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The Zoonotic diseases, agricultural production, and impact channels: Evidence from China

Binlei Gong\textsuperscript{a,1}, Shurui Zhang\textsuperscript{a,1}, Xiaoguang Liu\textsuperscript{b,\textsuperscript{1}}, Kevin Z. Chen\textsuperscript{a,c, \textsuperscript{**}}

\textsuperscript{a} China Academy for Rural Development and School of Public Affairs, Zhejiang University, Hangzhou, China
\textsuperscript{b} National Academy of Development and Strategy, Renmin University of China Beijing China
\textsuperscript{c} International Food Policy Research Institute, East and Central Asia Office, Beijing, China

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A B S T R A C T

The outbreak and wide spread of COVID-19 poses a new threat to global food security. This paper aims to address two important policy related issues, that is which agricultural subsector suffers more under zoonotic diseases and how do zoonotic diseases affect these subsectors. Using provincial panel data of 24 main farm commodities in China from 2002 to 2017, this paper identifies the impacts of zoonotic diseases and projects the potential disruption of COVID-19 to agricultural output in China under three scenarios. The main findings are as follows. First, zoonotic diseases have adverse impacts on almost all the farm commodities, while livestock on average suffers more than crops. Second, zoonotic diseases affect these subsectors mainly through the channel of adverse shocks on total factor productivity (TFP). Third, while a few subsectors can find a way to offset part of the TFP loss by applying more input, most subsectors suffer from both input reduction and TFP loss. Fourth, the spread of COVID-19 is projected to lower the growth rates of China’s crop and livestock sector by 1.1%–2.3% and 1.3%–2.6%, with TFP loss by 1.1%–2.0% and 1.4%–2.7%, respectively, in 2020. This paper then discusses several policy implications for mitigating the negative impacts of COVID-19 on agricultural production in China and elsewhere.

1. Introduction

The outbreak of worldwide COVID-19 has caused severe impacts on global economy and trade. The World Bank’s and International Monetary Fund’s mid-2020 reports in June project that the global economic growth rate will hit a negative growth of 5.2% and 4.9%, respectively. In September, the United Nations Conference on Trade and Development released its Trade and Development Report (2020). The report projects that global trade will shrink by about 20% in 2020, and in developing countries, 90–120 million people will fall into extreme poverty, and nearly 300 million people will face food security problems. Under this background, COVID-19 has caused widely serious concerns on global food security.

Most of the recent epidemics, such as SARS, H1N1, Ebola, and COVID-19, are zoonotic diseases. The outbreak of these epidemics could significantly affect all industries in China and beyond, including agricultural and food system (Gong et al., 2020). In order to contain the spread of these zoonotic diseases, strict controls on movement are typically imposed at all levels. These measures will likely lead to resource misallocation and efficiency loss, which has negative impacts on agricultural production. To policy makers, two questions are of great importance: which agricultural subsector suffers more, crops or livestock, under epidemics? and how do zoonotic diseases affect these subsectors? The answer to the former question decides which subsector needs more support, and the answer to the latter question determines the channels through which we can support.

This paper aims to answer these two questions using data from China. First, we have collected thirty-one provincial data for each of the twenty-four main farm commodities (including eighteen crops and six livestock) as well as the incidence rates and death rates of thirteen main zoonotic diseases in China from 2002 to 2017. Second, we have applied dynamic panel model to estimate the overall impact of zoonotic diseases on each of these farm commodities, and compare the difference between crops and livestock sectors, which answer the first question. Third, we...
have used a growth accounting method to decompose these overall impacts to see how zoonotic diseases affect input portfolio and TFP, which identifies the channels through which zoonotic diseases affect each commodity and hence answers the second question. Fourth, using the up-to-date number of COVID-19 infected persons and death rates, the projected numbers under different scenarios, and our estimated marginal effect, we have simulated the overall impact of COVID-19 on agricultural production in China. Finally, we draw several policy implications for mitigating the negative impact of zoonotic diseases on agricultural production for China.

2. Materials and methods

2.1. Methodology

The resource allocation among enterprises and within enterprises determines the total economic output. In the long run, optimal allocation will maximize output given inputs, while the deviation from optimal allocation is called resource misallocation (Gong and Sickles, 2020). Resource misallocation indicates inputs from flowing freely to sectors with high rate of return and therefore fails to achieve the highest attainable outcome, which results in efficiency loss (Gong, 2018). A number of studies point out that the gap in total factor productivity (TFP) between developing countries and developed countries is mainly due to the severe resource misallocation in developing countries (Hsieh and Klenow, 2009; Banerjee and Moll, 2010; Buera et al., 2011; Restuccia and Rogerson, 2017). Taking the zoonotic diseases into account, the direct impact of epidemics on agriculture is mainly through two channels: one is the impact of various strict control measures on the flow of agricultural inputs; the other is the impact of psychological panic on the social behavior of farmers. The above changes brought by these zoonotic diseases will likely lead to resource misallocation and efficiency loss, which has negative impacts on agricultural production.

Fig. 1 presents a three-step approach to investigate the mechanism of how zoonotic diseases affect agricultural growth (i.e., Δyit) through various channels. Step 1 aims to calculate TFP by the factor share method. Compared to conventional production function, this paper follows Young (1992, 1995) and Jin et al. (2010) to use the factor share method for two seasons: first, it is the official method to measure agricultural TFP in China; second, it is the appropriate statistical method to deal with small sample sizes. Step 2 introduces dynamic panel models of input determination and TFP determination equations to estimate the marginal impact of zoonotic diseases on inputs and TFP, respectively, where δ21 and θ21 are the marginal effects of incidence rate and ZD2a on death rate. In other words, 1% increase in incidence rate of zoonotic diseases (ZD1a) will lead to δ21% change in the k-th input (xkt) and θ21% change in TFP, whereas 1% increase in death rate of zoonotic diseases (ZD2a) will lead to δ22% change in the k-th input (xkt) and θ22% change in TFP. Notifiable infectious diseases in China are classified into three categories: Class A, Class B, and Class C. The classification is based on the transmission speed and fatality of the infectious diseases. The emergency systems and control mechanisms are different across classes. The major impact of infectious diseases (zoonotic diseases) on agriculture is mainly due to the resource misallocation and efficiency loss caused by the panic effects (e.g., abstainism) and the control measures (e.g., social distancing and lockdown). On the one hand, the panic effects depend on the transmission speed and fatality of the disease rather than if it is SARS or COVID-19. In other words, we are not afraid of the disease itself, but the incidence rate and death rate behind the disease. That is why some once-fatal zoonotic diseases are no longer destructive after effective drugs are invented. Moreover, control measures depend on the category a disease belongs to. The National Health Commission of the PRC has incorporated COVID-19 into Class B (Yang and Wang, 2020). Since this paper also aims to project the impact of COVID-19, we include all zoonotic diseases in Class B, and investigate the impact of the incidence rates and death rates on agriculture. The assumption is that zoonotic diseases have the same impact on agriculture when incidence rate, death rate, and control measures are the same. Finally, ZDt includes other control variables that may affect agricultural inputs and productivity, including infrastructure, technological innovation, international trade, educational level, irrigation system, natural disaster, agricultural fiscal expenditure as well as degree of marketization.

Step 3. use growth accounting to aggregate the overall impact of zoonotic diseases. To compare the main channels through which zoonotic diseases affect each commodity, a standard growth accounting method (Lin, 1992; Zhang et al., 2020) is adopted to aggregate the overall impacts on agricultural output through input portfolio and TFP as follows:

\[ \Delta y_t = \sum_{k=1}^{K} \beta_k \Delta x_{kt} + \Delta tpf_t \]  

(2)

which implies that the change in output (Δyt) can be decomposed into the contribution of inputs (∑ \( \beta_k \Delta x_{kt} \)) and contribution of TFP (Δtpf). Therefore, agricultural output increases by (∑ \( \beta_k \Delta x_{kt} + \theta_{21} \))% when the epidemic outbreak may decrease labor and fertilizer supply.

Step 2. use dynamic panel model to estimate the impact of zoonotic diseases on inputs and TFP. In order to estimate the impact of zoonotic diseases on input factors and TFP, dynamic panel models of input determination and TFP determination equations are applied to analyze the marginal impact through the mentioned channels above:

\[ \begin{align*}
\Delta x_{kt} &= \delta_{k1} \Delta p_{k-1} + \delta_{k2} ZD_k + \alpha + \lambda_t + \gamma_t + \nu_t \\
\Delta tpf_t &= \delta_{21} ZD_k + \theta_1 ZD_2 + \alpha + \lambda_t + \gamma_t + \nu_t
\end{align*} \]  

(1)

where \( y_t \) is output value and measured by yield as in many existing studies (Wang et al., 2016; Chen and Gong, 2020). \( x_{kt} \) represents the k-th input quantity, and \( tpf_t \) represents total factor productivity, all in logarithms for province i at time t. \( ZD_k = c(ZD_{1a}, ZD_{2a}) \) consists of two variables, in which \( ZD_{1a} \) is the incidence rate and \( ZD_{2a} \) is the death rate, both in logarithm and respectively measuring the transmissibility and toxicity of zoonotic diseases. \( \delta_{k1} = c(\delta_{21}, \alpha_{22}) \) and \( \delta_{21} = c(\beta_{21}, \theta_{22}) \) measures the marginal effect of zoonotic diseases on inputs and TFP, respectively, where \( \delta_{21} \) and \( \theta_{21} \) are the marginal effects of incidence rate and \( \delta_{22} \) and \( \theta_{22} \) are the marginal effects of death rate. In other words, 1% increase in incidence rate of zoonotic diseases \( (ZD_{1a}) \) will lead to \( \delta_{21} \)% change in the k-th input \( (x_{kt}) \) and \( \theta_{21} \)% change in TFP, whereas 1% increase in death rate of zoonotic diseases \( (ZD_{2a}) \) will lead to \( \delta_{22} \)% change in the k-th input \( (x_{kt}) \) and \( \theta_{22} \)% change in TFP. Notifiable infectious diseases in China are classified into three categories: Class A, Class B, and Class C. The classification is based on the transmission speed and fatality of the infectious diseases. The emergency systems and control mechanisms are different across classes. The major impact of infectious diseases (zoonotic diseases) on agriculture is mainly due to the resource misallocation and efficiency loss caused by the panic effects (e.g., abstainism) and the control measures (e.g., social distancing and lockdown). On the one hand, the panic effects depend on the transmission speed and fatality of the disease rather than if it is SARS or COVID-19. In other words, we are not afraid of the disease itself, but the incidence rate and death rate behind the disease. That is why some once-fatal zoonotic diseases are no longer destructive after effective drugs are invented. Moreover, control measures depend on the category a disease belongs to. The National Health Commission of the PRC has incorporated COVID-19 into Class B (Yang and Wang, 2020). Since this paper also aims to project the impact of COVID-19, we include all zoonotic diseases in Class B, and investigate the impact of the incidence rates and death rates on agriculture. The assumption is that zoonotic diseases have the same impact on agriculture when incidence rate, death rate, and control measures are the same. Finally, \( ZD_t \) includes other control variables that may affect agricultural inputs and productivity, including infrastructure, technological innovation, international trade, educational level, irrigation system, natural disaster, agricultural fiscal expenditure as well as degree of marketization.
3

incidence rate of zoonotic diseases ($ZD1_t$) increases by 1%, and agricultural output increases by $(\sum_{k=1}^K \beta_k \delta_{2k}^2 + \theta_{22})\%$ when the death rate of zoonotic diseases ($ZD2_t$) increases by 1%.

### 2.2. Data

We obtain thirty-one provincial annual data for each of the twenty-four main agricultural commodities (including eighteen crops and six livestock) in China from 2002 to 2017. In terms of crops, there are seven grain crops (Early Indica, Middle Indica, Late Indica, Japonica Rice, Wheat, Corn, and Soybean), six vegetables (Capsicum, Eggplant, Field Cucumber, Field Tomato, Greenhouse Cucumber, and Greenhouse Tomato), and five other cash crops (Cotton, Canola, Peanuts, Sugar Beet, and Sugar Cane). In terms of livestock, the data include Beef, Hog, Mutton, Broiler, Egg, and Dairy. These commodity-level datasets are collected from the Statistic Yearbook on the Compiled Materials of Costs and Profits of Agricultural Products of China. This yearbook is edited by China Price Information Centre, National Development and Reform Commission of China, which is responsible for the information release of infectious diseases and health data statistics. The data collection process of this yearbook is mainly from the annual health statistics of the provinces and the sample surveys organized by local health authorities. The incidence rate and death rate vary across different zoonotic diseases (Table 1), and the total incidence rate and death rate fluctuate over time (Fig. 2 and Fig. 3).

#### Table 1

| Zoonotic Diseases | Incidence Rate (persons per 100,000) | Zoonotic Diseases | Death Rate (deaths per 100 infections) |
|------------------|-------------------------------------|------------------|----------------------------------------|
| Brucellosis       | 3.354                               | Rabies           | 95.43                                  |
| Zoonotic Tuberculosis | 2.438                         | Human Avian Influenza | 57.61                                |
| Malaria           | 1.934                               | H7N9             | 35.83                                  |
| H1N1              | 1.026                               | SARS             | 5.23                                   |
| Schistosomiasis   | 0.266                               | Japanese encephalitis | 4.36                |
| Japanese Encephalitis | 0.233                         | leptospirosis    | 2.01                                   |
| Dengue            | 0.161                               | H1N1             | 1.00                                   |
| Rabies            | 0.119                               | anthrax          | 0.74                                   |
| Anthrax           | 0.068                               | zoonotic tuberculosis | 0.32                        |
| SARS              | 0.059                               | malaria          | 0.26                                   |
| Leptospirosis     | 0.048                               | brucellosis      | 0.02                                   |
| H7N9              | 0.004                               | schistosomiasis  | 0.00                                   |
| Human Avian       | 0.001                               | Influenza        | 0.00                                   |

In terms of zoonotic diseases, we collect official data on the provincial aggregated incidence rate and death rate of the following zoonotic diseases, including brucellosis, zoonotic tuberculosis, malaria, H1N1, schistosomiasis, Japanese encephalitis, dengue, rabies, anthrax, SARS, leptospirosis, H7N9, and human avian influenza. The zoonotic diseases data are collected from China Health Statistics Yearbook, which is an annual publication reflecting the development of health affairs and the health status of residents in China. This statistic yearbook is edited by National Health Commission of China, which is responsible for the information release of infectious diseases and health data statistics. The data collection process of this yearbook is mainly from the annual health statistics of the provinces and the sample surveys organized by local health authorities. The incidence rate and death rate vary across different zoonotic diseases (Table 1), and the total incidence rate and death rate fluctuate over time (Fig. 2 and Fig. 3).
Zoonotic diseases have negative effects on both TFP and production, except Capsicum and Eggplant (Table 3). A 1% increase in zoonotic diseases leads to a decrease of 0.019–0.042 percentage points of TFP, with Field Tomato suffering the most TFP loss. Meanwhile, zoonotic diseases cause additional adverse impacts on fertilizer input for Greenhouse Cucumber, making it suffer the most production loss among the 6 vegetables. To sum up, four of the six vegetables are expected to lose production due to a 1% increase in zoonotic diseases, varying in the range of 0.019–0.064 percentage points for different grain crops.

With respect to the six livestock, a 1% increase in zoonotic diseases leads to a decrease of 0.021–0.048 percentage points of TFP (Table 4). However, it becomes a little complex when considering the impacts on inputs. All of them, except Canola, find a way to compensate TFP loss by increasing inputs (e.g., labor for Cotton; Fertilizer for Sugar Cane; Machinery for Peanuts, Sugar Beet and Sugar Cane). As a result, the adverse effects of zoonotic diseases on production is smaller than on TFP. For instance, though Sugar Beet suffers the most TFP loss among the five crops, applying more machinery and other inputs compensate most of its TFP loss. To sum up, all the five crops are expected to lose production due to increase in zoonotic diseases, varying in the range of 0.017–0.028 percentage points for different crops.

With respect to the 6 livestock, a 1% increase in zoonotic diseases leads to a decrease of 0.022–0.036 percentage points of TFP (Table 5). Meanwhile, zoonotic diseases cause additional adverse impacts on labor input for Mutton, making Mutton suffer the most production loss among the six livestock. In contrast, Zoonotic diseases lead to an increase of labor input for Broiler and Egg to compensate their TFP loss, making Broiler suffer the least production loss among the 6 livestock. To sum up, all the six livestock are expected to lose production due to increase in zoonotic diseases, varying in the range of 0.018–0.040 percentage points for different livestock.

It is quite interesting to compare the effects of zoonotic diseases on crops and livestock (Table 6). Zoonotic diseases cause a relatively larger adverse TFP shock on livestock than on grains and vegetables. Zoonotic diseases cause additional negative effects on inputs for grains and vegetables, while livestock sector finds a way to increase input to offset some of the TFP loss. However, livestock sector still suffers more production loss than crops from zoonotic diseases due to larger TFP loss.

The consistent adverse TFP impacts of zoonotic diseases on almost all the farm commodities (through Table 2 to Table 6) is quite convincing and may come from three sources. Firstly, zoonotic diseases may cause health issues and even a panic effect on labor force, in addition to social distancing, leading to less communication/corporation and lower labor productivity in working hours. Secondly, strict prevention and control measures taken to contain the spread of zoonotic diseases may lead to poor transportation and labor movement, resulting in resource misallocation. Thirdly, it would make things worse if the outbreak and spread of zoonotic diseases, varying in the range of 0.018–0.040 percentage points for different crops.

### 3. Results

The results of model estimation and growth accounting shows that Zoonotic diseases have negative effects, to different extents, on almost all the twenty-four main farm commodities, except Capsicum and Eggplant, and cause production loss mainly through adverse shocks on TFP. The regression results of zoonotic diseases on grain crops, vegetables, other crops, and livestock are omitted to save space but available upon the request. The paper’s focus is on the growth accounting results of zoonotic diseases’ impacts.

For the seven grain crops, a 1% increase in zoonotic diseases leads to a decrease of 0.020–0.029 percentage points of TFP (Table 2). Meanwhile, zoonotic diseases cause additional adverse impacts on labor and fertilizer input for Late Indica, making Late Indica suffer the most production loss among the seven crops. Zoonotic diseases also cause additional adverse impacts on machinery input for Soybean and Japonica Rice, and make them suffer the most only next to Late Indica. In contrast, Zoonotic diseases have no negative effects on input for Wheat and Corn, even along with a positive effect on other inputs for Corn compensating its TFP loss, and makes them suffer the least among the seven crops. To sum up, all the seven crops are expected to lose production due to a 1% increase in zoonotic diseases, varying in the range of 0.020–0.045 percentage points for different grain crops.

With respect to the six vegetables, zoonotic diseases also have negative effects on both TFP and production, except Capsicum and Eggplant (Table 3). A 1% increase in zoonotic diseases leads to a decrease of 0.019–0.042 percentage points of TFP, with Field Tomato suffering the most TFP loss. Meanwhile, zoonotic diseases cause additional adverse impacts on fertilizer input for Greenhouse Cucumber, making it suffer the most production loss among the 6 vegetables. To sum up, four of the six vegetables are expected to lose production due to a 1% increase in zoonotic diseases, varying in the range of 0.019–0.064 percentage points for different grain crops.

As for the other five crops, a 1% increase in zoonotic diseases leads to a decrease of 0.021–0.048 percentage points of TFP (Table 4). However, it becomes a little complex when considering the impacts on inputs. All of them, except Canola, find a way to compensate TFP loss by increasing inputs (e.g., labor for Cotton; Fertilizer for Sugar Cane; Machinery for Peanuts, Sugar Beet and Sugar Cane). As a result, the adverse effects of zoonotic diseases on production is smaller than on TFP. For instance, though Sugar Beet suffers the most TFP loss among the five crops, applying more machinery and other inputs compensate most of its TFP loss. To sum up, all the five crops are expected to lose production due to increase in zoonotic diseases, varying in the range of 0.017–0.028 percentage points for different crops.

With respect to the 6 livestock, a 1% increase in zoonotic diseases leads to a decrease of 0.022–0.036 percentage points of TFP (Table 5). Meanwhile, zoonotic diseases cause additional adverse impacts on labor input for Mutton, making Mutton suffer the most production loss among the six livestock. In contrast, Zoonotic diseases lead to an increase of labor input for Broiler and Egg to compensate their TFP loss, making Broiler suffer the least production loss among the 6 livestock. To sum up, all the six livestock are expected to lose production due to increase in zoonotic diseases, varying in the range of 0.018–0.040 percentage points for different livestock.

### Table 2

Growth accounting of zoonotic diseases on grain crops.

| (%) | Early Indica | Middle Indica | Late Indica | Japonica Rice | Wheat | Corn | Soybean |
|-----|--------------|---------------|-------------|---------------|-------|------|---------|
| A. Input quantity | 0.001 | 0.000 | −0.020 | −0.014 | 0.000 | 0.005 | −0.015 |
| A1. Labor | 0.000 | 0.000 | −0.013 | 0.000 | 0.000 | 0.000 | 0.000 |
| A2. Fertilizer | −0.007 | 0.000 | −0.007 | 0.000 | 0.000 | 0.000 | 0.000 |
| A3. Machinery | 0.000 | 0.000 | 0.000 | −0.014 | 0.000 | 0.000 | —0.015 |
| A4. Others | 0.008 | 0.000 | 0.000 | 0.000 | 0.000 | 0.005 | 0.000 |
| B. TFP | −0.029 | −0.024 | −0.025 | −0.025 | −0.020 | −0.025 | −0.026 |
| Overall impact | −0.028 | −0.024 | −0.045 | −0.039 | −0.020 | −0.020 | −0.041 |
livestock segments, zoonotic diseases have additional channels to lower poultry. Secondly, one of the control measures to prevent the trans-sectors. 

Table 6
Growth accounting of zoonotic diseases on other crops.

| (%)    | Cotton (1) | Canola (2) | Peanuts (3) | Sugar Beet (4) | Sugar Cane (5) |
|--------|------------|------------|-------------|----------------|---------------|
| A. Input quantity | 0.001      | 0.000      | 0.008       | 0.030          | 0.009         |
| A1. Labor            | 0.019      | 0.000      | 0.000       | 0.000          | -0.030        |
| A2. Fertilizer       | 0.000      | 0.000      | -0.032      | 0.000          | 0.024         |
| A3. Machinery        | -0.018     | 0.000      | 0.040       | 0.008          | 0.015         |
| A4. Others           | 0.000      | 0.000      | 0.000       | 0.000          | -0.022        |
| B. TFP               | -0.029     | -0.021     | -0.025      | -0.048         | -0.032        |
| Overall impact       | -0.028     | -0.021     | -0.017      | -0.018         | -0.023        |

Table 7
The projected impact of COVID-19 on agricultural output.

| (%)                  | COS (1) | MES (2) | WOS (3) | COS (4) | MES (5) | WOS (6) |
|----------------------|---------|---------|---------|---------|---------|---------|
| A. Input quantity    | -0.14%  | -0.21%  | -0.27%  | 0.05%   | 0.07%   | 0.09%   |
| B. TFP               | -1.05%  | -1.53%  | -1.96%  | -1.43%  | -2.09%  | -2.68%  |
| Overall impact       | -1.19%  | -1.74%  | -2.23%  | -1.38%  | -2.02%  | -2.59%  |
project that COVID-19 will lower the growth rates of China’s crop and livestock sector by 1.1%–2.3% and 1.3%–2.6%, respectively, in 2020. Corresponding TFP loss will be 1.1%–2.0% in crop sector and 1.4%–2.7% in livestock sector.

It is worth noting that this paper may underestimate the actual impacts of the zoonotic diseases on agricultural production and the potential impacts of COVID-19 on agricultural output in China for reasons below. Firstly, the per unit measure used in the paper only capture the impacts of the zoonotic diseases on yield, not whole output or production. Secondly, the estimated impacts also include duty policy response. In other words, actual impacts are likely to be larger as actual cultivated areas of crops or the number of animals could be affected adversely. Thirdly, given the severity of COVID-19, the adverse impacts this time could be much larger than these of the previous diseases. Therefore, it is prudent for policy makers to consider the projected impacts of this paper as a lower bound estimation.

4. Conclusion and policy implications

Using provincial panel data for each of the twenty-four main farm commodities in China from 2002 to 2017, this paper investigates the impacts of the zoonotic diseases on agricultural production and projects the potential impacts of COVID-19 on agricultural output in China under three scenarios. The main findings are as follows. First, livestock on average suffers more than crops under epidemics, while zoonotic diseases have adverse impacts on almost all the main farm commodities, except Capsicum and Eggplant. Second, zoonotic diseases affect these subsectors mainly through the channel of adverse shocks on TFP. Third, while some of the subsectors can find a way to offset part of the TFP loss by applying more input, most subsectors suffer from both input reduction and TFP loss. Fourth, the spread of COVID-19 is projected to lower the growth rates of China’s crop and livestock sector by 1.1%–2.3% and 1.3%–2.6%, with TFP loss by 1.1%–2.0% and 1.4%–2.7%, respectively, in 2020.

In the face of the fast and wide spread of COVID-19 all over the world, the findings in the paper have important implications for mitigating the negative impacts of COVID-19 on agricultural production in China and elsewhere.

First, it is conceivable to policy makers that COVID-19 may cause severe adverse impacts on agricultural output and TFP. Twenty-two of the twenty-four main farm commodities would suffer both output and TFP loss by about 2 percent on average. Among grain crops, rice and soybean may suffer the most loss; among vegetables, greenhouse cucumber and field tomato may suffer the most loss; among livestock, dairy and mutton may suffer the most loss. It is worth noting that the current stable price of farm commodities in China is due to multiple reasons such as grain harvest in 2019, high stock and demand shrink due to the COVID-19 in early 2020. If agricultural production drops too much in 2020, it may cause food shortage by the end of 2020 or early 2021.

Second, it is crucial to ensure the access to inputs under COVID-19, especially the livestock sector, which may mitigate the adverse effects of zoonotic diseases on resource misallocation and efficiency loss in agricultural production. The control measures taken during the outbreak of epidemics, such as the strict controls on labor movement and transportation, may impede the access to inputs through two channels. The logistics and distribution of agricultural inputs can be adversely affected. Chinese government initiated the “green channel” for smooth distribution of agricultural products and inputs during the COVID-19, which guarantees the access to inputs.

Third, it is of great importance to reduce food loss and waste. This paper projects that COVID-19 will lower the growth rates of China’s crop and livestock sector by 1.1%–2.3% and 1.3%–2.6%, respectively, in 2020. This gap may not be filled by food imports, since most countries are still suffering from COVID-19. Cheng et al. (2018) estimate that 17–18 million tons of food were wasted every year in China’s catering sector, which accounts for almost 3% of China’s total food production and is enough to compensate the loss due to COVID-19. Considering the vulnerabilities of agricultural sector and the unknown trend of COVID-19, fostering a social environment where waste is shameful is of a special urgency.

There are a few limitations to this article that are worth emphasizing. First, although we think the major impact depends on the incidence rate, death rate, and control measures, we also agree with the reviewer that different diseases may still have different impact when other things being equal. Unfortunately, due to small sample size, we cannot estimate the impact of each and every zoonotic disease in the regression. Investigating the heterogeneous impact of various zoonotic diseases is an important task for future studies when richer data sources are available. Second, the major finding of the paper is that the negative impact of zoonotic diseases on agricultural production is mainly through TFP loss, which is more obvious in the livestock segment. Future studies with a casual model to identify how zoonotic diseases affect TFP loss are of great importance.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix. Description of Dataset

The data used in this paper are thirty-one provincial annual data for each of the twenty-four main farm commodities (including eighteen crops and six livestock) in China from 2002 to 2017. These commodity-level datasets are collected from The Compiled Materials of Costs and Profits of Agricultural Products of China.

In terms of crops, there are seven grain crops (Early Indica, Middle Indica, Late Indica, Japonica Rice, Wheat, Corn, and Soybean), six vegetables (Capsicum, Eggplant, Field Cucumber, Field Tomato, Greenhouse Cucumber, and Greenhouse Tomato), and five other cash crops (Cotton, Canola, Peanuts, Sugar Beet, and Sugar Cane). The output variable of each crop is measured as yield (kg per mu). The input variables include labor (labor-day), fertilizer (kg), machinery (CNY at 1980 constant prices) and other costs (CNY at 1980 constant prices).

In terms of livestock, six livestock products contain Beef, Hog, Mutton, Broiler, Egg, and Dairy. The output variable of each livestock is measured as main product weight of Beef, Hog, Mutton, and Dairy (kg per head), as well as Broiler and Egg (kg per 100 birds). The input variables include labor (labor-day), direct costs (CNY at 1980 constant prices) and indirect costs (CNY at 1980 constant prices).

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