed:

H3. *Logistics disruption affects rural household losses through the following channels: increase in output prices, sales reduction, increase in input prices, material shortages, capital shortages, and employee shortages.*

3. Data and Methodology

3.1. Data

In March 2020, we surveyed how rural households were affected by the COVID-19 pandemic. We and BOC Fullerton Village Bank jointly designed the questionnaire and the bank carried out the survey. BOC Fullerton Village Bank is the largest nationwide village bank in China. A survey was conducted of the bank's deposit and loan customers

in 101 counties across 17 provinces in Figure 2. To avoid the inconvenience to respondents of traveling, the bank manager interviewed the customers by telephone and filled in the questionnaire according to the customers' answers. The objectivity and authenticity of the questionnaire can be guaranteed because the bank managers have a better understanding of the customer's actual situation and want to know the actual difficulties of the customers during the epidemic. The survey was conducted at a time when China was in complete lockdown and inter-city traffic had not been restored. Therefore, our data reflected the logistics and loss situation of rural households during the worst period of the epidemic.

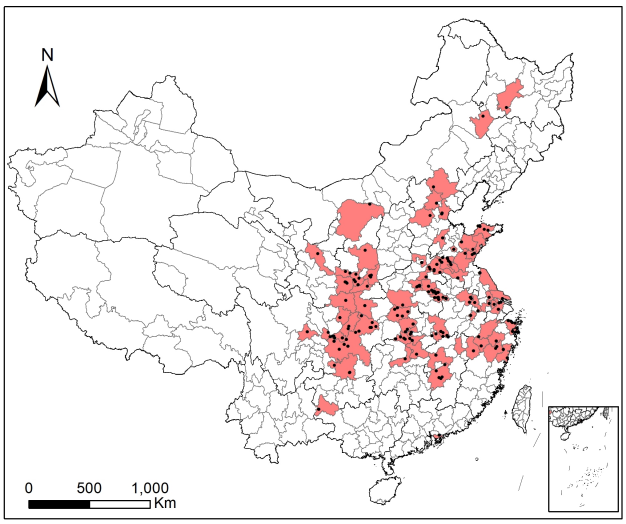

Figure 2. Geographical distribution of the survey households. The red area indicates the city where the sample is located and the black dots indicate the location of the participating bank branches.

A total of 2408 survey samples were distributed across 17 provinces, mostly in the eastern and central regions of China. The provinces were selected as they were more severely affected by the epidemic due to their dense population, developed economies, and convenient transportation. The survey respondents were new agricultural business entities, including agribusiness, cooperatives, family farms, and professional rural households. Their main businesses were planting, breeding, and other business. Compared with traditional small-scale households, this group of businesses operates at a larger scale and intensification and is more closely related to logistics in production and sales.

3.2. Variables

With respect to the variables to be explained, we selected three variables to measure the loss of rural households from the perspective of expected loss and actual loss. The variable "ExpLoss" concerns whether the expected year-round loss is severe, representing rural households' expectations of future losses. It equals one if the household's expected year-round loss is severe or modest and is zero otherwise. "Loss" is whether the household had suffered actual financial losses; it equals one if a financial loss occurred and zero otherwise. The variable "LogAm" is the log of the number of actual losses plus one, which is 0 for rural households with no losses and missing for rural households who have losses but do not fill in the specific amount. The main dependent variable, "Logistics", identifies whether logistics were disrupted for the household. This variable measures the degree of logistics disruption of each rural household under lockdown and traffic control policies, instead of using regional variables, which makes the study more accurate. The control variables include household demographic characteristics, economic characteristics, type of business operation, residential address, and type of agricultural business entity.

In addition, other variables measured include "PerInput", "PerOutput", "Insurance", and "GDP". Considering that the storage time of the means of production and products is a key factor closely related to logistics and affecting the income of rural households, two

variables "PerInput" and "PerOutput", are introduced to represent the storage status of inputs and outputs, respectively. The question in the questionnaire corresponding to the variable PerInput is the support time for aquaculture feed, planting fertilizer, and so on. There are four time periods to choose from. For convenience of processing, a support time less than 15 days is denoted as 1, otherwise, it is denoted as 0. The variable PerOutput reflects the storage status of agricultural products. If the product is perishable, PerOutput is assigned a value of 1; if the product is easy to store or there are no products, it is assigned a value of 0. We also considered measures rural households could take to reduce their losses, the most important of which is agricultural insurance. So the variable "Insurance" was introduced, which equals one if the household has agriculture insurance and zero otherwise. Since the regional macroeconomic situation is closely related to the fiscal revenue and rescue behavior of local government, the role of a local economic variable "GDP" was investigated, representing the GDP of the county where the rural household is located.

Six channel variables are introduced in the mechanism analysis. Logistics affects many links in the production and sales supply chain, ultimately affecting the loss of rural households. The variables of the sales channel are "Output Price Increase" and "Sales Reduction", which measure the status of the distribution channel in terms of both price and volume. The variables of the production channels include "Input Price Increase", "Material Shortage", "Capital Shortage", and "Employee Shortage", which describe the state of production channels in terms of price and the availability of means of production.

Definitions and descriptions of the variables are given in Table A1.

3.3. Methodology

The data in this paper were investigated at the early stage of COVID-19, which was the period of lockdown in China. The most important reasons for logistics disruption are lockdown policies and movement restrictions, which are generally recognized in the literature [18,64–66]. During this period, there were no serious natural disasters and no travel restrictions for other purposes in China. There have not been such large-scale logistics disruptions in China in recent decades. Therefore, it is reasonable to conclude that the logistics disruption was caused by the lockdown policy in the early days of COVID-19.

A linear probability model is used for the two loss measures as the explained variables are dummy variables; a linear regression with OLS estimation is used for LogAm. Robust standard errors are included in all models. The model is set as follows:

$$HouseholdLoss_i = \beta_0 + \beta_1 Logistics_i + \beta_2 Controls_i + \lambda_i + \varepsilon_i,$$

where the variable subscript i denotes the observation of household; the explained variable $HouseholdLoss_i$ is three different measures of loss, namely ExpLoss, Loss, and LogAm; $Logistics_i$ is whether the logistics of household i is disrupted; $Controls_i$ denotes all the control variables of household i; λ_i is the provincial fixed effect and ε_i is the error term.

We selected potential factors at different levels and added the interaction terms of logistics and potential factors into the model to consider the heterogeneity of the impact of logistics obstruction on the loss of rural households under the action of these factors. The model is set as follows:

$$HouseholdLoss_i = \beta_0 + \beta_1 Logistics_i + \beta_2 Logistics_i \times X_i + \beta_3 X_i + + \beta_4 Controls_i \lambda_i + \varepsilon_i,$$

where X_i denotes four potential factors, namely PerInput, PerOutput, Insurance, and GDP. PerInput is a binary variable that equals one if the support time of input is less than 15 days and zero otherwise; PerOutput is a binary variable that equals one if the output is perishable and zero otherwise; Insurance is whether agriculture insurance has been purchased; GDP is the GDP of the rural household's county.

In order to study the impact mechanisms of logistics disruption on rural household losses, we extracted relevant channel variables from the questionnaire and constructed the model as follows:

$$Channel_i = \beta_0 + \beta_1 Logistics_i + \beta_2 Controls_i + \lambda_i + \varepsilon_i,$$

where $Channel_i$ denotes six channel variables, namely Output Price Increase, Sales Reduction, Input Price Increase, Raw Material Shortage, Capital Shortage, and Employee Shortage. All of these are binary variables. The value of the variable is 1 if the corresponding problem occurs, and 0 otherwise. The definitions are shown in Table A1.

4. Results

4.1. Baseline Results

Table 1 presents the results of the baseline regressions (For conciseness, we only show the coefficients of the main variables and attach the full estimation results in Appendix Table A3). For all three loss measures, the coefficients for Logistics are highly significant with or without the inclusion of control variables, indicating that logistics disruption in production or marketing significantly increases household expectations of losses throughout the year, the probability of losses occurring, and the number of losses. Research hypothesis H1 is verified. The inclusion of control variables slightly reduces the coefficient for Logistics, indicating that the impact of logistics is very robust and has very strong explanatory power for explained variables. The coefficient for ExpLoss is slightly lower than that of Loss, indicating that the disruption of logistics has a greater impact on the actual losses suffered at that moment than the expected losses in the future, which reflects that rural households have optimistic expectations about the future situation. The obstruction of logistics means that the agricultural production chain is disrupted; both the supply of production materials and the marketing of products are affected. Therefore, logistics obstruction increases the cost, reduces the quantity of sales, and aggravates the loss of rural households.

Table 1. Impact of logistics disruptions on rural households' losses. In this table, we study the impact of logistics disruptions on rural households' losses. In columns (1) and (2), the dependent variable is ExpLoss; in columns (3) and (4), the dependent variable is Loss; in columns (5) and (6), the dependent variable is LogAm. *t*-statistics are calculated with robust standard errors in parentheses. Province fixed effects are controlled. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. See Appendix Table A1 for variable definition.

	ExpLoss		**Loss**		**LogAm**	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Logistics	0.30 ***	0.29 ***	0.33 ***	0.32 ***	0.56 ***	0.53 ***
	(17.53)	(16.96)	(19.39)	(18.76)	(16.67)	(16.17)
Constant	0.29 *	0.77 ***	0.28 **	0.43 **	0.22	0.41
	(1.94)	(3.33)	(2.37)	(2.09)	(1.39)	(1.17)
Controls	No	Yes	No	Yes	No	Yes
Province FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2408	2408	2408	2408	2237	2237
R-squared	0.14	0.16	0.15	0.19	0.13	0.16

4.2. Potential Factors

We examine the role of different household and economic factors on the impact of logistics disruptions on rural household losses, including perishable inputs (PerInput) and perishable outputs (PerOutput), the insurance purchased (Insurance), and the gross domestic product (GDP) of the rural households' county (GDP). In Table 2, columns (1)–(3) demonstrate the effect of PerInput on Logistics. Logistics × PerInput is highly significant for all three loss measures, indicating that perishable inputs significantly exacerbate the impact of logistics disruptions on losses. If the logistics are blocked and the inputs cannot be replenished in time, the households cannot start production even if they resume work, thus increasing the losses. Columns (4)–(6) show the role of PerOutput in Logistics. The interaction Logistics × PerOutput is significant for all three loss measures, indicating that the impact on losses of obstructed logistics is exacerbated by the fact that perishable

products are not easily stored. If logistics cannot be recovered in a short time, the perishable products will spoil and deteriorate, thus exacerbating losses.

Table 2. Impact of perishable inputs and outputs on logistics disruptions. In this table, we show the impact of perishable inputs and outputs on logistics disruptions for rural households. In columns (1) and (4), the dependent variable is ExpLoss; in columns (2) and (5), the dependent variable is Loss; in columns (3) and (6), the dependent variable is LogAm. *t*-statistics are calculated with robust standard errors in parentheses. Province fixed effects are controlled. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. See Appendix Table A1 for variable definition.

	ExpLoss	**Loss**	**LogAm**	**ExpLoss**	**Loss**	**LogAm**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Logistics	0.26 ***	0.30 ***	0.48 ***	0.26 ***	0.30 ***	0.46 ***
	(13.87)	(15.96)	(13.60)	(14.39)	(16.18)	(13.46)
PerInput	0.03	0.01	0.03			
	(1.05)	(0.44)	(0.64)			
Logistics × PerInput	0.17 ***	0.12 ***	0.27 ***			
	(3.81)	(2.71)	(3.03)			
PerOutput				0.08 *	0.10 **	0.16 **
				(1.83)	(2.27)	(2.08)
Logistics × PerOutput				0.13 **	0.10 *	0.33 ***
				(2.35)	(1.80)	(2.83)
Constant	0.74 ***	0.41 **	0.37	0.74 ***	0.40 *	0.38
	(3.18)	(2.01)	(1.04)	(3.23)	(1.93)	(1.08)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Province FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2408	2408	2237	2408	2408	2237
R-squared	0.17	0.20	0.17	0.17	0.21	0.19

In Table 3, columns (1)–(3) demonstrate the effect of Insurance on Logistics. Logistics × Insurance is negative for all three loss measures and significant for the dependent variables ExpLoss and Loss, indicating that the purchase of insurance reduces the impact of logistics disruptions on losses. The losses households suffer can be compensated by insurance, which directly reduces the losses and mitigates the impact of poor logistics [48]. Columns (4)–(6) demonstrate the GDP and logistics relationship. Logistics × GDP is negative and significant for the dependent variables ExpLoss and Loss, indicating that a stronger local economy reduces the impact of logistics on losses. Local governments with stronger fiscal capacity may introduce more subsidies or policies to support households; thus, a stronger local economic development level can mitigate losses caused by logistics more effectively. Research hypothesis H2 is verified.

Table 3. Impact of insurance and GDP on logistics disruptions. In this table, we study the impact of insurance and local GDP on logistics disruptions for rural households. In Columns (1) and (4), the dependent variable is ExpLoss; in columns (2) and (5), the dependent variable is Loss; in columns (3) and (6), the dependent variable is LogAm. *t*-statistics are calculated with robust standard errors in parentheses. Province fixed effects are controlled. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. See Appendix Table A1 for variable definition.

	ExpLoss	**Loss**	**LogAm**	**ExpLoss**	**Loss**	**LogAm**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Logistics	0.31 ***	0.35 ***	0.56 ***	1.61 ***	1.26 ***	1.21 *
	(15.79)	(17.04)	(14.13)	(4.31)	(3.43)	(1.72)
Insurance	−0.00	−0.08 ***	−0.15 ***			
	(−0.12)	(−3.77)	(−4.16)			
Logistics × Insurance	−0.07 *	−0.08 **	−0.07			
	(−1.86)	(−2.17)	(−1.04)			
GDP				0.05	0.01	−0.01
				(1.05)	(0.30)	(−0.11)

Table 3. *Cont.*

	ExpLoss	Loss	LogAm	ExpLoss	Loss	LogAm
	(1)	(2)	(3)	(4)	(5)	(6)
Logistics × GDP				−0.09 ***	−0.06 **	−0.05
				(−3.53)	(−2.56)	(−0.97)
Constant	0.75 ***	0.42 **	0.41	0.76 ***	0.44 **	0.43
	(3.21)	(2.00)	(1.15)	(3.32)	(2.10)	(1.22)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Province FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2408	2408	2237	2408	2408	2237
R-squared	0.16	0.21	0.17	0.16	0.19	0.16

4.3. Economic Mechanism

Logistics disruptions can affect the normal functioning of the entire agricultural production supply chain, resulting in economic losses. To test the economic mechanism of logistics disruptions on losses, we investigate six potential channels related to agricultural supply chains and changes in commodity, production, and business operation during the epidemic.

Columns (1)–(2) of Table 4 reflect the impact of logistics on the sales channel. Column (1) shows that outputs cannot be brought in from other areas due to logistics obstruction. Consequently, some rural household products become scarce and their prices rise, thus reducing household losses. Column (2) reveals that logistics disruptions make it difficult to sell products through normal marketing channels and the products are backlogged; thus, logistics disruptions significantly reduce the sale of goods and, thus, result in losses to households. The coefficient for Sale Reduction is the largest in columns (1)–(5), indicating the sales reduction caused by logistics disruption is the most significant economic impact on the supply chain. Therefore, reducing disruptions to sales channels should be the first policy choice to minimize rural household losses. Columns (3)–(6) of Table 4 reflect the impact of logistics on the production channel. Column (3) shows that logistics disruptions cause local inputs to become scarce; this increases production costs and reduces profits for households, thus increasing losses. By comparing the regression coefficients of columns (1) and (3), we find that the impact of logistics on the price of inputs is much greater than that of outputs. Columns (4)–(5) show that logistics disruptions aggravate the shortage of raw materials and capital, disrupting household production operations, which reduces products and increases losses. Comparing the coefficients for Logistics in Material Shortage and Capital Shortage, the coefficient of the latter is larger and more significant, indicating that logistics have a greater impact on capital shortage than material shortage. The government needs to pay attention to, and actively address, household financial needs when providing assistance to them. In contrast, column (6) shows that the impact of logistics disruptions on Employee Shortage is not significant, since most employees may be from the local area and, therefore, are less affected by the lockdown. Research hypothesis H3 is verified except for the Employee Shortage channel.

Table 4. The economic mechanism of logistics disruptions on rural household loss. The explained variable in each column is the potential economic mechanism of logistic disruptions that may affect rural households. *t*-statistics are calculated with robust standard errors in parentheses. Province fixed effects are controlled. ** and *** indicate significance at the 5% and 1% levels, respectively.

	Output Price Increase	Sale Reduction	Input Price Increase	Material Shortage	Capital Shortage	Employee Shortage
	(1)	(2)	(3)	(4)	(5)	(6)
Logistics	0.09 ***	0.36 ***	0.16 ***	0.02 **	0.09 ***	−0.01
	(5.94)	(19.97)	(9.77)	(2.12)	(5.21)	(−0.82)
Constant	−0.06	−0.03	−0.11	−0.02	0.85 ***	0.01
	(−0.30)	(−0.15)	(−0.58)	(−0.19)	(3.78)	(0.16)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes	Yes	Yes
Obs	2408	2408	2408	2408	2408	2408
R-squared	0.08	0.20	0.09	0.03	0.09	0.05

5. Discussion

The outbreak of COVID-19 has disrupted peoples' normal lives and brought economic losses to a large number of people, especially those in rural areas with low incomes and no formal jobs. Due to traffic restrictions, logistics are disrupted and rural households are faced with a series of problems, such as difficulty in obtaining the means of production, unmarketable products, and rising raw material prices, which ultimately lead to a decrease in rural household income or even losses. Existing studies have paid extensive attention to agricultural production, rural household livelihoods, and logistics issues. However, for rural people, there still needs to be an empirical analysis of the relationship between logistics disruption and rural household losses. From the perspective of empirical tests, this paper examines how logistics obstruction affects the losses of rural households.

First, we demonstrate that logistics disruptions can significantly increase rural household losses. When control variables are added to the model, the coefficient of logistics disruption is slightly reduced and still highly significant, indicating the robustness of logistics obstruction variables in the early stage of the COVID-19 epidemic in China. Although some households did not carry out large-scale farming and trading then, the logistics disruption generally reduced the income of rural households [13].

Second, we discuss the role of potential factors in the impact of logistics on rural household losses, including product characteristics, agricultural insurance, and macroeconomics. In the model with the interaction terms of logistics loss and potential factors, the coefficients of the interaction terms are significant. If the storage time of production materials is short, logistics disruption means the supply cannot be replenished in a timely way; if the output is not easily stored, logistics disruptions make the product unmarketable or even cause it to rot. All this adds to the household's loss. If rural households buy agricultural insurance, the losses caused by logistics disruptions will be significantly reduced. This implies that agricultural insurance is important in improving rural households' ability to resist risks. A higher level of regional economic development also helps to reduce the losses caused by logistics impact on rural households.

Third, we discuss the mechanism of logistics disruption that affect rural household losses, including sales and production channels. This supplements previous qualitative research [9]. In terms of sales channels, obstructed logistics make it difficult to transport products to the market, reducing sales volume. However, due to the market's decrease in supply, the price of products on the market increases. This partly makes up for lower sales, so it is negatively correlated with the loss. In terms of production channels, obstructed logistics, on the one hand, increase the price of raw materials and, on the other hand, create raw materials and capital shortage, which increases the losses of rural households. Among the six channels, logistics has the greatest impact on sales reduction. This means that the smooth flow of sales channels should be addressed first. Compared with the output price, logistics has a greater impact on the input price, which means that the increase in production costs is greater than the profit from sales. The channel of employee shortage is not significant, which may be because there are fewer migrant workers in the sample or most of the employees come from local areas.

Although many countries no longer pursue large-scale lockdowns, the lockdown of cities or regions still occurs to implement China's "dynamic zero-COVID" policy. For example, Shanghai was locked down from April to June 2022. Therefore, ensuring normal logistics, improving the supply of agricultural products, and maintaining the stability of the agricultural supply chain in epidemic areas is not only important for the stability of the market but also to safeguard the interests of rural households. Our research could contribute to more logistics and supply-chain intervention policies.

6. Conclusions

Based on a survey of Chinese rural households in the early stages of the COVID-19 pandemic, we find that logistics disruptions are associated with significant rural household losses. Perishable production inputs and outputs increase the impact of logistics disruptions

on economic losses. At the same time, the purchase of insurance and a stronger local economy significantly reduce the impact of logistics disruptions on losses. We also find that logistics disruptions significantly increase the price of inputs and outputs. While the former increases production costs and losses, the latter can reduce losses. Further, we show logistics disruptions also affects elements of production operations, such as reducing product sales and increasing shortages of capital and raw materials, while having no significant effect on the shortage of labor that is predominantly hired locally.

Our findings have several policy implications. First, we highlight the impact of lockdown policies on not just the agricultural supply chain, but also household economies; logistics channels should be maintained for agricultural products—especially perishable ones. With respect to the period of traffic control, green channels for agricultural production should be set up, especially sales channels, to ensure that agricultural products can be transported from rural areas to cities. Ensuring unimpeded sales is the most fundamental measure to ensure rural household income and reduce losses. Second, the storage infrastructure could mitigate losses incurred from a shortage of means of production and perishable outputs. Building warehouses with larger capacity and better cold storage facilities can help stabilize product supplies and prices during the lockdown period, or for other unforeseen disruptions to logistics. Third, government support should be accompanied by targeted subsidies for price shocks resulting in higher costs and lower selling prices. It is important to improve publicity relating to subsidies, so that more rural households are aware of measures to benefit the people. Fourth, the government and financial institutions should work together to provide rural households with timely credit facilities to reduce liquidity risk and develop more comprehensive agricultural insurance to cover the risks associated with product reduction and price volatility.

A limitation of the study is that our data were obtained in the period when the COVID-19 epidemic was at its most severe and traffic control was most stringent in China. For future studies, researchers could study the extent of logistics disruptions and the impact on rural and urban people's incomes under different forms of quarantine policies in different countries. In addition, the operation of supply chains other than the agricultural supply chain under logistics disruption may be investigated.

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Appendix A

Table A1. List of variables and summary statistics.

Variables	Levels/Definition	Mean	Std
ExpLoss	Indicator that equals one if the Expected Loss in the year is severe or modest and zero otherwise.	0.270	0.444
Loss	Indicator that equals one if a financial loss occurred and zero otherwise.	0.291	0.454
LogAm	log(1+ Loss Amount) (in RMB 10,000).	0.408	0.834
Logistics	Indicator that equals one if logistics have been disrupted and zero otherwise.	0.532	0.499
LogAge	log(respondent age).	3.778	0.212
Family Size	Number of family members.	3.897	1.171
Family Income	Indicator that equals one if family income is above 100,000 in 2019 and zero otherwise.	0.846	0.361
Family Profit	Indicator that equals one if the main business profit is above 50% of total profit in 2019 and zero otherwise.	0.246	0.431
Loan	Indicator that equals one if family bank debt is above 200,000 and zero otherwise.	0.336	0.472
Loan to Income Ratio	Indicator that equals one if loan to income ratio is above 40% and zero otherwise.	0.115	0.320
Residence	Village Residence	0.309	0.462
	Town Residence	0.575	0.494
	County Residence	0.115	0.320
Main Business	Planting	0.417	0.493
	Breeding	0.515	0.500
	Other Business	0.068	0.251
Business Entity	Agribusiness	0.049	0.215
	Cooperatives	0.063	0.242
	Family Farm	0.179	0.383
	Professional Farm	0.710	0.454
PerOutput	Indicator that equals one if output is perishable and zero otherwise.	0.126	0.332
PerInput	Indicator that equals one if support time of input is less than 15 days and zero otherwise.	0.198	0.398
Insurance	Indicator that equals one if household has agriculture insurance and zero otherwise.	0.249	0.432
GDP	The GDP of the rural households' county (in RMB 10^{11})	0.385	0.324
Output Price Increase	Indicator that equals one if output price increases and zero otherwise.	0.172	0.377
Input Price Increase	Indicator that equals one if input price increases and zero otherwise.	0.206	0.404
Sales Reduction	Indicator that equals one if sales reduction and zero otherwise.	0.344	0.475
Raw Material Shortage	Indicator that equals one if raw material shortage and zero otherwise.	0.055	0.228
Capital Shortage	Indicator that equals one if fund shortage and zero otherwise.	0.230	0.421
Employee Shortage	Indicator that equals one if employee shortage and zero otherwise.	0.061	0.239

Table A2. The impact of logistics disruption on agricultural supply chain.

Impact Channel	Specific Channel	Performance of Influence [References]
Sales Channel	Output price volatility	Vegetable wholesale price downturn [37]; Chinese cabbage price hike [38]; The impact of COVID-19 on prices of four major food products are different [62]; Spiked price of the highly perishable product in India [16]; Dramatically increased food prices [3];
	Sales reduction	Sales contraction [37]; The marketing quantity of agricultural products dropped dramatically [38] Sales volume for most family farms is expected to fall [49] Large amounts of unmarketable agricultural products [9] Overstocked agricultural products [58] The produce/livestock market is either closed or significantly disrupted in Senegal [52]
Production Channel	Input price increase	Rising operating costs of most family farms [49] Hinder agricultural production inputs [9]
	Material shortage	Lack of production inputs for vegetable production [48] More than one-third of family crop farms were unable to purchase any agricultural materials [49]
	Capital shortage	Some of the rural households surveyed wanted to increase the loan amount and obtain extensions [63] Farmers used up half of their savings and borrowed more [17]
	Employee shortage	Shortage in agricultural workforce [37] A drastic decline in labor mobility intensity [38] A shortage of labor and decreased production efficiency [58] Labor shortage and increase in labor costs [48]

Table A3. Baseline regression with full results. In this table, we study the impact of logistics disruptions on rural household losses with full results. In columns (1) and (2), the dependent variable is ExpLoss; in columns (3) and (4), the dependent variable is Loss; in columns (5) and (6), the dependent variable is LogAm. *t*-statistics are calculated with robust standard errors in parentheses. Province fixed effects are controlled. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. See Appendix Table A1 for variable definition.

	ExpLoss		Loss		LogAm	
	(1)	(2)	(3)	(4)	(5)	(6)
Logistics	0.30 ***	0.29 ***	0.33 ***	0.32 ***	0.56 ***	0.53 ***
	(17.53)	(16.96)	(19.39)	(18.76)	(16.67)	(16.17)
LogAge		−0.08 **		0.02		0.02
		(−2.02)		(0.47)		(0.23)
Family Size		0.02 ***		0.03 ***		0.04 ***
		(2.91)		(3.65)		(2.68)
Family Income		−0.02		0.02		0.04
		(−0.66)		(0.65)		(1.07)
Family Profit		−0.05 ***		−0.06 ***		−0.08 **
		(−2.59)		(−3.21)		(−2.04)
Loan		−0.02		−0.00		0.15 ***
		(−0.81)		(−0.09)		(3.53)
Loan to Income Ratio		0.04		0.06 *		0.03
		(1.28)		(1.89)		(0.50)
		Other Business (as reference group)				
Planting		−0.14 ***		−0.32 ***		−0.43 ***
		(−3.68)		(−7.87)		(−5.55)
Breeding		−0.09 **		−0.31 ***		−0.43 ***
		(−2.44)		(−7.57)		(−5.47)
		County Residence (as reference group)				
Village Residence		−0.04		−0.00		0.03
		(−1.27)		(−0.08)		(0.44)
Town Residence		−0.04 **		−0.04 *		−0.10 ***
		(−1.99)		(−1.83)		(−2.66)

Table A3. *Cont.*

	ExpLoss		Loss		LogAm	
	(1)	(2)	(3)	(4)	(5)	(6)
			Agribusiness (as reference group)			
Cooperatives		−0.06		−0.01		−0.03
		(−1.13)		(−0.24)		(−0.23)
Family Farm		−0.09 *		0.06		0.04
		(−1.79)		(1.28)		(0.39)
Professional Farm		−0.06		0.00		−0.04
		(−1.22)		(0.02)		(−0.44)
Constant	0.29 *	0.77 ***	0.28 **	0.43 **	0.22	0.41
	(1.94)	(3.33)	(2.37)	(2.09)	(1.39)	(1.17)
Province FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2408	2408	2408	2408	2237	2237
R-squared	0.14	0.16	0.15	0.19	0.13	0.16

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