Journal of Rural Studies 109 (2024) 103318

Contents lists available at ScienceDirect

Journal of Rural Studies

journal homepage: www.elsevier.com/locate/jrurstud

Farmers' perceived effect of the COVID-19 pandemic and its relationship to preparedness and risk perception

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ARTICLE INFO

Keywords:
Agri-food supply chain
Risk perceptions
Perceived impact
Perceived preparedness
Probit with sample selection

ABSTRACT

The impact of the COVID-19 pandemic across the agri-food sector was significant and pervasive, challenging farmers' resilience through multiple disruptions to the supply chain. To support forward planning in face to future shocks, this research examines the perceived impacts of the COVID-19 pandemic by farmers themselves, providing insights from the UK. Using a nation-wide online survey carried out during two distinct waves of the pandemic in 2021, the study reveals changing perceptions and the relationship between preparedness and perceived impacts. Results indicate that perceptions of both the severity of the COVID-19 impacts and preparedness for such impacts in the future, were scaled down as the pandemic evolved. Findings suggest that a farmer feeling more prepared in the present to withstand shocks is positively influenced by them perceiving the impact of COVID-19's in their business as severe. This effect is reinforced for farmers that felt more prepared to withstand COVID-19's impacts when the pandemic unfolded, as well as for those that perceive the impact of COVID-19 as long-term. Farmers in our sample appear to have adapted to the shocks to their businesses through supply-side interventions, focusing on having higher flexibility in delivery of products and diversifying their supply networks. Doing so requires them to absorb an increase in both fixed and variable costs, which can end-up been transferred to the consumer. Government support moving forward should focus on strengthening and, perhaps, re-imagining the whole supply industry and re-defining the role of farmers as more than food producers, but also as stewards of climate and food resilience.

1. Introduction

The impact of the COVID-19 pandemic across the agri-food sector was highly significant and pervasive, forcing major entities such as the European Union to introduce emergency measures such as extra income support for farmers, increase efficiency of the food supply chain through 'green lanes' (to keep food flowing) and carry out fewer on-the-spot farm checks (European Commission, 2020). Similarly, the United Kingdom relaxed legal requirements on its Competition Law (Barling, 2020; Garnett et al., 2020) and introduced regulations on delivery times while offering government support for businesses (Defra, 2021a). The UK government also waived restrictions for workers from Romania and Bulgaria to enter the country (Paul, 2020) and a national campaign was also launched to recruit British workers (Reynolds, 2020; Ranta and Mulrooney, 2021).

Despite such efforts, the majority of agri-food professionals in Europe reported losses in sales and disruptions to logistic services during the beginning of the pandemic, with delays in payments and accessing credit also reported throughout the duration of the pandemic (Di Marcantonio et al., 2022). Food production in the UK in 2021 was down in the crop and livestock production industries (Guilbert et al., 2022), also considering the cumulative effect of the transition period of the exit from the EU (Defra, 2021a). Farmers' resilience specifically was considerably challenged due to absenteeism in the workforce (both in the short and longer-term), financial challenges and disruptions in the wholesale market (Defra, 2021a). The UK government has since advocated the need for "business continuity planning within the agri-food industry" to mitigate risk (Defra, 2021a). Doing so requires forward planning along

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https://doi.org/10.1016/j.jrurstud.2024.103318
Received 24 July 2023; Received in revised form 17 April 2024; Accepted 8 June 2024
Available online 14 June 2024

Journal of Rural Studies 109 (2024) 103318

with the ability to assess past events and future risk in the food supply chain. To support this, this research examines the perceived impacts of the COVID-19 pandemic on farming by farmers themselves, as identification of risks by primary producers is critical in anticipating and dealing with disruptions in the supply chain (Yazdani et al., 2022). We do so by providing insights from UK farmers obtained from two online surveys carried out in 2021, examining changes in views between two distinct periods during COVID-19, namely the second lockdown and the subsequent easing of restrictions country-wide. We use the farm holding as the unit of analysis since responses to shocks ultimately require action by farmers at the level of their own farm holding.

This paper adds to the emerging but still limited body of literature on what is arguably one of the major societal 'shocks' in recent history. There is a wide and well-established literature focusing on the mediating effect of risk perceptions, past experiences cognitive understanding to farmers' behaviour post (or during) relatively 'conventional' market or weather-related shocks (Martey et al., 2021a; Jezeer et al., 2019; Eakin et al., 2014; Shinbrot et al., 2019) – but arguably, the COVID-19 pandemic sent shocks across sectors, at a global scale (de Oliveira and Tegally, 2023). While it took a hundred years for a large pandemic to occur since the previous one, and we do not know when the next pandemic will be, we know that the leading causes of climate change can increase the risk of pandemics occurring (deforestation, urbanisation and livestock husbandry all bring more animals in closer contact with humans, which in turn increases the likelihood of pathogens moving from animal to humans) (de Oliveira and Tegally, 2023). Warmer temperatures also have an influence in infectious diseases; and increase in rainfall, or changes in sea currents, also affect the incidence and location of waterborne diseases, while the location and extent of vector-borne diseases are determined by climate patterns, further increasing risks of food supply-related shocks (Ferreira et al., 2023) and having a rapid and pervasive impact across economies (Arndt et al., 2020). Further, geopolitical conflicts can also trigger major shock waves across the agricultural sector, as illustrated by the Russian invasion of Ukraine – for example, Laber et al. (2023) quantified the propagation of Ukraine's localised agricultural shutdown as a 10^8 'shock' transmission to agricultural production in 192 countries. Whether it is the emergence of a new pandemic, or the destabilising effects of climate change and geo-political conflicts, food production shock frequency is increasing through time at a global scale (Cottrell et al., 2019). This is acknowledged by the UK government, with increased emphasis on food resilience post-COVID (Defra, 2021a).

In this context, high adaptability on the part of food producers has been highlighted as a key mitigating factor (Rivington et al., 2021). Understanding farmers' decision-making mechanism prior to and during such major shocks becomes imperative as part of supporting needed increased resilience. While several studies have looked into farmers' risk perceptions at some point in time during the COVID-19 pandemic, (e.g. Luo et al., 2022;, Yazdanpanah et al., 2021 Middendorf et al., 2021; Perrin and Martin, 2021; Wilkinson et al., 2022; Underhill et al., 2023; Coopmans et al., 2021; Durant et al., 2023 – with only one in the UK, limited to the South West: Wilkinson et al., 2022) – ours is the first one to explore the evolution of these actions and perceptions as the pandemic unfolded (across two distinct time periods). This paper aims to fill the knowledge-practice gap between perceived risk, perceived impact from Covid-19-related disruptions to farming activities and actions to mitigate impacts of shocks to farming. As decision-making of farmers on actions to adapt to shocks, such as COVID-19 restrictions, is expected to depend on perceptions of past risk and the perceived impact of shocks, descriptive findings are enriched with the use of a Heckman two-stage approach (Deressa et al., 2011; Si et al., 2022) that explores such relationships. Further, to the authors' knowledge, this is the only study that explores the relationship between perceived preparedness to shocks at the time of the pandemic and the perceived severity of COVID-19's impact on farmers' business.

2. Methods

2.1. Survey design

The questionnaire used in our surveys included a profiling section eliciting farmer and farm characteristics such as farm size, ownership, type of farm activity and share of income dependent on farming. COVID-19 related questions included identification of the types of disruptions caused to farming, both from the supply (local labour or subcontractor activity, hiring foreign labour, availability of inputs or machinery, disruptions in selling or delivering products, decreases in production and changes in cropping or livestock patterns) and demand side (decrease in sales, demand for products or decreases in income). These categories of supply and demand disruptions correspond to those being publicly discussed at the time.[1] Such public information was processed by the research team and formulated in simple categories in the questionnaire. Participants were asked to rank the perceived severity of the impact that the COVID-19 pandemic was having in a five-point scale ranging from "not severe at all" to "very severe".

Using the same categories of disruptions, participants were asked to indicate which of them they believed would experience long lasting impacts from the pandemic. Participants were also asked how the COVID-19 disruptions compared with previous disruptions. Next came a series of questions on their perceived preparedness to withstand the pandemic's impact, measured using Likert scales as common in the adaptation literature (e.g. Le Dang et al., 2014; Mercado et al., 2016); with a five-point scale ranging from "Not at all prepared" to "Completely prepared". Participants were then asked how long they perceived the effects of the pandemic would last, ranging from being "already over" to lasting "10 years and more". A final question asked how prepared they felt to withstand the long-lasting impacts of the pandemic, ranging from "Not at all prepared" to being "completely prepared".

The next set of questions focused on the types of adaptation measures taken during the pandemic by the participants. These involved options to change markets targeted, changes in suppliers, changes in cropping or livestock patterns, hiring local labour only and changing forward planning. Such adaptation measures were selected to mirror the disruptions (e.g. disruption on foreign labour was mirrored by the measure "hiring local labour") and were aligned with National Farmers Union's reporting (NFU, 2023). Participants were also asked to indicate which of the aforementioned adaptation measures they will be taking in the long-term.

The final section of the questions asked respondents for some key socio-demographic questions such as gender, age, and highest education level attained. Not all participants answered all COVID-19-related questions; if they had previously stated that they believed that there was no impact of COVID-19 in their business they were re-directed to the next section of the questionnaire. All farm and socio-demographic questions were answered in the completed questionnaires. In both data collection waves, questions were identically phrased to allow for comparisons.

2.2. Sampling and data

Two distinct samples of UK farmers were obtained via the survey company Qualtrics. Data collection took part in two waves during 2021. The first wave of responses was collected in the first two weeks of February 2021 and the second in October 2021. The above timelines coincide with enforcing a second round of restrictions and rises in COVID-19 infection cases (represented by first wave of data collection) and after the relaxing of restrictions and large vaccination rates across

[1] These types of disruptions publicly discussed ended being reflected broadly in the UK Parliament's 7th Report on Food Security (2023) and can also be traced in similar literature (e.g. Nordhagen et al. (2021) and Jha et al. (2023)).

the UK (represented by the second wave of data collection) (UK Government, 2022a). This resulted in 194 and 251 useable, complete responses for the first and second waves respectively, totalling in 445 cross-UK responses.

The summary statistics from the two waves, compared with the whole of the UK farming population are presented in Table 1. Overall, our two samples contain younger, more educated farmers who managing larger land holdings than the UK average. This is to be expected, since online surveys tend to attract young, educated participants (Olsen, 2009) while official statistics tend to register the registered owner/-father, who is not always the person actually managing the farm (older and often less formally educated). Our sample also includes an over-representation of dairy farms, particularly with respect to upland livestock farms (some deviation in this respect is also somewhat unavoidable due to lack of commercially available quota sampling per farm type). While differences between the sample and the overall farming population of the UK is clearly a limitation of this study, the collected sample is within expected representativeness of the farmers surveying literature in the UK (Daxini et al., 2018; May et al., 2021; Tyllianakis et al., 2023) - particularly considering how notoriously difficult is to access and survey farmers (Polain et al., 2011). In any case, the non-probabilistic nature of the sampling technique does not allow for claims of representativeness over the whole of the UK industry to be made. Therefore, although the statistical accuracy of the results can be trusted, they should be treated as indicative of the sample and not of the whole UK farming population.

It is also important to highlight that, because we have two different samples, one for each of the waves that are analysed here, strictly speaking our data sample is not panel (i.e. different observations for the same individuals over time).[2] Theoretically, this poses limitations to the study, since the individuals across the two samples might vary in characteristics that matter for the analysis. In practice, this only matters if the samples vary across characteristics that influence the object of study (in this case, perceived impact, prepared, disruption or action). To check for this, we have carried out a number of tests. Firstly, we identify if there are any statistical differences across the socio-demographic variables of respondents across the two samples using paired samples T-tests. Then, for each of the variables that are used in any subsequent analysis, we have checked whether they vary across the statistically significantly different farm and socio-demographic variables across waves. For that, we have used Chi-Square tests of Independence, which check whether two variables are likely to be related. Only for those where the results of the Chi-Square test are significant there may be implications for the results, that we discuss explicitly. In any case, and because there is always the possibility that un-observed factors are at play (as in any other survey-based quantitative study), this limitation is carried forward to the discussion more generally.

Table 1
Summary statistics for the two data collection waves and comparison with the UK population.

Characteristics	1st wave	2nd wave	UK farming population
Average age in years	*54 (st. dev = 10)*	*41 (st.dev = 12)*	59[a]
Average gross farm income in £/year	*£59,121 (st. dev = 21,267)*	*£46,293 (st.dev = 24,548)*	£51,900[a]
Average hectares	*193.2 (st. dev = 767.3)*	*246.8 (st.dev = 1709)*	159.9 (Total Utilised Agricultural Area)[a]
Gender	*Male = 86%*	*Male = 67%*	Male = 85%[a]
Education	No formal qualifications = 8% Secondary school = 24 % Vocational/ professional agricultural education = 24% College education = 67%	No formal qualifications = 4% Secondary school = 20 % Vocational/ professional agricultural education = 24% College education = 51%	n.d. Vocational/ professional agricultural education = 17%[b] College education = 45%[b]
Farm type[c]	Arable = 15 % Dairy = 24% Lowland livestock = 6% Upland livestock = 7% Mixed (arable and livestock) = 25% Other = 7%	Arable = 11 % Dairy = 22% Lowland livestock = 16% Upland livestock = 8% Mixed (arable and livestock) = 28% Other = 7%	Arable = 28%[a] Dairy = 6%[a] Lowland livestock = 21%[a] Upland livestock = 33%[a] Mixed (arable and livestock) = 8%[a] Other = 5%*

[a] EUROSTAT, 2017 Agriculture database.
[b] UK Government, 2016
[c] Farm types correspond to the generic categories established by the UK Government (UK Government, 2022b).
Sources:

2.3. Analytical approach

The analysis is composed of three strands. Firstly, through descriptive statistics, we provide an overview of the results over each of the two waves with respect to perceived impact, resilience and impact effect of COVID-19.

In a second strand, we check for differences across the two waves, using Mann-Whitney U tests. With this, we want to identify significant changes in perceptions as the pandemic evolved, firstly with respect to impact and preparedness and then in relation to the type of disruptions. Further differences across the two waves with respect to the type of actions taken by farmers in response to those disruptions are also tested.

Moving beyond descriptions and differences, a third strand of analysis looks at the relationship across perceived preparedness and perceived severity of impacts. We use a Heckman two-step model and estimate it through a binary probit model with sample selection (Van de Ven and Van Praag, 1981). This approach has been used in the field of farmers' decisions before, with decisions assumed as contingent on a variety of determinants such as farm characteristics and other factors (Cooper and Keim, 1996; Michels et al., 2020; Abate et al., 2019). The binary probit model is applied in two stages and through two equations: first, a sample of observations is identified ("selected") through a binary variable taking the value 1 to indicate those who belong in a category and its relationship with covariates is examined (Equation (1)). Then an "observed" or "outcome" variable is regressed on covariates that also determined the binary variable in the first stage, alongside with other covariates (Equation (2)). This model is useful as it allows to determine the size and type of impact an endogenous variable (such as perceived impact from a shock) can have on an observed one (such as perceived preparedness to withstand shocks at the present). Table 2 below describes the variables used in our application of this model, which is explained next.

In detail, we examine whether feeling more prepared to withstand the COVID-19 shock to one's farming business as it occurred (our dependent variable in the 'outcome' Equation (2) below, *PreparedNow*), is contingent on perceiving its impact on one's business as severe or very severe (our dependent variable in the 'selection' Equation (1), *SevereImpact*). In each of these equations we test for the effect of the perceived preparedness to withstand COVID-19 impacts as they occurred (variable *PreparedThen*) and the perceived impact duration (variable

[2] Due to the restrictions in accessing farmers directly due to data protection laws, it was not possible to repeat the survey with exactly the same respondents at the time of the study.

Table 2
Variables used and their assumed relationships with regards to perceived preparedness and perceived impact from COVID-19 to a UK land manager's business.

Variable name	Description	Hypothesis
SevereImpact	Perceiving the impact of COVID-19 to one's business was severe/very severe	H1
PreparedThen	Feeling prepared/very prepared to resist the impact of COVID-19 as the pandemic unfolded.	H1, H2
ImpactDuration	Believing that the impact of COVID-19 on one's business with last at least 10 years	H1, H2
PreparedNow	Feeling prepared/very prepared to resist the impact of shocks similar to COVID-19 at the present	H2
Actions	Types of actions a farmer undertook to address COVID-19 disruptions to one's business	H1
FarmChar	Farm and farmer characteristics	H2

ImpactDuration), according to expectations based on the literature (Coopmans et al., 2021; Durant et al., 2023).[3] In Equation (1) we also include the different actions farmers had taken as a reaction to the pandemic (variable *Action*) as these are expected to influence the perception of the severity of impacts (Martey et al., 2022a; Durant et al., 2023). In Equation (2) also we test for the mediating effect of farmer and farm characteristics (represented by the vector *FarmChar*):

$$SevereImpact_i = \beta + \beta_{1i}PreparedThen + \beta_{2i}ImpactDuration + \beta_{3i}Actions_j + \varepsilon_i \quad \text{(Selection Eq.1)}$$

$$PreparedNow_i = \gamma + \gamma_{1i}PreparedThen + \gamma_{2i}ImpactDuration + \gamma_{3i}FarmChar_j + u_i \quad \text{(Outcome Eq.2)}$$

To be identified, the selection equation needs to not contain at least one variable not appearing in the outcome equation. The β_i and γ_i are the coefficients to be estimated, γ and β are the constants for each equation while the ε_i and u_i are the error terms and their correlation is estimated and reported as ρ in section 3.5. The Selection and Outcome equations also define our two testable hypotheses (see Table 2) as:

H1. Perceiving COVID-19's impact as severe is influenced by feeling prepared, the duration of the impact and actions taken to prepare for shocks to farming.

H2. Perceived present preparedness to deal with COVID-19-type shocks is influenced by feeling prepared to deal with past shocks, the duration of the impact and farm characteristics.

3. Results

In the next sub-sections, first we provide an overview of perceived impact, resilience and impact effect through summary statistics, to then present the comparison between perceived impact and preparedness across waves, followed by an analysis of the difference in type of disruptions across. Subsequently, we discuss which actions were taken in response to COVID-19 disruptions, also comparing across the two waves. Finally, we present the results from the two-stage modelling of the relationship between perceived preparedness and impact from shocks.

3.1. Overview of perceived impact, resilience and impact effect of COVID-19

Table 3 shows responses to the three questions on perceived severity of the impact of the pandemic on their business, their level of preparedness to resist those impacts and their perception on whether the impacts will persist, during the two distinct waves.

Table 3
Summary statistics of perceived impact, resilience and impact effect of COVID-19.

Question	Observations	Mean	St. deviation
1st wave			
How severe was the impact of COVID-19 to your business?	176	3.55	0.80
How prepared were you to resist the impact of COVID-19 as the pandemic unfolded?	176	3.00	1.03
How long do you think the impacts of these crises on your farming activity will persist?	176	2.28	0.72
How prepared are you now to resist impacts?	173	3.12	0.96
2nd wave			
How severe was the impact of Covid-19 to your business?	248	2.88	1.33
How prepared were you to resist the impact of COVID-19 as the pandemic unfolded?	251	2.61	1.13
How long do you think the impacts of these crises on your farming activity will persist?	251	1.93	0.97
How prepared are you now to resist impacts?	251	2.70	1.01

Note: Each question took values between 1 and 5 apart from the final one which took values between 1 and 4.

From the summary statistics, it appears that participants stated, on average, lower levels of perceived severity of the impacts of COVID-19 in wave 2 than in wave 1. Similarly, participants in the second wave appeared, on average, more optimistic about the impact of COVID-19 disruption on their farming business while acknowledging that they were less prepared to withstand the disruptions impact during the easing of the lockdown restrictions (wave 2).

It is to be noted that the paired T-tests identified that the only socio-demographic variable that varies significantly across our two samples is 'age', i.e. the rest of the variables (gender, education, farm type, farm size and income) do not diverge in a statistically significant way at the 5% level (see Table A1 in the Appendix). The Chi-Square tests of independence showed that 'age' might have an effect on the cross-waves differences regarding the perception of severity of the impacts, preparedness and certain types of disruptions (specifically shortage of labour) presented next (see Table A2 in the Appendix for more information).

3.2. Differences in perceived impact and preparedness across waves

Results of Mann–Whitney U tests confirmed that differences between waves are significant with respect to perceived impact (i.e., expected duration and severity) and perceived preparedness.[4] Farmers considered the impact of COVID-19 as less severe during the easing of the lockdown restrictions, compared to the first one ($X^2 = 17.352$, p-value<0.001) with a Rank-Biserial Correlation coefficient of -0.215. It was also confirmed that participants felt more prepared to deal with COVID-19's impact during the easing of the lockdown restrictions than during the second lockdown (wave 1 in this study) ($X^2 = 15.23$, p-value<0.001) with a Rank-Biserial Correlation coefficient of -0.175. Participants also felt less prepared to deal with future impacts to their farming activities during the easing of restrictions than during the second lockdown ($X^2 =$

[3] It should be noted that the selection equation (Eq. (1)) can contain unobserved factors (Chatzistamoulou and Tyllianakis, 2022) which can have an effect on how prepared a farmer feels as the shock occurs.

[4] The two-sample Kolmogorov –Smirnov showed that these variables were non-normally distributed at $p < 0.001$ level.

38.44, p-value<0.001) with a Rank-Biserial Correlation coefficient of −0.203. Finally, participants during the easing of the lockdown restrictions were more pessimistic regarding the effects of COVID-19 and similar crises, believing they will last longer, compared to respondents during the second lockdown ($X^2 = 17.915$, p-value<0.001) with a Rank-Biserial Correlation coefficient of −0.194. It appears that perceptions of participants regarding the severity of the of COVID-19's impact were scaled down as the pandemic unfolded, as well as were the levels of "optimism" concerning preparedness for such impacts, or regarding their duration. Conversely, 9% of participants of the first wave claimed there was no impact at all from COVID-19 to their business compared to 14% of participants of wave 2, showing salient differences in perceptions between the two waves. As the Mann – Whitney *U* test examines variables at the mean, further nuances from variations in perceptions (either positive or negative) cannot be captured.

3.3. Differences in type of disruptions to farming across waves

The responses to the different types of perceived types of disruptions caused by the pandemic are presented in Fig. 1 below. These categories refer to whether a respondent chose at least one of the options offered below, as they were allowed to select multiple types of disruptions.

The summary statistics of Fig. 1 show a change in perceived impacts between the two different waves, per type of disruption. Disruptions in labour and supply chains were more pronounced, on average, in the second wave where lockdown restrictions were being gradually lifted while decreases in production and being forced to change cropping or livestock patterns were less frequently chosen in this period compared to the second lockdown period (wave 1). Decreases in sales and/or income were, on average, similar across the two waves.

Mann–Whitney U tests were carried out to determine if these differences between waves are statistically significant and reported in Table 4. All differences were statistically significantly different between waves, apart from the disruptions in income (the Rank-Biserial Correlation coefficient in all variables was positive and did not straddle the 0 value). Therefore, the supply-related disruptions were more prevalent as the pandemic unfolded (during the easing of restriction, i.e., wave 2), compared to the second lockdown (wave 1) while supply issues such as hiring of labourers or subcontractors (domestic or from abroad) were more prevalent at the height of the pandemic (during the second lockdown, i.e., wave 1) compared to the easing of restrictions (wave 2). The comparison at the average level does not allow for diversity of perceptions or behaviours to be explored beyond the farm and socio-economic characteristics included in the models.

3.4. Actions taken in response to COVID-19 disruptions to farming

Farmers undertook several actions in response to the pandemic. Actions included in the survey are taken from the recommendations of

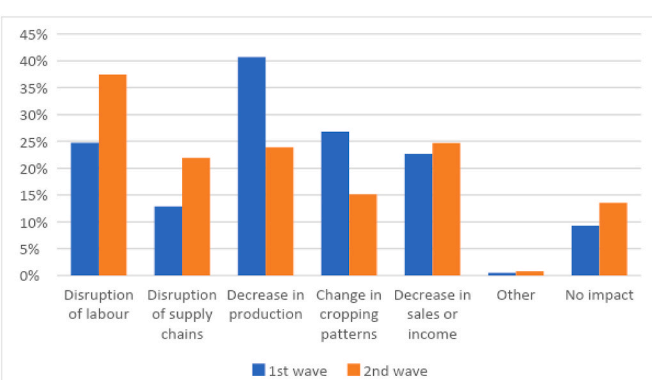

Fig. 1. Frequencies of potential perceived disruptions from COVID-19.

Table 4
Differences between waves regarding types of disruptions to one's farming business.

Disruption of labour	**	Source: UK Parliament (2023); Jha et al. (2023)
Disruption of supply chains	**	Source: UK Parliament (2023); Jha et al. (2023)
Decrease in production	***	Source: Nordhagen et al. (2021); Jha et al. (2023))
Change in cropping patterns	***	Source: Nordhagen et al. (2021)
Decrease in sales and/or income	n/s	Source: Nordhagen et al. (2021)

Note: ***, ** indicate statistical significance at the 99% and 95% level, respectively.

UK Parliament's 7th Report on Food Security (UK Parliament, 2023) cross-referenced with those from Tittonell et al. (2021). Fig. 2 shows them across the two waves. Interestingly, these show a clear increase in uptake of each measure between the two waves, despite the fact that second-wave responses came during the easing of lockdown measures and farmers might have been keen in returning to their normal activities.

3.5. Relationship between perceived preparedness and perceived impact from shocks

The results of the probit model with sample selection for the full sample (i.e., both waves combined, comprising of 445 cross-UK farmers) are presented in Table 5 below. All covariates in the selection equation (estimated through Eq. (1) in section 2.3) apart from income are binary, taking the value 1 if the statement is true, zero otherwise. The farmer and farm variables in the outcome equation (estimated through Eq. (2)) include gender (taking the value 1 if the respondent is male, zero otherwise), age (a continuous variable), if a respondent has a university education or higher (Highly educated taking the value 1, zero otherwise) and income (a log transformed variable of gross farm income).

The Wald test of independence is statistically significant (p-value<0.001) that the chosen coefficients cannot be simultaneously equal to zero. The Likelihood ratio test of $\rho = 0$ was also rejected (p-value<0.001) indicating the appropriateness of using the sample selection method (Michels et al., 2020) and the presence of endogenous effects on perceived resilience, preparedness and perceived impact of COVID-19 on one's farm business.

Results in the selection equation show that high existing level of preparedness and extended perceived duration of COVID-19 impacts have a statistically significant and positive influence in a farmer feeling that COVID-19's impact was more severe, confirming the so-called 'risk perception paradox (Wachinger et al., 2013). This means that H1 cannot be rejected. Farmers who took actions, namely, made changes in cropping and husbandry practices and hiring local labour were the ones who perceived the impacts of COVID-19 as severe.

Results from the outcome equation show that high perceived preparedness to withstand ongoing shocks is positively and statistically significantly influenced by perceived preparedness to withstand future shocks and by having a high perceived duration of COVID-19 impacts. This means H2 cannot be rejected. When it comes to the effect of farmer and farm characteristics on preparedness, only education is significant in the model, meaning that being highly educated positively influences perceived preparedness.[5] Finally, the correlation coefficient ρ is positive and highly significant indicating, as expected, that a farmer perceiving

[5] Age' not being significant across the two samples means that the detected differences across out two samples (see section 3.1.) does not affect results in the probit model with sample selection. As a reminder, the socio-demographic variable 'education' is not statistically significant across the two samples (across waves), which means that the fact that we did not use panel data does not affect the model in this respect.

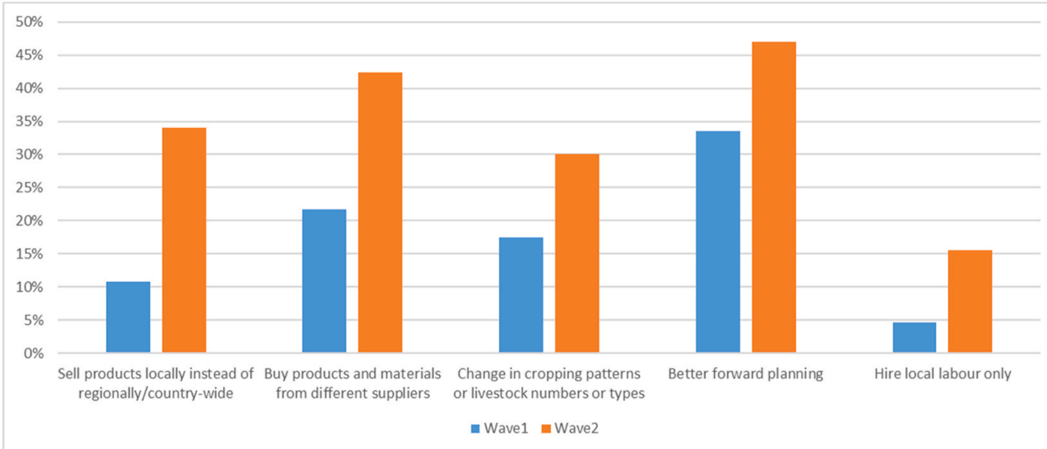

Fig. 2. Frequencies of additional actions/changes in the farm business undertaken by respondents during/after each wave of the COVID-19 pandemic.

Table 5
Results of probit model with sample selection with clustered standard errors on the endogenous relationship between perceived impact of COVID-19 and perceived present preparedness to withstand shocks.

Selection equation		
There is severe/very severe impact of COVID-19 to my business	**Coefficient**	**St. Error**
I was prepared/very prepared to resist the impact of COVID-19	0.272**	0.136
Impacts of the COVID-19 disruption will last at least 10 years in my farming activity	0.619***	0.220
Sell products locally instead of regionally/country-wide	0.085	0.136
Buy products and materials from different suppliers	0.146	0.112
Change in cropping patterns or livestock numbers or types	0.203*	0.123
Better forward planning	0.093	0.116
Hire local labour only	0.494**	0.202
Constant	−0.319**	0.127
Outcome Equation		
Being prepared/very prepared now to address impacts	**Coefficient**	**St. Error**
I was prepared/very prepared to resist the impact of COVID-19	1.319***	0.161
Impacts of the COVID-19 disruption will last at least 10 years in my farming activity	0.495**	0.223
Income (log)	−0.023	0.119
Gender	0.121	0.161
Age	0.008	0.006
Highly educated	0.331**	0.141
Constant	−1.924	1.387
P	11.657***	0.123
Rho	1.000	<0.001
Observations	443	
Wald test of Independence ($\rho = 0$)	9019.03***	
Wald X^2	98.01***	
Pseudo LR	−394.669	

Note: ***, **, * indicate statistical significance at the 1%, 5% and 10% level, respectively.

the impact of COVID-19 as high is associated with a farmer having high perceived preparedness to withstand current shocks.

4. Discussion

Past studies have found evidence of association between farmer resilience and preparedness (e.g., Yazdanpanah et al., 2021) and perceived COVID-19's impacts (Luo et al., 2022). To the authors' knowledge, this is the first study that finds this combined effect of preparedness and sensitivity on farmer resilience. Our work offers unique insights to farmers' perceptions across two distinct periods during the COVID-19 pandemic using data from the UK. Findings confirmed that, after the second lockdown and when restrictions started to being lifted, farmers' perceptions changed. While some of the reported differences might be in part due to age differences across the two samples that we used and other possibly un-observed factors, they still reveal interesting insights on how perceptions evolved during the pandemic. In particular, farmers seemingly became more optimistic with respect to the expected impact of COVID-19 in their business while acknowledging that they were not, and continued to not be, prepared to withstand shocks similar to COVID-19. To the authors' knowledge there are no other studies between farmers examining changes in perceived preparedness and perceived impact during COVID-19.

The responses across the two waves, presented in Table 4, show significant differences, with the second lockdown surveyed farmers (wave 1) reporting higher perceived impacts on production (decreases) while impacts in labour (increased difficulty in procuring labour hands) became more evident in the easing of restrictions (wave 2). Findings from the first wave are similar to other European studies that took place during the first wave of the pandemic reporting moderate to low impacts on labour procurement (see for example the French study amongst organic dairy farmers in Perrin and Martin (2021) and a study amongst Flemish farmers in Belgium in Coopmans et al., 2021). Contrary to the 55% of farmers in the cross-European study of Helfestein et al. (2022), and the 38% reported in Wilkinson et al. (2022)'s 2020 survey of farmers in the South-West of England, 11% of farmers (across waves, see Fig. 1) in our study considered COVID-19 as having no impact on their farm activities. This perhaps is an indication of the compound effects of Brexit and COVID-19 on UK's exports, imports and tariffs (Defra, 2021b).

Similar to other studies examining perceived risk from COVID-19 disruptions to agricultural activities (e.g., Xie et al., 2021) we find that high perceived risk is associated with high perceived impact from COVID-19 disruptions, both in the supply and demand side. Higher perceived preparedness from COVID-19 shocks to supply chains has been linked to an increased focus on storage space for products (Huss et al., 2021). Additionally, higher COVID-19 perceived risk has been associated with farmers adopting more coping mechanisms for climate change impacts on agriculture (Martey and Kuwornu, 2021; Luo et al., 2022) and adopting more sustainable agriculture practices as a specific response to COVID-19 disruptions (Martey et al., 2022b). In our study, higher perceived impact from COVID-19 was associated with addressing supply disruptions in farming activity such as by hiring local labour only (see Table 5). In this study, perceived risk and impact were treated as an antecedent to observed behaviour and therefore we did not focus on drivers of risk perceptions as a response to a shock. Increased cognition of COVID-19 risk has been found to lead to higher risk perceptions and, consecutively to higher receptivity towards environmentally friendly farming (Luo et al., 2022) with drivers of risk perceptions being a separate research area (see e.g., Paudel et al., 2019).

The types of disruptions to farming, presented in Fig. 1, indicate that disruptions in labour (hiring foreign or domestic labour), disruptions in cropping patterns or livestock numbers and decreases in production were the largest disruptions during the first wave of the pandemic (see Table 4). During the easing of restrictions, disruptions in labour and decreases in income or sales were reported by most respondents. Past studies examining the effects of COVID-19 on agriculture and farming have mainly focused on smallholders (e.g., Middendorf et al., 2021; Martey et al., 2022a; Huss et al., 2021; Pagannini et al., 2020) for whom sourcing of labour is not considered a factor in decision-making and therefore when considering responses to shocks.

Regarding the influence of socio-demographic characteristics, we found significant and positive associations between education and perceived impact of COVID-19 and perceived preparedness to withstand its impacts (see Table 5). No other studies have examined the impact of education on perceived impact and preparedness to COVID-19. Apart from education, no other farmer sociodemographics were found to influence these variables although past studies have found differences between male and female farmers regarding coping mechanisms for climate shocks (Mehar et al., 2016) but the nature of our data with only 20% (on average, across waves) of respondents being female did not allow for such comparisons. Nevertheless, gender being non-significant in such studies is not uncommon (e.g., Durant et al., 2023). Finally, farm size has been found to have a positive effect on perceived resilience to COVID-19 shocks (Durant et al., 2023). Interestingly, in its own assessment of the agri-food sector's response to COVID-19, the UK government notes that the ability to better plan ahead to mitigate farming business risk might be more feasible for larger agri-food businesses than for small and medium enterprises (Defra, 2021a). Our sample contains responses from respondents reporting a higher average UAA than the mean in the UK (see Table 1) which could be an approximation of farm business size and consequently our results can offer some support to Defra's assertion.

Next, our analysis demonstrated the influence of perceived risk by COVID-19 on feeling more prepared to withstand the impacts of shocks to farmers' business (see Table 5). To our knowledge, this is the first study that examines the relationship between risk perceptions and perceived resilience, across the duration of the COVID-19 pandemic, in a Global North country (Durant et al. (2023) - in California (US) only focuses on the first wave). Our study showed the uptake of measures that allow more flexibility such as hiring local labour and changing cropping and husbandry patterns (see results in the 'Selection equation' results in Table 5) have an indirect and positive effect in someone feeling more prepared to withstand the impacts of shocks, such as COVID-19. Studies that examined the responsive capacity to COVID-19 shocks of larger farmers indicate that, similar to our study, actions such as ability to reorient sales, having higher stocks and the ability to renegotiate supplier prices is related to higher perceived resilience and preparedness (Coopmans et al., 2021; Meixner et al., 2022; Durant et al., 2023).

Additionally, we also find that high perceived past preparedness and extended perceived duration of COVID-19 impacts have a statistically significant and positive influence in a farmer feeling that COVID-19's impact was more severe (see Table 5 and Wald test of independence results in Section 3.5). Finally, our study provides evidence of the endogenous relationship between perceived risk and perceived resilience to shocks (see bottom of Table 5). Such findings indicate that farmer resilience is associated with both perceived preparedness and increased sensitivity to shocks. Here it is important to note that *perceived* ability can be very different from objective ability (Grothmann and Reusswig, 2006) and humans are not always aware of their objective action scope and can over or underestimate their ability to adapt (Elrick-Barr et al., 2017); and a dominant narrative of capability (i.e. actors believing they have the capacity to adapt) might actually prevent investment in adaptive action.

The interpretation of our results is restricted by the nature of quantitative research method used in this study, which only allows to establish relationships across variables obtained through close-ended standardised responses. More could be un-packed in future research complementing this analysis with qualitative data collection in a mixed-methods approach (e.g. combining the questionnaire within semi-structure interviews or focus groups), where questions such how does perceived preparedness relate to actual preparedness, could be explored. Such combination with qualitative research would have also allowed to determine the effect of the geo-political dynamics and/or other broader social phenomena such as the labour migration movements during the pandemic.

Other limitations of this study concern sample composition and questionnaire-related heuristics. Firstly, as indicated in the introduction, ideally, we would have used panel data for this study, i.e. observations for the same individual across the two waves. These tests that we have carried out demonstrate that despite this limitation, the samples are still sufficiently similar for the analysis and for the corresponding results not to be significantly affected. We argue that, considering the difficulties of studying this field, these are still definitely worth-while of exploration and valuable contribution.

With respect to sample composition, larger farms tend to be over-represented in our sample which might result in farmers being more capable to withstand restrictions or adapt to challenges (Tyllianakis et al., 2023). We also do not address potential differences with respect to geographical characteristics due to the limitations of the sampling ability (not limited to our study, but more broadly on this field) which can affect generic risk perceptions (Thomalla et al., 2006) across geographies (Cameron et al., 2021). Finally, questionnaire-related heuristics are expected to affect participant farmers' understanding of concepts such as risk and perceived impacts (Tyllianakis, 2024). Such issues therefore should influence results and can require qualitative analyses to further provide clarity.

5. Conclusions

This study has explored for the first time how farmers' actions and perceptions of preparedness and impact to a shock such as the COVID-19 evolved as pandemic unfolded, using a sample from the UK. It is also the first one to explore the relationship between perceived preparedness to shocks at the time of when they hit and the perceived severity of the impact on farmers' business. Despite the limitations of farmer-based research like in this study (notably in terms of sampling), understanding farmers' decision-making mechanisms prior to and during such major shocks is imperative in order to support better forward planning in the agri-food industry, at a time where systems' volatility is increasing.

Perceptions of participants regarding the severity of the of COVID-19's impact and the levels of "optimism" concerning preparedness for such impacts, or regarding their duration, were scaled down as the pandemic evolved (i.e., across the two waves). Results also indicate that the perceived severity of the impact of the pandemic in their business affects farmers' feeling of preparedness to withstand other similar shocks. This effect is reinforced if a farmer had high perceived preparedness to withstand COVID-19's impacts by the time the pandemic unfolded and if they perceive the impact of COVID-19 as long-term. This finding highlights the duality of risk perceptions, with farmer resilience being dependant both on past and present risk perceptions. Therefore, farmers more concerned about shocks are those who are more likely to adapt but also use past experiences to do so.

Our findings also indicate that as the pandemic unfolded, farmers undertook more measures to enhance their resilience such as making changes in cropping patterns or livestock numbers or types and hiring local labour only. It is likely that smallholders and part-time farmers might not be able to adapt in such shocks (Defra, 2021a) and therefore be forced out of the market, exacerbating issues of land abandonment (Tyllianakis, 2024). Finally, our results show changes in risk perceptions and perceived preparedness, as the pandemic progressed. In particular, farmers experiencing severe impacts from COVID-19 and farmers with higher perceived preparedness to withstand such impacts are more likely to identify supply-side disruptions such as hiring of labourers or subcontractors (domestic or from abroad) and procurement of equipment or being able to sell one's products in the market. As the pandemic unfolded, long-term effects and impacts that reflect the demand-side of farming such as decreases in production, sales or income were considered less of a threat.

Farmers' resilience in this study is linked to actions meant to absorb shocks to their businesses through supply-side interventions, focusing on having higher flexibility in delivery of products and diversifying their supply networks. Doing so requires them absorbing an increase in both fixed and variable costs which, if transferred to the consumer, can exacerbate the UK's cost-of-living crisis. Government support moving forward should focus on strengthening and, perhaps, re-imagining the whole of the supply industry. Creating smart agri-food networks that allow for efficient allocation, storage and transport of goods through an increased reliance on modern technologies such as online inventories and live-tracking of deliveries could be beneficial. Such a transformation should not be limited in the supply-side of agri-food networks but perhaps also in re-defining the role of farmers as more than food producers. Given the cumulative impacts of climate change, Brexit, supply costs and external shocks such as pandemics and conflicts, re-imagining the role of farmers as agents of change, climate and food resilience and community stewardship becomes paramount.

Further research done in collaboration with farmers' representatives or other institutions with direct access to farmers could allow improved sampling, allowing to examining differences in perceived risks, preparedness and impact across statistically representative farm types and socio-demographics. Mixed-methods research involving qualitative analysis to further un-pack some of the complexities underpinning farmers' perception (such as the effects of broader geopolitical and social phenomena such as labour migration movements) would also be highly beneficial.

CRediT authorship contribution statement

Emmanouil Tyllianakis: Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Investigation, Formal analysis, Data curation. **Kolade V. Otokiti:** Writing – original draft. **Shervin Shahvi:** Writing – original draft. **Julia Martin-Ortega:** Writing – review & editing, Writing – original draft, Resources, Investigation, Conceptualization.

Declaration of competing interest

The authors have no relevant financial or non-financial interests to disclose and no competing interests to declare that are relevant to the content of this article.

Data availability

The authors do not have permission to share data.

Acknowledgements

Data collection for this research was possible thanks to the RePhoKUs project, funded by the Global Food Security's 'Resilience of the UK Food System Programme' with the UK's Biotechnology and Biological Science Research Council (BBSRC), the Economic and Social Research Council (ESRC), the Natural Environment Research Council (NERC) and the Scottish Government (Grant No. BB/R005842/1); as well as the CONSOLE project, funded by the European Union's Horizon 2020 research and innovation programme (Grant Agreement No. 817949). Data collection received ethical approval from the Research Ethics Committee of the University of Leeds under both projects (references LTSEE-093 and LTSEE-104 respectively). Authors are grateful to project members for their valuable comments to the questionnaire design and the two anonymous reviewers for their comments and feedback.

Appendix

Table A1
Testing for differences across waves and relationships across variables.

Variables	*Statistically significant differences across the two waves*
Adaptive actions	
Sell products locally instead of regionally/country-wide	n/s
Buy products and materials from different suppliers	n/s
Change in cropping patterns or livestock numbers or types	n/s
Better forward planning	n/s
Hire local labour only	n/s
Sociodemographics	
Income	n/s
Gender	n/s
Age	a
Highly educated	n/s
Farm type	n/s
Farm size	n/s

[a]Denotes statistical significance at the 1% level.

Table A2
Chi-squared tests of independence between Age and adaptive actions

Variable combinations	*Chi-squared tests of independence*
Age*There is severe/very severe impact of COVID-19 to my business	n/s
Age*I was prepared/very prepared to resist the impact of COVID-19	n/s
Age*Impacts of the COVID-19 disruption will last at least 10 years in my farming activity	n/s
Age*Being prepared/very prepared now to address impacts	n/s
Age*Sell products locally instead of regionally/country-wide	n/s
Age*Buy products and materials from different suppliers	n/s
Age*Change in cropping patterns or livestock numbers or types	a
Age*Better forward planning	n/s
Age* Hire local labour only	a

[a] Denotes statistical significance at the 5% level.

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