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Full length article

## Digital food sharing and food insecurity in the COVID-19 era

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## ABSTRACT

Sharing food surplus via the digital sharing economy is often discussed as a promising strategy to reduce food waste and mitigate food insecurity at the same time. Yet if and how the global pandemic has affected digital food sharing are not yet well understood. Leveraging a comprehensive dataset covering over 1.8 million food exchanges facilitated by a popular peer-to-peer food sharing platform, we find that UK activity levels not only rose during the Covid-19 pandemic, but outperformed projections. A potential explanation for this growth might be the rise of food insecurity during the pandemic. Yet examining the sociodemographic characteristics of platform users, average user activity and food exchanges before and during the pandemic, we find no compelling evidence that the platform's pandemic-era growth results from a large influx of food insecure users. Instead, we posit that the growth in digital food sharing relates to lifestyle changes potentially triggered by the pandemic.

## 1. Introduction

Food insecurity is a major global issue in both poorer as well as richer economies (Development Initiatives Poverty Research Ltd., 2021). Over the past few years the global pandemic has led to a dramatic increase in food insecurity related not only to economic hardship but also to factors such as supply chain disruptions (following labor shortages, or restrictions on transport and trade), and changes in food demand and access (Béné et al., 2021; Laborde et al., 2020). In the US, for example, 21 million additional people are believed to have joined the food insecure during the pandemic (Silva, 2020). Similarly, in the UK, surveys conducted during the pandemic reveal that 26–28% of households with children cut down meal sizes or skipped meals due to financial difficulties, and reports from French Universities suggest high rates of meal skipping and inability to access sufficient food (Alderman, 2021; Food Standards Agency, 2020).

This rise in food insecurity during the pandemic took place in the context of significant amounts of food waste. For example, recent estimates suggest that in the United States (US), food waste amounts to 123 kg per capita each year. In the United Kingdom (UK), where many efforts have targeted food waste reduction, food waste per capita is estimated at 94 kg per capita annually, 70%–86% of which is thought to be still edible (United Nations Environment Programme, 2021; Vanham et al.,

2015).

The dynamics of food waste generation were also affected by the pandemic, as disruptions emerged at every link in the global food supply. At the household level, travel restrictions, social distancing guidelines, closure of food services (e.g. restaurants and bars), and changes in time use patterns (e.g. work from home) influenced households' dietary habits and preferences (Bennett et al., 2021; Krishnamoorthy et al., 2021). Some report that the pandemic lowered consumers' preference towards fresh produce, and increased consumption of sweets, snacks, and highly processed foods, while others suggest that the pandemic triggered higher preference for healthier food options, including fresh produce and home cooking (Kumar and Babu, 2021; Roe et al., 2021; Secondi et al., 2022; Sharma et al., 2021). The pandemic also affected consumers' food acquisition patterns, leading to record demand for home delivery services and online grocery shopping, (Chang and Meyerhoefer, 2021; Gao et al., 2020; Sharma et al., 2021; Statista, 2022; Wang et al., 2020). Such changes in dietary preference and acquisition patterns alongside boarder lifestyle and time use shifts affected food waste generation in contradictory ways. Heightened awareness prompted by concerns about food availability and more careful food planning and management practices, likely reduced household food waste generation, while stockpiling and panic-buying likely increased it (Babbitt et al., 2021; Everitt et al., 2022; Ikiz et al., 2021; Iranmanesh

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et al., 2022; Principato et al., 2022; Secondi et al., 2022; Vittuari et al., 2021; WRAP, 2021).

Although the pandemic's effects on food waste generation are not yet fully understood, the co-existence of both unmet demand for food and food waste within the same geographies, points to an opportunity-transferring unwanted but edible foods to those interested in consuming them could potentially deliver environmental and social benefits and perhaps help to reduce food insecurity. Digital sharing platforms, in particular, can facilitate real-time, nearly instantaneous exchanges of goods (Richards and Hamilton, 2018). The ability to match surplus supply with unmet demand in a cost effective and efficient manner makes digital food sharing platforms ideally suited to the practice of food sharing and redistribution.

Over the past two decades, rapid innovation and wide-scale adoption of information and communication technologies have enabled the rise of a digital sharing economy in which individuals can buy, rent or share their underutilized assets with peers (Botsman and Rogers, 2010; Frenken and Schor, 2017; Michelini et al., 2018; Schor, 2020; Schor and Vallas, 2021; Sundararajan, 2017). Although non-monetized and monetized sharing of underutilized assets is a longstanding practice within social networks, digital technologies have reduced transaction costs, removed barriers-to-entry, and lowered the risk of sharing with strangers by incorporating crowd-sourced reputational data (Belk, 2014; Curtis and Mont, 2020; Einav et al., 2016; Schor, 2016; Sundararajan, 2017). As a result, sharing and exchange platforms have expanded significantly since their introduction in the 1990s proliferating into almost every domain of consumption including food. Examples ranging from personal catering platforms, in-home meal sharing among strangers, in-person food swaps, to Peer-to-Peer exchanges of edible yet unwanted foods (i.e. EatWith, DishDivvy, EzCater, Olio). (Davies and Evans, 2019; Davies et al., 2019; Harvey et al., 2020; Kristof, 2021) The pandemic accelerated exposure, experience, and openness to digital food environments as a more accessible avenue for procuring food, potentially opening the sharing economy to a more diverse user base.

Generally, the sharing economy is thought to deliver environmental benefits by using existing product stocks more efficiently, be it unoccupied car seats, apartments, or surplus food (Davies and Evans, 2019; Meshulam et al., 2022; Storch et al., 2021). Yet whether this is indeed the case remains unclear as the empirical body of work reports mixed results. While some find that sharing reduces environmental burdens (Firnknorn and Müller, 2012; Makov et al., 2020; Martin et al., 2019), others report that sharing induces additional demand ultimately adding rather than reducing overall environmental burdens (Tussyadiah and Pesonen, 2016; Warmington-Lundström and Laurenti, 2020; for an extensive review of empirical evidence on the environmental performance on sharing platforms and please see Meshulam et al. (2022)). Zooming in on food, while recent work suggests that digitally facilitated food sharing has environmental benefits (Makov et al., 2020), the biggest potential benefit of food sharing may be in mitigating food insecurity. Indeed, community-based interventions – including food sharing – have been promoted as an important policy entry point to combat food shortages and supply disruptions (O'Meara et al., 2022). Moreover, recent work by Nica-Avram et al. (2021) suggests that data from food sharing platforms could potentially help inform national measures of food insecurity.

Yet the degree to which the food insecure participate successfully and benefit from these types of peer-to-peer food sharing activities during the pandemic remains unclear. First, concerns over hygiene and contamination during a pandemic may hinder any activity on the platform, including among the food insecure (Krishnamoorthy et al., 2021). Second, previous work suggests that cultural capital is a pre-requisite for successful participation in digital sharing platforms (Schor et al., 2016). Third, the types and quantities of foods shared might not be compatible with the needs of those experiencing food insecurity. Finally, sourcing food via sharing involves inherent uncertainties which might make transaction costs too high for those really in need (Makov et al., 2020).

Here, we analyze a comprehensive dataset covering the activity of close to 2 million users provided by the popular peer-to-peer food sharing platform Olio. We investigate whether digitalized food sharing platforms offered a viable way to reduce food insecurity during the Covid-19 global pandemic. To this end, we examine supply, demand, and the rate of activity before and after the onset of Covid-19 and explore differences between users who joined before vs. after the pandemic in terms of socio-demographic makeup and activity patterns (e.g., the number of items collected weekly). We then discuss the implications of our results and evaluate digital food sharing platforms in the broader context of food insecurity and food related behaviors during the pandemic.

## 2. Methods

To explore the effects of COVID-19 and related stay-at-home (i.e. lockdown or shelter in place) restrictions on the digital sharing economy, we examined a comprehensive dataset covering over 1.8 million food items listed worldwide between October 2019 and January 2021 (inclusive) on Olio. While the platform itself is a for-profit entity, all food exchanged is offered free of charge. At the time of writing, the platform had over 6 million registered users worldwide ( $\approx 8\%$  of which are active users who have listed or collected one or more times). While the platform is active in more than 120 countries worldwide, most of the activity is concentrated in six locations: Mainland UK (84% of all foods listed), Channel Islands (10%), Sweden (2%), Singapore (1.1%) USA (0.86%) and Mexico (0.66%). In our analyses we focus on the UK, the largest and most mature network.

### 2.1. Data preparation

The raw dataset, as provided in SQL from by the platform, contained fully anonymized information on all food listings and users on the platform. For listings, the dataset included: a unique identifier (listing ID), detailed verbal descriptions of the food item including collection notes and comments (see Appendix Section 1 for example), listing date and time, listing location (latitude and longitude), and a unique anonymized identifier for the user who offered the food (provider ID). For collected listings (i.e. listings that were picked up), the dataset also contained a unique collection identifier (collection ID), collection date and time, and the collecting user's unique identifier (collector ID). The data provided also included fully anonymized data on platform users including a default notification location, typically user's home address defined in the system by the users themselves. As information was provided in several SQL tables, to generate our working database we matched and merged listings to collection(s) based on the listing ID.

Next, we mapped users to their country of residence based on their default notification location using Python Geopandas (Jordahl et al., 2021) and Shapely (Gillies and others, 2007) packages. Focusing only on the UK, we then mapped each user to their respective Lower Layer Super Output Area (LSOA – a geographical UK census tract with a mean population of 1500 people or 650 households) and assigned each to their respective income decile according to the UK 2019 Index of Multiple Deprivation (Ministry of Housing Communities and Local Government., 2020). While Olio provided the raw data, platform representatives did not take part in designing the study, the research questions, the analysis, nor the writing of the manuscript.

### 2.2. Overall activity levels

To reveal the pandemic's impacts on platform activity overall, we examined the total number of items offered, the number of exchanges, new user registration, and collection rates before and during the pandemic and by the type of food collected. First, we used data on the number of food items exchanged daily between October 2019 and February 2020 (i.e., pre-pandemic time period) to forecast daily

exchanges from April 2021 onwards (i.e., pandemic period) using the Prophet forecasting model. Prophet is an open-source Python package created by Facebook's Core Data Science team to forecast time series data. Prophet is considered especially well-suited for forecasting activity and network growth over time in online environments (Taylor and Letham, 2018). To allow for maximal trend flexibility, changepoint prior scale was set to high value. We then compared the results of our forecasting with the actual number of food items exchanged to reveal how the pandemic affected overall activity.

For platforms' short- and long-term viability, attracting and retaining users is a key requirement, as increased numbers of users generate critical network effects that can help the platform become more resilient (Rochet and Tirole, 2003). Increased activity as measured via new user registrations can be interpreted as proof that the platform was not negatively affected by the pandemic. As such, we also examined new user registration rates over time, and conversion from registered to active users (i.e. a user who either offered or collected a listing posted to the platform).

As our third measure of activity, we examined collection rates the share of offered listings that were eventually collected. To calculate collection rates over time, we divided the number of listings collected by the overall number of listings posted to the platform. Finally, following reports of changes in consumer food preferences before vs. during the pandemic, we also examined collection rates by food type. To this end, we first classified all food listings into 13 pre-determined food type categories using Bidirectional Encoder Representations from Transformers (BERT), a novel yet widely used Transformer-based Natural Language Processing (NLP) technique. The classification, relied on a training set containing over 51,684 Olio listings which were manually classified to specific food type categories following the approach outlined in Makov et al. (2020). Using a sequence length of 100 tokens, the model was fine-tuned on our training data and achieved a 92.8% classification accuracy on the test set. The Olio BERT model was then used to classify all 1.8 million food listings included in our analysis into food types, using the Hugging Face PyTorch library in Python.

### 2.3. Food insecurity

Since no official government assessments for food insecurity levels across different regions in the UK were available at the time of writing, to examine whether food insecurity was driving activity on the platform, we examined the relationship between platform activity and two different measures of food insecurity. The first measure is an estimate for January 2021, as measured by the Food foundation and defined by Moretti et al. (2021). The second, is the number of parcels handed out by the Trussell trust—the largest NGO dedicated to battling food insecurity in the UK (The Trussell Trust, 2021). While the first measure is limited in scope as it covers only a single month and the second measure is only a proxy for food insecurity, taken together they provide insight into the potential relationship between food insecurity and food sharing.

However, since a comparison at the Local Authority level might be too aggregated, we also explored differences at the individual user level to see if they displayed evidence of food insecurity.

### 2.4. Network characteristics

To examine the redistributive nature of the Olio network, and if and how it might have been affected by the pandemic we examine the ratio between providing users (i.e., users who gave one or more item in a given week) and collecting users (i.e., users who collected one or more items in a given week). Harvey et al. (2020) examined the nature of the Olio network in 2017 and found that it is more redistributive in nature than reciprocal. Relatedly, we reason that if the network is serving a redistributive function, the overlap between providing users and collecting users will be even smaller than it was before the pandemic. To shed light on any emerging trends, such as the rise of food insecurity, we

also examine weekly changes in the ratio between providing and collecting users over time (i.e., the first difference).

### 2.5. Activity at the user level

Much like platform activity, the number of users joining the platform could have continued to grow over time regardless of the pandemic. To reveal whether activity resulted from an influx of food insecure users joining the platform during the pandemic we compared the income levels of new users registering for the platform to see if there are differences before and during the pandemic. Since income is not always a good proxy for food insecurity and to address the possibility of an ecological fallacy (via defining the user's income based on their default location), we also investigated typical user activity such as the number of weekly collections and the share of heavy collectors before and during the pandemic. This analysis assumes that an increase in user activity can be indicative of covid-related food shortages that result in higher sourcing of food from the platform.

For these comparisons, we focused on users who joined the platform from September 2019 onwards, dividing them into three user cohorts: (1) Pre-Covid cohort- users who registered on the platform between September 2019 and February 2020, (2) Covid I cohort- users who registered between March 1, 2020 and August 31, 2020, and (3) Covid II cohort- users who registered on the platform between September 1, 2020 and the end of our study period, January 2021. The distinction between the two COVID cohorts also aligns with the return of restrictions after they were lifted in the UK. Finally, to expose any general shifts among collecting users, we also compared the income levels of collecting users before vs. during the pandemic, regardless of the user's registration cohort. While the relationship between income and food insecurity is complex, lower income populations tend to be at higher risk for food insecurity, a link potentially exacerbated by greater financial instability during the pandemic (Brown et al., 2022; Loopstra et al., 2019).

### 2.6. Food exchanges

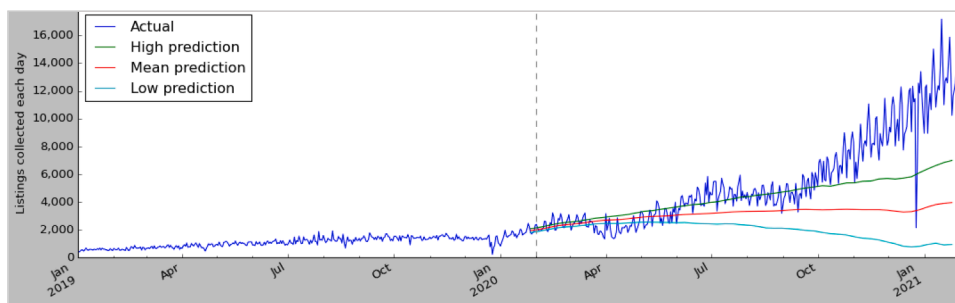
We explored whether the pandemic brought about any changes in the patterns of food exchanges across income levels, by generating two heatmaps depicting the number of listings exchanged according to the providing and collecting user's income decile, before and during the pandemic (i.e. between September 2019- January 2020, and between September 2020- January 2021 respectively). Our analysis included only exchanges where both the collecting and providing user could be reliably assigned to a specific LSOA according to its geographic boundaries.

## 3. Results

### 3.1. Overall activity levels

Our analysis reveals that activity levels (as measured by the overall number of daily collections) were outperforming projections derived using pre-pandemic data and Facebook's Prophet model (Fig. 1) indicating a surge in activity beyond expectation. A series of repeating analyses using ARIMA, TBATS, and STL Decomposition yielded similar results confirming the robustness of our findings (see Appendix, Section 2.1 and Figure S1).

Similarly, we find that after an initial drop, monthly registration rates also rose substantially during the pandemic, while conversion rates from registered to active users remained fairly constant. Just before the pandemic began, in January 2020, more than 54,000 people registered to use the platform. Signups briefly decreased in March (39,000), April (18,000), and May 2020 (28,000). However, this was reversed beginning in June and new user registrations have subsequently accelerated. In January 2021 > 75,000 new users signed up to the platform (see



**Fig. 1.** Number of daily exchanges during the pandemic- predicted vs. actual. Actual activity presented in blue. Upper, Lower and Medium predictions derived using Facebook’s prophet model and activity data from Jan 2019 till February 2020, are presented in Green, Red and Yellow lines respectively. Gray horizontal line indicates the prediction timespan.

Appendix, Figure S2).

In terms of the types of foods offered for sharing, there is some interesting variation in supply before and during the pandemic (see Fig. 2). In particular, we found more offerings of fresh produce, and fewer offerings of sandwiches at the onset of the pandemic. In part this is likely due to food venues closing during the pandemic. Examining the share of listings collected we find that average pre-Covid collection rates (i.e., the share of collected listings out of all listings offered each month) were about  $65\% \pm 2\%$ . During the pandemic collection rates increased to  $68\% \pm 6\%$ . Examining collection rates by food types reveals a similar upward trend across all food major food types making it hard to draw any specific conclusions about changing demand (see Appendix Figure S3). The one exception is perhaps fresh produce where collection rates first drop but then quickly bounce back. Given the increase in supply, it is hard to say whether this reflects lower interest in fresh produce or simply a transition period after a supply shock. Taken together, the continued increase in network activity, new user registration, and rising collection rates across all major food types indicate that the pandemic accelerated food sharing beyond predictions, which suggests that concerns about viral contagion were not sufficient to dampen the desire to share food.

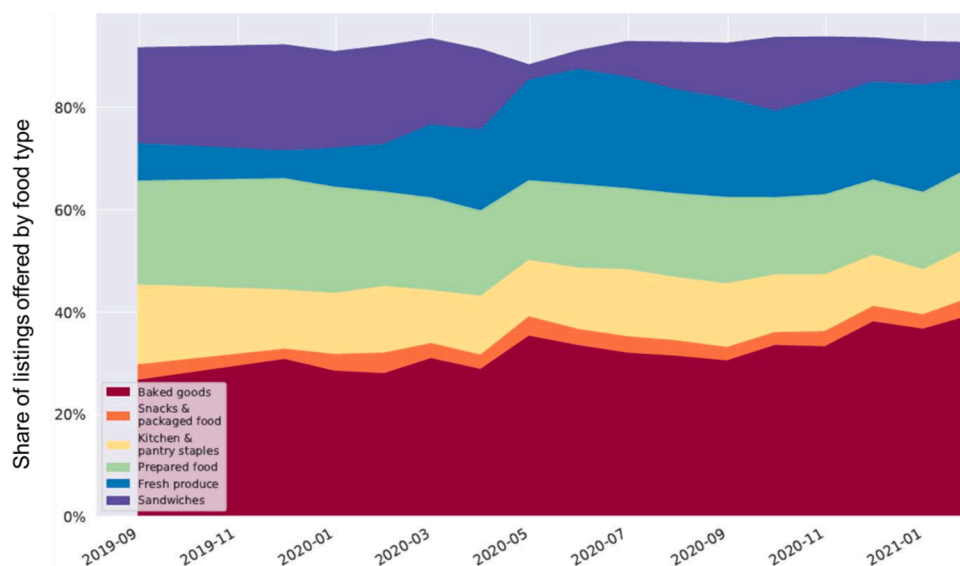
### 3.2. Food insecurity and redistribution

Indeed, one explanation for the robust increase in activity is that the rise in food insecurity might be driving users to this unconventional way of accessing food. Our analysis however, yielded no compelling evidence

that this is indeed the case. Since official government data on food insecurity levels across the UK were not available, we examined the relationship between available indicators or proxies of food insecurity and activity on the platform. We found no significant correlation between estimates of food insecurity available at the Local Authority level at the height of the pandemic (Moretti et al., 2021) and collection rates on the platform ( $p = 0.39$ , see Appendix, Figure S4).

Relatedly, the number of parcels handed out by the Trussell Trust, the leading food aid NGO active in the UK (The Trussell Trust, 2021) did not significantly predict the number of platform listings collected at the local authority level ( $\beta=0.96, p = 0.1$ ) when controlling for population size and the number of listings offered in multiple regression analysis ( $R^2= 0.98, F(3219), p<0.000$ ; see Appendix, Section 2.4). To illustrate, Figure S5 in the Appendix presents geographic heatmaps for food insecurity prevalence (measured as the share of households struggling with food insecurity according to Moretti et al. (2021); Figure S5a), and food sharing activity (measured as the percent of active Olio users collecting shared foods; Figure S5b). As is evident, food insecurity and the share of active food sharing users do not seem to occur at the same areas. For example, around Cambridge and Bedford, the prevalence of food insecurity was relatively low while food sharing was relatively high.

Moreover, if food insecure users in need are indeed driving this surge in activity, we would expect that the ratio of collectors to providers would increase substantially compared to pre-pandemic levels (Nica-Avram et al., 2021). We find, however, that while the volume of food being shared and number of participants on the platform increased dramatically during the pandemic period, the redistributive effects of



**Fig. 2.** Share of listings offered for sharing via the platform by food type over time.

the platform remain relatively unchanged. Specifically, the ratio of users who provide food to those who collect food are relatively similar before and during the pandemic (e.g., 1:1.85 in January 2020 vs., 1:1.9 in January 2021) with no apparent upward (or downward) trend (see Appendix, Figure S5). Finally, if increased activity was driven by food insecurity, we would expect to see almost no food listings from the more popular food types left unclaimed. Our results, however, suggest that during the pandemic 20%–30% of all listings were not collected. In other words, despite a slight yet study increase in collection rates across all food types, overall, the share of foods not collected remained relatively similar to pre-covid rates.

Because it is possible that the level of aggregation of our food insecurity measures is too high to reveal underlying heterogeneity, we also explored user activity for any evidence of food insecurity. While the nature of the network appears to be similar to pre-pandemic trends, there may be underlying changes in user demographics and behaviors that are cancelling each other out. An obvious possibility is a growth in activity by the food insecure. Another possibility is that the pandemic could have driven new types of users to the platform who engage in more collection behavior. To examine whether food sharing performance is due to a large influx of food insecure users, we focused on three cohorts of users: those who came on the platform between September 2019 and February 2020 (Pre-Covid Users), those who joined between March 1, 2020 and August 31, 2020 (Covid I Users) and those who joined between September 1, 2020 and January 2021 (Covid II Users).

First, we compared income levels among new users who registered before (Pre-Covid cohort) and during the pandemic (Covid I+II cohorts). We found no discernable differences (see Appendix Section 2.6). Next, we compared the average number of items collected by active users (i.e., users collecting one or more items that week) in each Cohort. As Fig. 3 demonstrates, while the average number of items collected each week increased from 3.6 in the first week of January 2020 to more than 6.8 items a year later, this growth persisted across all user cohorts. Third, examining distributions, we found that within any given month, the vast majority of users collect five listings or fewer, and fewer than 10% of users collect 20 or more listings. Here too, results are uniform across cohorts (see Appendix, Figure S7). Finally, we also compared income levels of all users who collected food before vs. during the pandemic, regardless of their registration cohort. We found no significant difference here either (see Appendix, Figure S8).

Fig. 4 shows food exchange frequency by the income decile of the providing and collecting users before (Fig. 4a) and during the pandemic (Fig. 4b). As is evident from the darker colors along the diagonal in both pre-pandemic and pandemic times exchanges are mostly among users who belong to similar income deciles. Moreover, while pre-pandemic exchanges were concentrated mostly among users associated with lower income deciles (see darker red in lower left side of Fig. 4a), during the pandemic food sharing took root across broader populations,

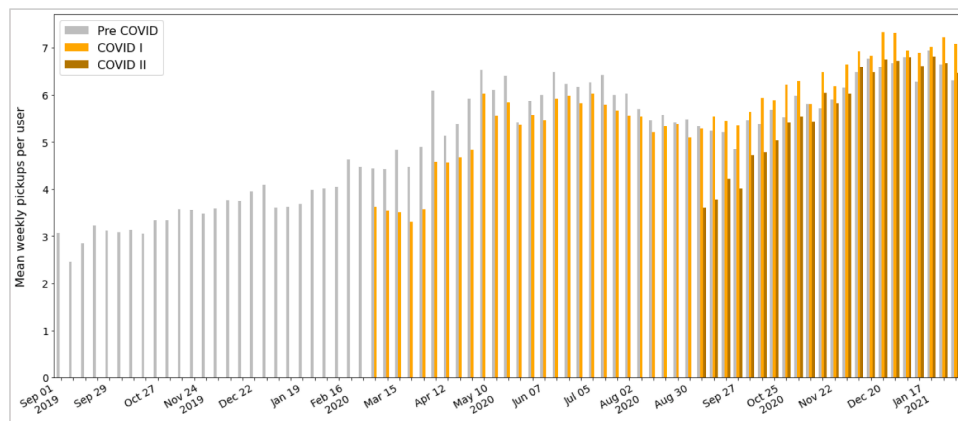
spreading to higher income deciles as well (see darker red colors along the diagonal in Fig. 4b). These findings and particularly the expansion of food sharing into populations at the top of the income distribution curve suggest that factors beyond food insecurity led to increased interest and participation in food sharing during the pandemic.

#### 4. Discussion and conclusions

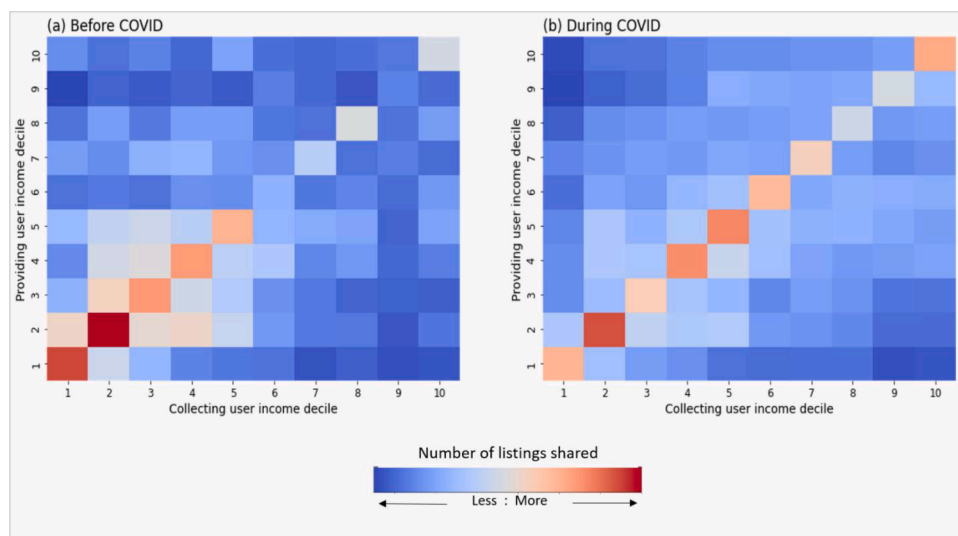
The Covid-19 pandemic has exacerbated food insecurity, and in some parts its long-term impacts are still unfolding. Against the backdrop of a global pandemic, which reduced mobility and isolated individuals and communities, we find that activity on a digitized food sharing platform in the UK has increased considerably. After a short dip in participation in spring 2020, food sharing on Olio grew despite fear of contamination, a threat to which food, with its strong symbolic association with “purity and danger,” (Douglas, 2002) is especially vulnerable.

We did not find a significant relationship between food insecurity measures and food sharing activity on the platform (Moretti et al., 2021; The Trussell Trust, 2021). Additional analyses at the individual user level did not reveal discernible differences in terms of income or activity profiles between users who joined the platform before the pandemic and those who joined during the first or the second six months of the pandemic). Future research should validate these findings using more comprehensive, official measures of food insecurity, as these were not available for the UK at the time this study was conducted. The ratio between providers and collectors (i.e. givers and receivers) remained stable before and during the pandemic, which suggests that the local sharing networks did not see a sudden surge in users who are only interested in collecting food, as one would expect from the food insecure (Nica-Avram et al., 2021)

Finally, analyzing the frequency of food exchanges across income deciles we found that providers typically shared food with collectors who had similar income levels as their own, indicating the absence of a significant distributional shift from higher to lower income households. While we examine supply and demand by food type, quantifying the mass of food shared or its nutritional quality goes beyond the scope of the current research. As such it is possible that there were differences in terms of the amount and nutritional quality of items collected by lower vs. higher income populations, as well as heavy vs. average collectors—a promising direction for future work. That said, it is important to note that while the relationship between income and food insecurity is complex, lower income populations tended to be at higher risk for food insecurity both before and during the pandemic (Brown et al., 2022; Loopstra et al., 2019, 2015; Power et al., 2020). Thus, we conclude that while there is undoubtedly some distribution to food insecure users occurring, one potential benefit of a food sharing platform—to redistribute food across income categories—appears to not have been realized during the pandemic. These results are well aligned with past work



**Fig. 3.** Mean weekly pickups per user, by user cohort. Pre-COVID (Grey) number of listings collected each week on average by users who joined the platform between September 2019 and February 2020 inclusive; COVID-I (Orange) number of listings collected each week on average by users who joined the platform between March 2020 and August 2020 inclusive; COVID-II (Brown) number of listings collected each week on average by users who joined the platform between September 2020 and January 2021 inclusive.



**Fig. 4.** Heat map of food exchanges frequency by income decile of providing users (y-axis) and collecting users (x-axis). Panel a represents exchange frequency by providers' (vertical) and collectors' (horizontal) income percentile between September 2019 and January 2020 (pre-COVID). Panel b represents exchange frequency by providers' (vertical) and collectors' (horizontal) income percentile between September 2020 and January 2021 (COVID time). In both panels, exchange frequency ranges from fewest (dark Blue) to highest (dark red) number of exchanges.

examining the nature and flow of foods between users of varying income levels before the pandemic (Makov et al., 2020; Nica-Avram et al., 2021). To the best of our knowledge, our findings present one of the first empirically driven analyses of food insecurity and digitally enabled peer-to-peer food sharing in the Covid-19 era. As such they add to the food insecurity literature, and the growing body of work dedicated to the effects of the global pandemic, as well as the emerging line of research which seeks to examine the social impacts of the digital sharing economy (Davies and Evans, 2019; Davies et al., 2019; Harvey et al., 2020; Michelini et al., 2018; Nica-Avram et al., 2021; Schor, 2020).

There are a number of spatial, technological and cultural factors which may account for this sharing platform's limited ability to cater to the food insecure. The first is housing segregation by income. Because residential neighborhoods are relatively homogeneous with respect to income, large-scale redistribution from higher to lower-income areas requires travel which can be costly in terms of time and money or difficult to carry out during lockdowns. Peer-to-peer platforms such as Olio grow largely as a result of local density, and residential income segregation inhibits their ability to facilitate cross-income class transactions. Relatedly, our reliance on users' notification location as a proxy raises concerns regarding ecological fallacy, and limits our ability to capture variations in income within LSOA areas. Future work should clarify whether notification locations are indeed good proxies for users' socio-demographics.

Cultural factors may also play a role in inhibiting the participation of food insecure households. The first wave of users on platforms such as Olio have been highly-educated and technically-savvy (Makov et al., 2020). Food insecure individuals may be reluctant to participate or deterred from remaining due to their lack of cultural capital (Bourdieu, 2018; Cansoy and Schor, 2016). Another factor is that Olio is not an anonymous food distribution site, so users who are persistent receivers rather than givers are identifiable on the platform. Past work revealed that users who actively solicited food on Olio, often avoided pronouns and used passive wording, which suggests that food insecurity may be a source of embarrassment and shame (Nica-Avram et al., 2021; Purdam et al., 2015). A number of sharing innovations that rose to prominence during the pandemic, such as Free Fridges, also do not require registration, and if they are accessed when no one is present, can be used anonymously.

Since evidence of the increase in activity occurred within higher income deciles, including the top decile, activity patterns suggest that factors other than food insecurity were at play. The pandemic resulted in unprecedented disruptions to food supply and access (Laborde et al., 2020). Coupled with mandatory lockdowns, closure of food service

outlets, and changes in time use patterns the pandemic shifted consumer's attitudes, dietary preferences and engagement with food preparation and waste, all of which could potentially affect interest and participation in food sharing. For one, at-home cooking and food-related activities also became more popular during lockdown, which potentially increased awareness and adoption of different food waste reducing behaviors (Babbitt et al., 2021; Bender et al., 2022; Principato et al., 2022; Roe et al., 2021; Vittuari et al., 2021). For example, people sought creative recipes that would allow them to utilize food leftovers, and paid closer attention to expiration dates (Iranmanesh et al., 2022; Principato et al., 2022). The pandemic also heightened consumers' awareness regarding the consequences of food waste and increased pro-environmental attitudes more broadly (Castellini et al., 2021; Tchetchik et al., 2021). Together with unprecedented adoption of online food sourcing, restrictions on movement, and more flexible schedules, pandemic era lifestyle changes may have affected people's interest in food valorization and increased the likelihood they would participate in food sharing. Future work should examine if and how the factors mentioned above potentially affected interest and participation intensity in peer-to-peer food sharing, and whether the effects persisted beyond the time period examined here.

One likely driver of growth in food sharing is the power of network effects. In some locations, the platform is reaching enough people to reliably offer sufficient supply and demand to meet users' needs, thereby creating a positive feedback loop. When new users are integrated into the network they find more local supply, and more of them are converted into active users. In addition, there has been a rapid shift toward e-commerce which may have broadened the platform's potential user base (Douglas, 1966). Comparison with platform activity in the Bay Area in the United States is suggestive of this interpretation. There, much lower network density has left it unable to weather the initial downturn in activity, and usage collapsed without recovering (see Appendix, Section 2.8 and Figure S9). While a more in-depth analysis of network effects is beyond the scope of this paper, future work should explore how size and activity volumes affect the resilience of peer-to-peer local sharing networks.

Our findings suggest that while peer-to-peer food sharing platforms likely have a niche role to play in efforts to ensure food access, they are not a substitute for institutional solutions such as food allowances, large-scale food provisioning, or income support, and if they are to serve the food insecure, they may need to consider changes in how they operate. Rather, Olio's strengths lie in avoiding food waste and the environmental impacts of surplus food, community building, saving users money, and enhancing well-being via the provision of tasty, prepared

foods. While the social benefits of food sharing are notoriously challenging to measure, it seems that in these areas, the platform has done well during the pandemic, expanding its network and active user base at a rate higher than pre-pandemic, and hosting robust levels of transactions. As such, the platforms' peer-to-peer food sharing networks likely contribute to achieving important food-related goals such as the democratization of food systems, education towards reducing food waste, and increasing community participation in alternative food supply chains (Davies et al., 2019). Such networks have the potential to reduce the risk of future food shortages during emergencies and foster greater resilience in urban food systems.

### CRedit authorship contribution statement

Tamar Makov, Tamar Meshulam, Mehmet Cansoy and Juliet B. Schor designed the study.

Tamar Makov, Tamar Meshulam and Mehmet Cansoy performed the analysis

Tamar Makov, Tamar Meshulam, Mehmet Cansoy, Juliet B. Schor and Alon Shepon wrote the manuscript.

### 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.

### Data availability

The authors do not have permission to share data.

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### Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:[10.1016/j.resconrec.2022.106735](https://doi.org/10.1016/j.resconrec.2022.106735).

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