Improving our understanding of the use of online food delivery services to access food prepared out-of-home

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This thesis is submitted for the degree of Doctor of Philosophy

Declaration

This thesis is the result of my own work under the supervision of Dr Thomas Burgoine and Professor Jean Adams and includes nothing which is the outcome of work done in collaboration except as declared in the preface and specified in the text. This thesis is not substantially the same as any work that has already been submitted before for any degree or other qualification except as declared in the preface and specified in the text. Finally, it does not exceed the prescribed word limit for the Clinical Medicine and Veterinary Medicine Degree Committee.

Matthew George Keeble

22 November 2022

Abstract

Food prepared out-of-home is typically energy-dense and nutrient-poor. More frequent consumption of this food is associated with poorer overall dietary patterns and obesity. Previous research has tended to focus on access to food prepared out-of-home in the physical food environment, which is often greatest in more deprived areas. However, this food can now also be accessed through online food delivery services. Although online food delivery services are globally established, there is limited public health knowledge about the prevalence of their use and factors influencing this, the sociodemographic characteristics of customers, and the extent to which the opportunity to use them is socioeconomically patterned. The aim of my thesis was to help better understand the use of online food delivery services to access food prepared out-of-home.

First, I analysed survey data collected in 2018 to identify the prevalence of online food delivery service use and the sociodemographic characteristics of adult customers across Australia, Canada, Mexico, the United Kingdom, and the United States of America. From 19,378 respondents, around one in six had used an online food delivery service in the past week. Respondents who were male, younger, more highly educated, living with children and those who identified with an ethnic minority had greater odds of online food delivery service use. These patterns were similar in each country but the strength of associations varied. Notably, respondents with a high versus low level of education had greater odds of online food delivery service use in all countries except the United Kingdom.

Second, I conducted telephone interviews with 22 adults living in England who were frequent online food delivery service customers. Participants reported that they could access a higher number of food outlets and a broader range of cuisines through online food delivery services compared with the physical food environment. Additionally, these services allowed participants to access exclusive price-promotions and use streamlined purchasing processes, which were seen as unique advantages. Participants reported that they believed the food available through online food delivery services was mostly unhealthy. Nevertheless, this food met their expectations about `takeaway food`. Despite reported drawbacks of online food delivery services, which included over-convenience and, paradoxically, access to unhealthy food, participants reported no intention to discontinue use because it was normal to purchase food prepared out-of-home in this manner.

Informed by existing evidence and my qualitative research, I investigated associations between access to food prepared out-of-home through online food delivery services and online food delivery service use, and body weight. In my individual-level data-linkage study of 3067 adults living in Great Britain, the number of food outlets accessible online was positively associated with online food delivery service use in the past week. However, it was not associated with body weight. Despite the perspective of frequent customers, the number of cuisine types accessible online was not associated with online food delivery service use.

Finally, I examined access to food prepared out-of-home through online food delivery services in England and variation according to area-level socioeconomic position. In a cross-sectional study, I found that the number of food outlets accessible online was highest in the most deprived areas of England in November 2019. I followed this with a repeat-cross sectional study that assessed changes in the number of food outlets accessible online over time, within the context of the Coronavirus Disease 2019 (COVID-19) pandemic. I found that it was only in the most deprived areas of England that the number of food outlets accessible online in March 2022 surpassed the number from November 2019. Taken together, these findings indicate that online access to food prepared out-of-home in England is socioeconomically patterned, and that inequalities therein widened over time.

The findings from my thesis help better understand multiple aspects of online food delivery service use. The number of food outlets accessible online emerged as being particularly important. A higher number was positively associated with online food delivery service use, which suggests it can influence food purchasing practices. Indeed, this was supported by the views of frequent online food delivery service customers in my qualitative research. Additionally, the number of food outlets accessible online was highest in the most deprived areas of England in November 2019, and increasingly so over time compared with less deprived areas. Thus, the opportunity for online food delivery service use is unequal across the socioeconomic spectrum in England. Future research should seek to understand how food purchased through online food delivery services contributes to overall dietary patterns and health, and the need for public health intervention.

List of relevant publications, contributions, and dissemination

Manuscripts included in my thesis and dissemination of findings

Chapter 2 is published in the *International Journal of Environmental Research and Public Health* as: Keeble, M., Adams, J., Sacks, G., Vanderlee, L., White, C.M., Hammond, D., Burgoine, T. (2020), Use of online food delivery services to order food prepared away-from-home and associated sociodemographic characteristics: a cross-sectional, multi-country analysis, https://doi.org/10.3390/ijerph17145190. I presented the findings from this research at the 2020 International Society of Behavioral Nutrition and Physical Activity Annual Congress during an online symposium: "New ways of purchasing (fast) food: are we transitioning away from tradition?".

Chapter 3 is published in *BMC Public Health* as: Keeble, M., Adams, J., Burgoine, T. (2022), Investigating experiences of frequent online food delivery service use: a qualitative study in UK adults, https://doi.org/10.1186/s12889-022-13721-9. An abstract for this chapter is also published in *The Journal of Epidemiology and Community Health* as: Keeble, M., Burgoine, T., Adams, J. (2022), P14 Investigating frequent online food delivery service use: a qualitative study in UK adults, https://dx.doi.org/10.1136/jech-2022-SSMabstracts.113. I shared the findings from this research during an oral presentation at the 2021 UK Society for Behavioural Medicine Annual Scientific Meeting (held online), and a poster presentation at the 2022 Society for Social Medicine Annual Scientific Meeting, held in-person in Exeter, United Kingdom.

Chapter 4 is published in *BMC Public Health* as: Keeble, M., Adams, J., Hammond, D., Vanderlee, L., Burgoine, T. (2021), Associations between online food outlet access and online food delivery service use amongst adults in the UK: a cross-sectional analysis of linked data, https://doi.org/10.1186/s12889-021-11953-9. I shared the findings from this research during an oral presentation at the 2022 International Medical Geography Symposium, held in-person in Edinburgh, United Kingdom.

Chapter 5 is published in *Applied Geography* as: Keeble, M., Adams, J., Bishop, T.R.P., Burgoine, T. (2021), Socioeconomic inequalities in food outlet access through an online food delivery service in England: a cross-sectional descriptive analysis, https://doi.org/10.1016/j.apgeog.2021.102498. I shared the findings from this research during oral presentations at the 2021 American Association of Geographers Annual Meeting (held online), the 2021 Public Health Research and Science Conference (held online), and the 2022 International Medical Geography Symposium, held in-person in Edinburgh, United Kingdom.

Chapter 6 is under review at *JMIR Public Health and Surveillance* as: Keeble, M., Adams, J., Burgoine, T. Changes in online food access during the COVID-19 pandemic and associations with deprivation: a repeat-cross sectional analysis. I shared the findings from this research during an oral presentation at the 2022 International Medical Geography Symposium, held in-person in Edinburgh, United Kingdom, and a poster presentation at the 2022 UK Public Health Science National Conference, held in-person in Glasgow, United Kingdom. For the latter, the abstract is published in *The Lancet* as: Keeble, M., Adams, J., Burgoine, T. (2022), Changes in online food access during the COVID-19 pandemic and associations with deprivation: a longitudinal analysis, https://doi.org/10.1016/S0140-6736(22)02264-4. I will also share the findings from this research during an oral presentation at the 2023 American Association of Geographers Annual Meeting, held in-person in Denver, United States of America.

Contributions to publications not included in my thesis

I have contributed to the following research that is under review or published, as well as published grey-literature:

I. Bennett, R., **Keeble, M.**, Zorbas, C., Sacks, G., Driessen, C., Grigsby-Duffy, L., Adams, J., Burgoine, T., Backholer, K. The potential influence of the digital food retail environment on diet and health: a systematic scoping review of the literature. Under review at *Obesity Reviews*.

II. Goodman, S., Armendariz, G., Corkum, A., Arellano, L., Jauregui, A., **Keeble, M.**, Marshall, J., Sacks, G., Thrasher, J., Vanderlee, L., White, C.M., Hammond, D. (2021), Recall of government healthy eating campaigns by consumers in five countries, *Public Health Nutrition*, https://doi.org/10.1017/S1368980021001415.

III. Yau, A., Singh-Lalli, H., Forde, H., **Keeble, M.**, White, M., Adams, J. (2021), Newspaper coverage of food insecurity in UK, 2016-2019: a multi-method analysis, *BMC Public Health*, https://doi.org/10.1186/s12889-021-11214-9.

IV. **Food Foundation** (2021 and 2022): "Broken Plate Report 2021". Available from: https://foodfoundation.org.uk/wp-content/uploads/2021/07/FF-Broken-Plate-2021.pdf, and "Broken Plate Report 2022". Available from: https://foodfoundation.org.uk/publication/broken-plate-2022.

V. **Obesity Health Alliance** (2021): "Turning the Tide: A 10-year Healthy Weight Strategy". Available from: https://aso.org.uk/news/turning-tide-10-year-healthy-weight-strategy.

VI. **Public Health England** (2020): "Using the planning system to promote healthy weight environments. Guidance and supplementary planning document template for local authority public health and planning teams". Available from: https://www.gov.uk/government/publications/healthy-weight-environments-using-the-planning-system.

Invited speaker

I was invited to speak at the following online events to present the findings from the research included in my thesis:

I. **Nutrition and Obesity Policy Research and Evaluation Network (NOPREN)** (2021): "Online fast-food retail in the UK: research progress and future challenges".

II. **Public Health England Healthy Places Spatial Planning and Obesity Symposium** (2021): "Evaluation of planning policy, planning appeals, exclusion zones and online food delivery services".

III. **The Association for the Study of Obesity Webinar: Obesity and the Environment- where are we now?** (2021): "Investigating online access to takeaway food".

IV. **Cambridge Global Food Security Coffee Break Seminar Series** (2021): "New ways of buying takeaway food: what do we know about online food delivery services?".

Awards and collaborations

I. Winner of the National Institute for Health and Care Research (NIHR) School for Public Health Research three-minute thesis video competition.

II. Collaboration established with Early Career Researchers at the University of Newcastle, University of Hertfordshire, and Lancaster University to apply for NIHR Applied Research Collaboration funding. In November 2022, we submitted a proposal to investigate consumer perspectives on the appropriateness and acceptability of a Takeaway Masterclass intervention.

III. Collaboration established with policy and practice partners from the United Kingdom and the United States of America to host a workshop at the 2023 American Planning Association National Planning Conference: "Spatial planning and community development for healthier diets".

Acknowledgements

Science is a team sport. I would not be presenting this thesis without the team I have had behind me over the past four years.

I am extremely grateful to my supervisors, Tom Burgoine and Jean Adams. Under their supervision, I have been provided with innumerable opportunities to develop as a researcher and an individual. Their patience, direction, and energy made my PhD journey stimulating and immensely enjoyable. I would also like to thank them for teaching me to be ambitious and to persevere, especially when we were adapting to a new way of working and studying during a global pandemic.

To the multiple researchers that I have had the opportunity to collaborate with: Tom Bishop, David Hammond, Gary Sacks, Lana Vanderlee, and Christine White, thank you for allowing me to learn from each of you. I would also like to thank colleagues in the Population Health Interventions group at the MRC Epidemiology Unit for entertaining my presentations and poster designs, and for showing a genuine interest in my research. CEDAR (as it will always be in my mind) is a truly special place to work and study.

Aspects of my thesis rely on already collected data. I would like to thank the many participants who provided it and the researchers who helped to collect it. Thank you also to the participants in the primary research I conducted.

Finally, thank you to my friends and family for their ongoing support. I want to give special thanks to my sisters, Anna and Charlotte, for humouring my weekly phone calls, being as excited about the small wins as I have been and acting as the voice of reason; and to my parents for their unconditional love and the sacrifices they have made for me.

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BMI	Body mass index
CI	Confidence intervals
COVID-19	Coronavirus Disease 2019
GEE	Generalised estimating equation
GIS	Geographic information system
IFPS	International Food Policy Study
IMD	Indices of Multiple Deprivation
IQR	Interquartile range
IRR	Incidence rate ratios
LSOA	Lower super output area
MAUP	Modifiable areal unit problem
OR	Odds ratio
OS POI	Ordnance Survey Points of Interest
SD	Standard deviation
UK	United Kingdom
USA	United States of America
WHO	World Health Organization

Chapter 1:
Introduction

In my thesis, I will present research on the use of online food delivery services to access food prepared out-of-home. Before defining these services and discussing why they may be a concern for public health, I provide relevant background and context for my research. I begin this chapter by describing the relationship between food and diet, obesity, and health. Next, I define food prepared out-of-home and discuss its energy and nutrient content, established public health concerns about the purchase and consumption of this food, and factors that plausibly influence this. After defining the digital food environment and discussing existing evidence, I focus on the use of online food delivery services. In the sections that follow, I outline why knowledge about the use of these services is important in the context of food prepared out-of-home and public health. I conclude this chapter by stating the overall aims and structure of my thesis.

1.1 The link between food, diet, obesity, and health, and inequalities therein

All foods, including those that can be prepared and cooked at home and those that are sold ready-to-consume, often purchased outside of the home, contribute to overall dietary patterns (1, 2). Overall dietary patterns contribute to health, with greater consumption of micronutrient rich foods, such as fruits, vegetables, legumes, pulses, and nuts linked to overall dietary patterns that can be health protecting (3, 4), and lead to less weight gain over time (5). However, poorer overall dietary patterns have been associated with the onset of cardiovascular diseases and several non-communicable diseases and cancers (6-8). Promoting healthier food consumption is therefore a recognised public health priority (9, 10). This is especially important because population-wide dietary patterns often fail to meet published dietary guidelines (11). Additionally, over 600 million adults globally and 28% of adults in England were estimated to be living with obesity between 2015 and 2019 (12, 13).

Individuals with less access to social and economic resources, and lower income and levels of education consistently have poorer diets and health compared with those who have greater resource access, and higher income and levels of education (14, 15). Figure 1.1, published by the National Food Strategy (an independent review of the United Kingdom (UK) food system) using data from the National Diet and Nutrition Survey collected between 2014 and 2016, demonstrates that in both children and adults, those living in lower income households (i.e. more deprived) generally consume fewer fruits and vegetables (16). There are also differences in

obesity prevalence across the socioeconomic spectrum, with adults living in more deprived areas reported to have a higher body mass index (BMI) (17). Figure 1.2, also published by the National Food Strategy, shows that the proportion of adults with either overweight or obesity was highest amongst those in the most deprived areas of England in 2019 (16). Together, Figure 1.1 and Figure 1.2 indicate that differences in food consumption and obesity prevalence are unevenly distributed across the socioeconomic spectrum in England.

Figure 1.1: Differences in the consumption of fruits and vegetables across age groups and income quintiles in England.
Notes: Q = quintiles. F&V = fruits and vegetables. Reproduced from the National Food Strategy, published in 2022, based on data from the National Diet and Nutrition Survey (16).

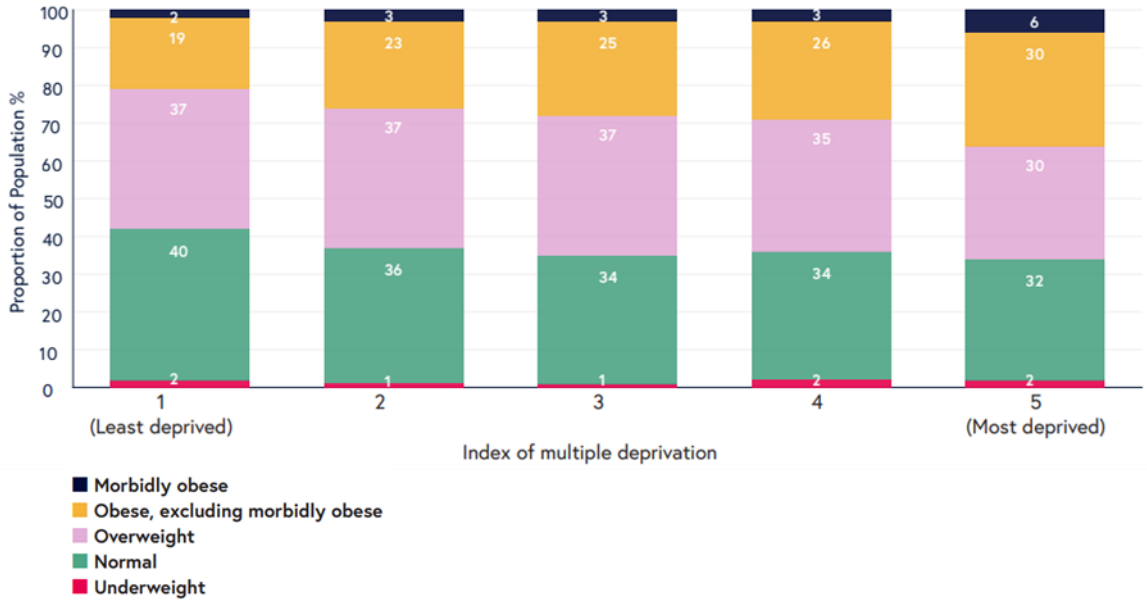

Figure 1.2: Differences in the prevalence of adult obesity in England across income quintile.
Notes: Reproduced from the National Food Strategy, published in 2022, based on data from the Health Survey for England and the English Indices of Multiple Deprivation (16).

Olstad and Kirkpatrick (18), amongst others (19, 20), propose that the selection of one type of food over another is a response to environmental factors and cultural contexts. In the physical food environment, food can be purchased from retail outlets such as convenience stores, supermarkets, restaurants, and hot food takeaway outlets, each of which operate with customer-facing premises that often co-locate (21-23). The focus of my thesis is the purchase of food prepared out-of-home, specifically, through online food delivery services, which I will discuss in Section 1.4.3.

1.2 Food prepared out-of-home

In the next sections, I will first define food prepared out-of-home. I will then discuss the popularity of this food (Section 1.2.2), its energy and nutrient content (Section 1.2.3), and public health concerns regarding its consumption (Section 1.2.4).

1.2.1 Definitions of food prepared out-of-home

Heterogeneity in definitions of food prepared out-of-home has contributed to it being a poorly defined food category (24). In one scoping review, no consistent definition was used across 57 included articles (25), with further reviews reporting similar findings (26, 27). For my thesis, I have considered food prepared out-of-home to be a broad category that includes meals (rather than snacks) served ready-to-consume for either on-premises or off-premises consumption. This

food is sold by many retailers in the physical food environment, including hot food takeaway outlets and restaurants (28, 29).

1.2.2 The popularity of food prepared out-of-home

The number of chain and independent outlets selling food prepared out-of-home has increased over time in the UK (30). In one area of England (Norfolk), the number of hot food takeaway outlets increased by 45% between 1990 (n=265) and 2008 (n=385) (31). This evidence was from a single area and for a single type of food outlet selling food prepared out-of-home, which does not capture the full range of outlets from which this food can be accessed. Nevertheless, between 2004 and 2018, the number of a broader range of food outlets selling this food increased at the national level in the Netherlands (32), and Mexico (33), and over large sub-national geographies in Australia (34), and New Zealand (35).

The increased supply of food prepared out-of-home is partly a reflection of increased demand. In many countries, it is popular to purchase and consume this food (36), with greater consumption and expenditure over time reported in the United States of America (USA) (37), and Australia (19). For the UK, estimated revenue for out-of-home food retail exceeded £20 billion in 2022, compared with around £18 billion in 2012 (38). Further growth has also been forecast (39). In addition, national dietary surveillance data collected between 2008 and 2012 indicated that over one fifth of adults consumed food prepared out-of-home inside a food outlet (27%), or at home (21%), once per week or more (40).

1.2.3 The energy and nutrient content of food prepared out-of-home

Food prepared out-of-home is often high in calories, with meals sold in portion sizes that exceed public health recommendations for single-meal energy content (41, 42). Moreover, a single meal can provide almost all of, or more than, the average recommended daily energy requirements for adults in the UK (43). Food prepared out-of-home also tends to be high in total fat, saturated fat, salt and in some cases, sugar (44). Amongst comparable menu items from chain restaurants in the UK and the USA, 97% and 96%, respectively, exceeded public health recommendations for at least one of salt, fat, saturated fat, or sugars (45). Moreover, there is evidence that it would be difficult to consume food prepared out-of-home and adhere to the recommended upper-limit for daily salt intake in the UK (6 g for adults) (46). Although the majority of food prepared out-of-home is energy-dense and nutrient-poor (47, 48), in some instances foods lower in calories and fat and salt are available (41). Nevertheless, availability does not necessarily equate to purchasing. In one study, only a minority of meals purchased out-of-home over a two-week period were considered healthy according to the author's

classification (meals containing less than 693 calories, less than 2% saturated fat, virtually no trans-fat, and at least 75 g of vegetables) (49).

1.2.4 Public health concerns about the consumption of food prepared out-of-home

There is evidence from systematic and narrative reviews that more frequent consumption of food prepared out-of-home is associated with poorer overall dietary patterns and health, and living with a higher body weight (29, 50-53). This evidence has contributed to the publication of documents that outline public health concerns regarding the consumption of this food (54-56). In the next section, I will briefly outline evidence for diet and body weight.

1.2.4.1 Associations between the consumption of food prepared out-of-home and diet and body weight

Across four extensively validated indicators (the Healthy Eating Index, Diet Quality Index, Healthy Diet Indicator and Mediterranean Diet Score), overall trends indicate that more frequent consumption of food prepared out-of-home is associated with poorer overall dietary patterns (57-60). For the Healthy Eating Index, Barnes and colleagues reported that consumption of food prepared out-of-home was inversely associated with intake of vegetables, whole grains, and fibre and positively associated with overall daily energy intake (58). Similar trends for energy intake have been reported amongst adolescents living in the UK (59). Evidence that the consumption of food prepared out-of-home contributes to poorer overall dietary patterns is important given the link between diet and health that I discussed in Section 1.1.

Evidence of an association between the consumption of food prepared out-of-home and body weight is inconsistent (61). A mixed evidence base partly reflects that previous research in this area has often been cross-sectional. This study design provides a limited opportunity to understand the temporality of associations (62). The importance of study design was demonstrated in the findings of one systematic review that included 16 studies (63). A positive association between more frequent consumption of food prepared out-of-home (`fast food` in this instance) and BMI was reported across seven prospective cohort studies, but rarely across six cross-sectional studies (63). Although several other systematic reviews have reiterated that the evidence base taken as a whole is equivocal, they also report a trend between more frequent and greater overall consumption of food prepared out-of-home and elevated body weight (36, 52, 64). While recognising that further research is required, it has been suggested that there is sufficient evidence of an association with body weight to raise public health concerns about the consumption of food prepared out-of-home (29, 63, 65).

1.2.5 Factors proposed to influence the consumption of food prepared out-of-home

Moving on from public health concerns about food prepared out-of-home, in the next sections, I discuss factors that are proposed to influence its purchase and consumption.

1.2.5.1 The socioecological model

Socioecological models provide a framework that can help us to understand factors that act at different levels to influence health (66). Figure 1.3 is a widely-cited model reproduced from Dahlgren and Whitehead (67). This model illustrates proposed determinants of health that overlap and interact with one another, including area-level determinants such as socioeconomic and environmental factors, and individual-level determinants such as sociodemographic factors (68). Given that socioecological models can help to understand the complexity of health determinants, it has been reproduced and applied to the context of food purchasing and consumption (69-72). I use the Dahlgren and Whitehead model as a framework to consider factors that plausibly contribute to the purchase and consumption of food prepared out-of-home.

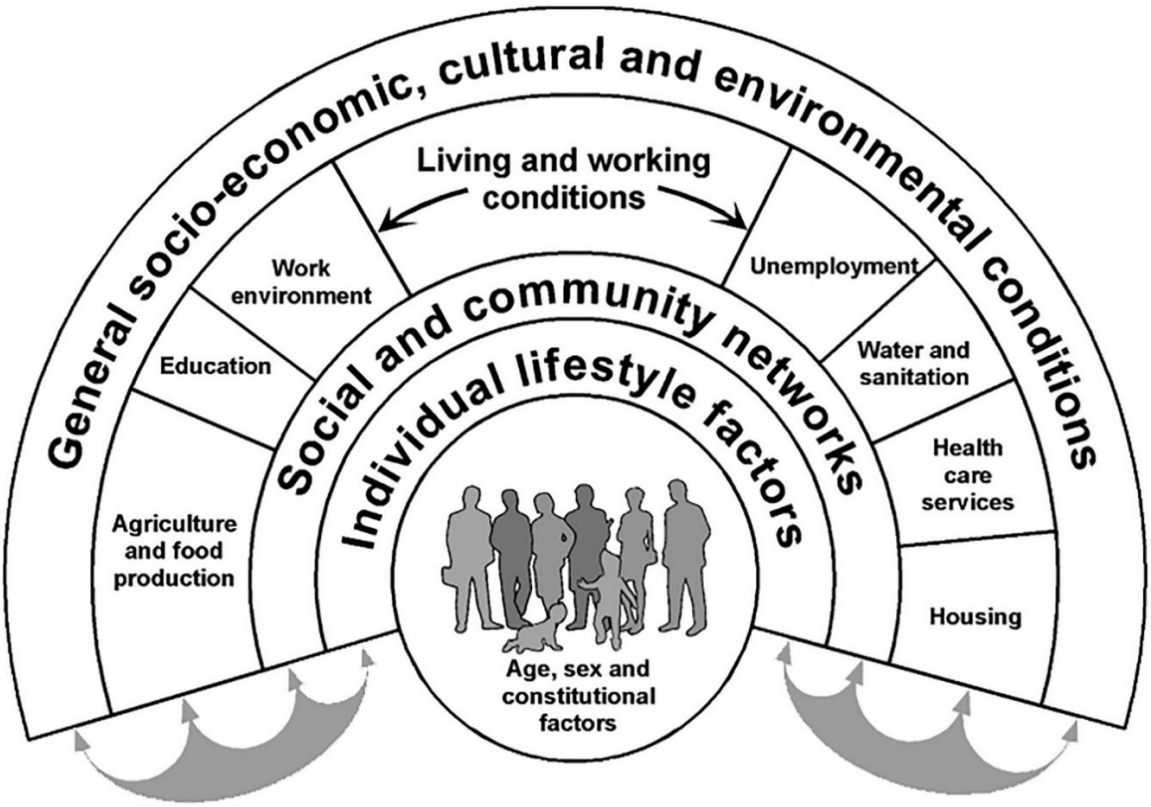

Figure 1.3: Socioecological model of the proposed determinants of health.
Note: Reproduced from Dahlgren and Whitehead (67) .

1.2.5.2 A conceptual framework of food access

Penchansky and Thomas described how healthcare access encapsulates multiple overlapping domains: availability, accessibility, affordability, accommodation, and acceptability (73). Away from healthcare, Charreire and colleagues (27), and others (74), have suggested that these domains are important for food-related practices. It is hypothesised that greater food access in the physical food environment will be associated with greater overall and more frequent purchase and consumption of food sold. In part, this is due to individuals receiving purchasing cues and having the opportunity for their needs to be met within each of the aforementioned domains (61, 75). Thus, the five domains defined by Penchansky and Thomas have been adapted for food access in the physical food environment, as shown in Table 1.1, and used within research examining the purchase and consumption of fruits and vegetables (76), and food prepared out-of-home (50).

Table 1.1: Name and definition of the domains of access in relation to the physical food environment.

Domain	**Definition** [a]
Availability	The presence of certain types of food outlet
Accessibility	The location of food supply and the ease of getting to that location
Affordability	Food prices and people's perceptions of worth relative to cost
Accommodation	People's attitudes about how well a given food supply accepts and adapts to their individual needs
Acceptability	People's attitudes about attributes of their local food environment, and whether or not the given supply of products meets their personal standards

[a] definitions reproduced from Caspi et al. (77).

One systematic review reported that almost two-thirds of 432 articles published between 2007 and 2015 examined aspects of food availability and accessibility through geospatial analysis (78). However, despite being theoretically plausible, evidence of an association between these domains of food access and food-related practices is mixed, with numerous reviews reporting positive, null and negative associations (25, 29, 36, 61, 64, 79, 80). A further systematic review from 2012 synthesised evidence according to the domains of food access defined in Table 1.1 (77). Across 38 included studies, more than two-thirds (n=26) conducted geospatial analysis. Of these studies, 20 investigated food outlet availability, measured in terms of presence or count. Focusing on food prepared out-of-home, of the five studies that investigated a relationship

between a spatial food environment exposure through geospatial analysis (availability or accessibility domains of food access in this instance) and the purchase and consumption of food sold (60, 81-84), only one found a positive association (83). In their study, Thornton and colleagues reported that access to one additional brand of fast-food chain increased the odds of monthly fast food purchasing by 13%. Moreover, there was some evidence from unadjusted and partially adjusted analyses that the density (i.e. count) of food outlets was associated with monthly and weekly fast food purchasing. However, this association was attenuated after adjustment for individual-level sociodemographic characteristics.

Although previous research has tended to use geospatial analysis to investigate the availability and accessibility domains of food access, the remaining domains (i.e. affordability, accommodation, and acceptability) are not necessarily spatially dependent. In part, an inconsistent evidence base might reflect that these domains have been investigated less frequently than more spatially dependent domains (77). This is important since the price and type of food prepared out-of-home, and sociocultural norms therein, can influence purchasing practices (85-87), especially when multiple food outlets are accessible (76, 88). Indeed, failing to consider that food purchasing practices are complex and influenced by multiple overlapping factors is a recognised limitation of previous research in this area (27, 74). Further methodological variation across previous research, including how neighbourhood food environments were characterised in terms of their shape and size, the spatial scale of analyses, data used, and the specific relationships investigated may have also attenuated evidence of a positive association (26, 27, 89-91). Moreover, it is necessary to consider that most of the previous research regarding access to food prepared out-of-home has been conducted in the context of the physical food environment. Food prepared out-of-home can now also be accessed through purchasing formats (i.e. the way that food is acquired) that are part of food retail within the digital food environment. I will discuss this further in Section 1.4.3.

1.2.5.3 Socioeconomic position

In Section 1.1, I indicated that there are socioeconomic inequalities in both overall dietary patterns and obesity prevalence. Physical food environments that provide abundant access to food prepared out-of-home have been referred to as obesogenic (92), and obesity-promoting (93). Within the socioecological model (see Section 1.2.5.1: Figure 1.3), socioeconomic and environmental factors are included as plausible determinants of health. These factors can influence the spatial distribution of food outlets in the physical food environment. As such, a possible association between area-level socioeconomic position and measures of food access has been a consistent focus of previous research (51, 53, 94). Much of the current evidence is

from the USA (95, 96), and differences in the measurement of socioeconomic position and the spatial distribution of food outlets in the physical food environment makes comparisons between countries difficult (97). Elsewhere, there is evidence that the number of food outlets selling food prepared out-of-home in the physical food environment is higher in more deprived areas of the UK (31, 98, 99). As shown in Figure 1.4, using 2017 Local Authority data from the Food Standards Agency, Public Health England reported that fast-food outlet density per 100,000 population was positively associated with deprivation at the Local Authority level in England (100). Populations living in these areas might receive a higher number of cues to purchase foods sold, which can influence food purchasing practices (2), and shape sociocultural norms about the appropriateness and acceptability of this food (101). Accordingly, unequal access to food in the physical food environment might contribute to overall dietary patterns, and related inequalities. I will discuss evidence on these inequalities within the context of online food delivery services in Section 1.4.5.1.

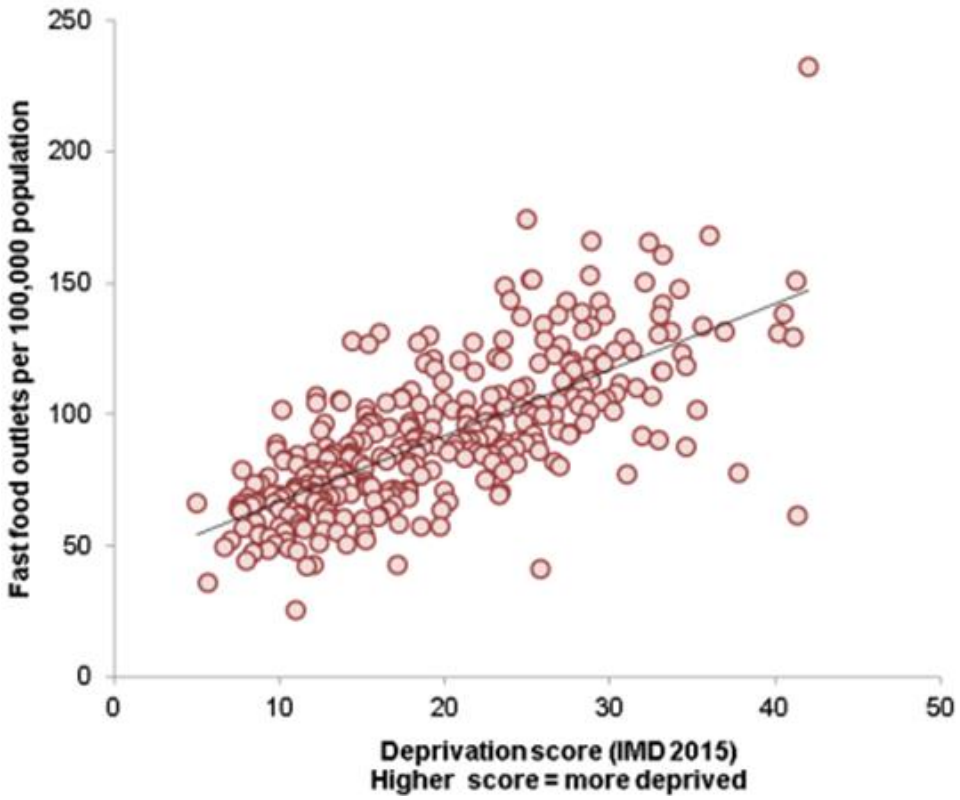

Figure 1.4: Relationship between Local Authority level of deprivation and the density of fast-food outlets.
Notes: Reproduced from Public Health England (with modification), published in 2018 (100). Fast-food outlets predominantly sell food prepared out-of-home. Data are from the Food Standards Agency (2017) and the English Indices of Multiple Deprivation (2015).

Moving away from area-level socioeconomic and environmental determinants of health, the socioecological model shown in Figure 1.3 (see Section 1.2.5.1) also suggests that individual-level factors are a determinant of health. Individual-level socioeconomic position is often characterised in terms of education, income, and occupation (102, 103), however, there is no clear consensus about the most appropriate measure to use (104). In the context of food, each measure provides a different indication about how purchase and consumption practices might be influenced, including the ability to interpret food labels, the availability of finances for food purchasing and time for meal preparation (102, 103). Although education, income and occupation are related, they are imperfectly correlated (105), and heterogeneity in their characterisation can make comparisons between them difficult (106, 107). Nevertheless, there is evidence that purchasing and consuming food prepared out-of-home varies based on measures of education, income, and occupation (50, 61, 107). To exemplify, amongst adults living in Australia, those with the highest level of education consumed more food prepared out-of-home compared with those who had lower levels of education (108). In England (109), and the USA (110), however, adults with the highest level of education consumed the least food prepared out-of-home. Furthermore, there is evidence that the purchase and consumption of food prepared out-of-home varies by location, with more highly educated individuals accessing this food through restaurants rather than hot food takeaway outlets (111), and that they purchase healthier foods (112). Taken together, these findings suggest that country-specific context and food characteristics interact with individual-level factors to influence purchasing practices. This is reflected in qualitative research that reported on the complexities of takeaway food consumption (113-115). Moving on to income, amongst females living in Australia, those in the lowest income group (less than 500 Australian Dollars per week) consumed food prepared out-of-home more frequently than those in higher income groups (104). Elsewhere, however, household income was not associated with overall consumption of food prepared out-of-home (112). Finally, for occupation, purchasing and consuming food prepared out-of-home inside of food outlets was more common amongst adults in higher (e.g. managerial) rather than lower (e.g. manual) employment classifications (40, 116).

1.2.5.4 Individual-level sociodemographic characteristics

In the previous section, I discussed how the purchase and consumption of food prepared out-of-home varies by individual-level socioeconomic position. Further individual-level sociodemographic characteristics including age, sex and ethnicity are also suggested to influence these food-related practices (50, 107, 117, 118). Next, I briefly discuss evidence related

to each of these sociodemographic characteristics in turn, with acknowledgement that they intersect.

Although there is evidence that food prepared out-of-home is consumed by individuals of all ages, consumption tends to be highest in younger populations (36). For instance, the proportion of adults in the UK that purchased food prepared out-of-home once per week or more between 2008 and 2012 was over 40% amongst those aged 19 to 29 years, and 20% for those aged between 60 and 69 years (40). Elsewhere, frequency of consumption was inversely associated with age amongst adults in the USA (119). There are multiple reasons why younger adults might be more inclined to consume food prepared out-of-home and visit food outlets in-person. Doing so offers convenience compared with cooking at home, can form part of routines and habits, and adolescents have reported that food outlets are a safe and social place to meet (120-122).

Regarding sex, males have been reported to consume food prepared out-of-home more frequently than females (111, 123). To some extent, differences in consumption might reflect that males prepare food for themselves less frequently (124, 125), and spend less time cooking at home (126, 127), compared with females who are traditionally placed into roles responsible for food purchasing and preparation (128). These differences are not necessarily biologically driven, and it is recognised that food practices are influenced by sociocultural norms (129). Since social, environmental and cultural, factors can influence the gender to which a person self-identifies (130), the aforementioned differences might be a reflection of gender rather than sex. However, sex assigned at birth is commonly measured in research (131).

Finally, there is evidence that consumption of food prepared out-of-home varies across ethnicity groups (132). However, evidence in the context of Western Europe is limited. In part, this is because ethnic minorities are under-represented in research (133, 134), and because multiple ethnic groups are often aggregated into a single category, which limits the opportunity for a more granular understanding of differences (135). Making comparisons between countries in terms of ethnic differences in the consumption of food prepared out-of-home is also difficult due to variations in historical and cultural influences on food practices (136). Focusing on evidence from the UK, the consumption of food prepared out-of-home was most prevalent and frequent amongst Black and South Asian adolescents aged 13-15 years living in London (137). Furthermore, adults that identified with a White ethnicity had lower odds of consuming food prepared out-of-home more than twice per week, compared with those who identified with a non-white ethnic group (111). Finally, females that identified with an ethnic minority reportedly consumed food prepared out-of-home when time was limited (138).

1.3 The digital food environment

So far in this chapter, I have discussed the importance of a healthy diet, that food prepared out-of-home is typically high in calories, total fat, saturated fat and salt, and evidence that consumption of this food can have implications for overall dietary patterns, body weight and health. To reiterate, there is established public health concern about the consumption of food prepared out-of-home. Most of the previous research in relation to this food was conducted in the context of the physical food environment. However, food prepared out-of-home can now also be accessed through online food delivery services, which form part of the digital food environment.

1.3.1 A definition for the digital food environment

The internet is used by two-thirds of the global population (139), and many aspects of daily life have become partially, if not fully, digitalised (140). Widespread internet use, a demand for greater convenience within changing sociocultural norms and technological advances have contributed to the development of the digital food environment, which acts in parallel with the physical food environment (141-143). Although the digital food environment has existed for over two decades, it is not well defined (144). According to the European region of the World Health Organization (WHO), the digital food environment is *"a range of elements, including social media, digital health promotion interventions, digital food marketing and online food retail"* (145). In the digital food environment, factors that plausibly influence food-related practices are present and interacted with in online settings (146). While I recognise that the digital food environment is complex and multifaceted, of particular interest to my thesis is `online food retail`, and specifically, the use of online food delivery services to purchase food prepared out-of-home. I will discuss the use of these services in Section 1.4.3. Next, however, I consider existing evidence on the digital food environment.

1.3.2 Previous research in the context of the digital food environment

A systematic scoping review from 2022 synthesised evidence on the digital food environment published between 2000 and 2019 (147). Although 357 studies were included, and the number of publications increased from 2012 onwards, there was limited public health focused research. In part, this reflects that research was more frequently published in journals focused on marketing, business or economics (n=82 studies), or food and nutrition (n=93 studies), rather than medicine or health (n=80 studies). Moreover, although online food retail was the most investigated setting (n=95 studies), research did not typically focus on food prepared out-of-home.

Elsewhere, within public health focused research, limited elements of the digital food environment have been studied (148). Digital food marketing is recognised for its influence on food purchasing practices and preferences (149, 150). Various features of social media have been associated with food-related sociocultural norms (140). And, it has been suggested that the digital food environment and purchasing formats therein challenge multiple Sustainable Development Goals related to health and wellbeing that were adopted by the United Nations in 2015 (151, 152). Specifically for online food retail, although multiple types of food can be purchased, research to date has often focused on food from supermarkets rather than other types of food (153). For example, there has been limited research into the purchase of food prepared out-of-home through internet-based purchasing formats such as online food delivery services (148).

1.4 Online food delivery services

Delivery of food prepared out-of-home is not new. Historically, ordering food prepared out-of-home for delivery would have involved contacting food outlets (i.e. businesses) directly by telephone. Since the emergence of online food delivery services, however, this is no longer necessarily the case (154), with these services referred to elsewhere as `disruptors` to traditional food retail (155). In the sections that follow, I will discuss why a better understanding of online food delivery service use is important from a public health perspective.

1.4.1 A definition for online food delivery services

The online food delivery service business model has been referred to by others as *"meal delivery services"* (156), *"food delivery apps"* (141), *"digital food ordering platforms"* (157), and *"internet based ordering and delivery"* (158). Despite this variation, each definition refers to the same type of service. That is, one that aggregates information about food outlets (for example, menus, price-promotions, contact details, previous customer reviews) onto a single digital platform and provides customers with the opportunity to purchase food prepared out-of-home before having it delivered. In the absence of an established or agreed upon definition, I have used *"online food delivery services"* in my thesis, which is similar to how one internationally established service and the market leader in the UK (Just Eat) refers to themselves.

1.4.2 The global presence and popularity of online food delivery services

International operations of online food delivery services including Just Eat and Uber Eats has led to a presence in each continent (141, 142, 156, 159-162). In addition, there are also small-scale online food delivery services that facilitate access to food prepared out-of-home across local

geographies, such as within a single city. In some cases, however, internationally established online food delivery services have acquired small-scale services. In turn, this has contributed to a concentration of online food delivery services operating across multiple markets under the branding of different subsidiaries. For example, Just Eat has a portfolio that includes SkipTheDishes in Canada and Menulog in Australia (163).

In part, the aforementioned global presence reflects an increased popularity of online food delivery service use (143, 146, 148). For instance, Just Eat has operated in the UK since around 2006, however, demand for this type of service has increased only more recently as customers reportedly seek a convenient and time efficient way to order and receive food prepared out-of-home within a digital and on-demand society (24, 39). There may be further unique aspects of the online food delivery service business model that have contributed to this popularity, which I investigate from the perspective of customers in Chapter 3. In the next section, I describe the process of online food delivery service use.

1.4.3 Purchasing food prepared out-of-home through online food delivery services

In Section 1.4, I stated that historically, having food prepared out-of-home delivered would have typically involved contacting food outlets (i.e. businesses) directly by telephone to place orders. Food businesses would then prepare and deliver meals. This is dissimilar to the business model of online food delivery services, which primarily involves three groups of stakeholders: online food delivery services, food businesses, and customers. When the research in my thesis was conceived, online food delivery services primarily aggregated information about food businesses onto a single platform and allowed customers to place their orders. Once customers had placed their orders, food businesses would prepare and deliver meals. However, the business model of these services has evolved, and in some instances, online food delivery services now facilitate meal delivery. The focus of my thesis is the delivery of food prepared out-of-home when ordered through online food delivery services, irrespective of who is responsible for delivery.

Figure 1.5 illustrates the process of online food delivery service use. Below, I summarise key points from this figure:

- Before food prepared out-of-home can be purchased through online food delivery services, a given online food delivery service must operate in a given area, food businesses must be registered to accept orders through this service, and individuals must be registered as customers.

- Online food delivery services and food businesses continuously interact with one another to provide a range of information that customers can use to inform their purchasing practices.

- Food ordered through online food delivery services is typically prepared inside of existing customer-facing food outlets located in the physical food environment. Thus, the online food delivery service business model is predicated on the location of food outlets in the physical food environment.

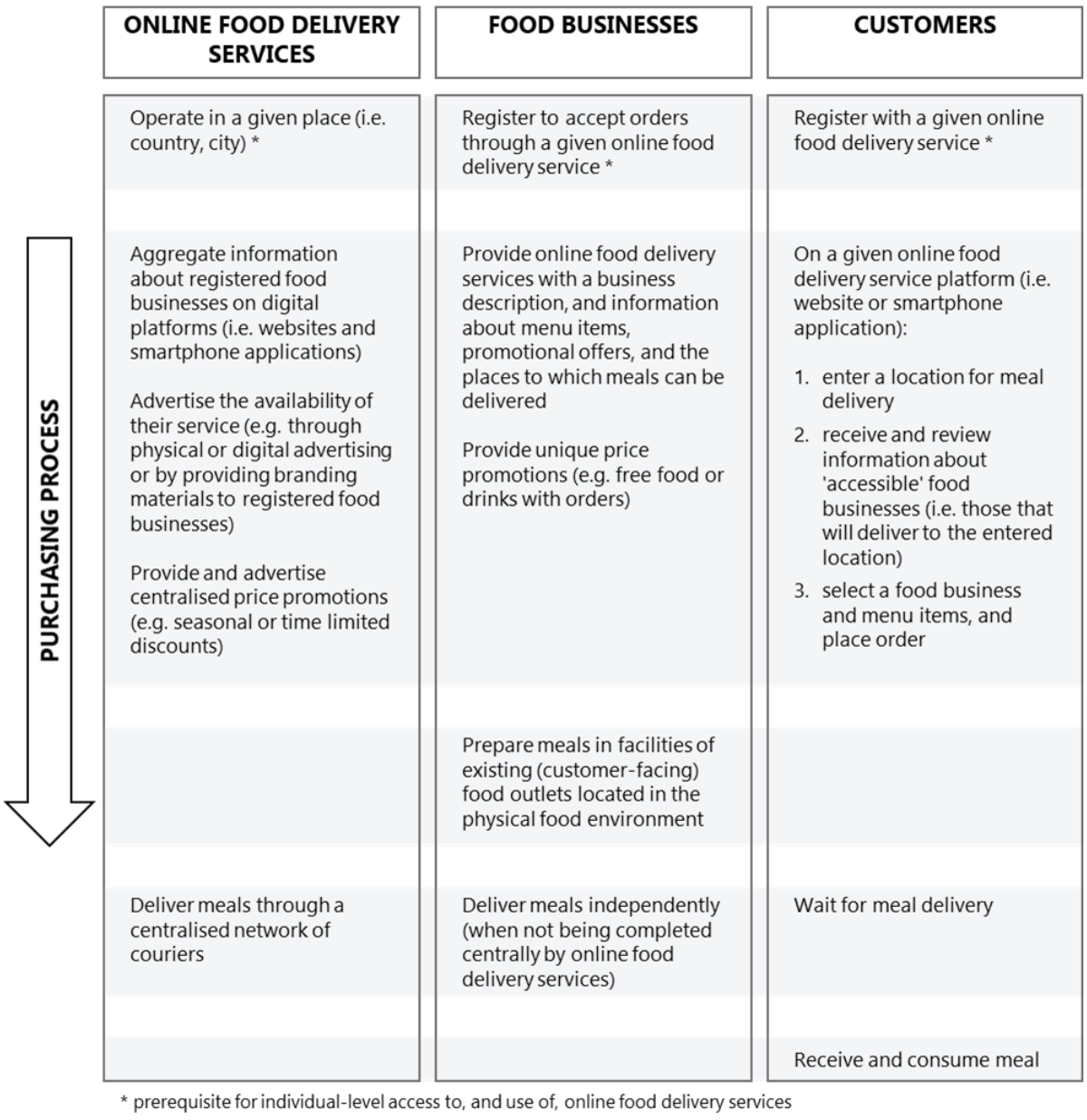

Figure 1.5: The role of individual online food delivery services, food businesses, and customers in the process of purchasing food prepared out-of-home through the online food delivery service business model.

1.4.4 A proposed pathway between the use of online food delivery services and body weight

Figure 1.6 is a proposed causal pathway showing factors that plausibly influence online food delivery service use. Since I use Figure 1.6 to highlight the research focus of the upcoming empirical chapters, I have not illustrated the multiple preceding or proceeding factors that could influence those included and that I will investigate. Nevertheless, as evidenced elsewhere (36, 50), I acknowledge that bodyweight, for example, is determined by multiple factors that extend beyond the physical food environment or online food access. For example, physical activity levels and overall dietary intake. Figure 1.6 was informed by the evidence discussed in the previous sections; particularly the socioecological model (see Section 1.2.5.1) and the domains of food access (see Section 1.2.5.2). I propose that online food delivery service use depends on individuals having `online food access` (i.e. access to food prepared out-of-home through online food delivery services). This online food access might be influenced by area-level socioeconomic position due to the location of food outlets in the physical food environment. However, there are also broader social and economic factors including labour workforce, industrial development, digital connectivity and area-specific food related traditions and values, which may also be influenced and informed by area-level socioeconomic position. Moreover, online food access could also be influenced by individual-level characteristics, since some populations, for example, those who are younger, more highly educated and living in urban areas, have higher levels of digital literacy, which could lead to them spending more time using internet-enabled devices and receiving prompts for food prepared out-of-home (164). Finally, online food delivery service use might be associated with body weight further along the causal pathway.

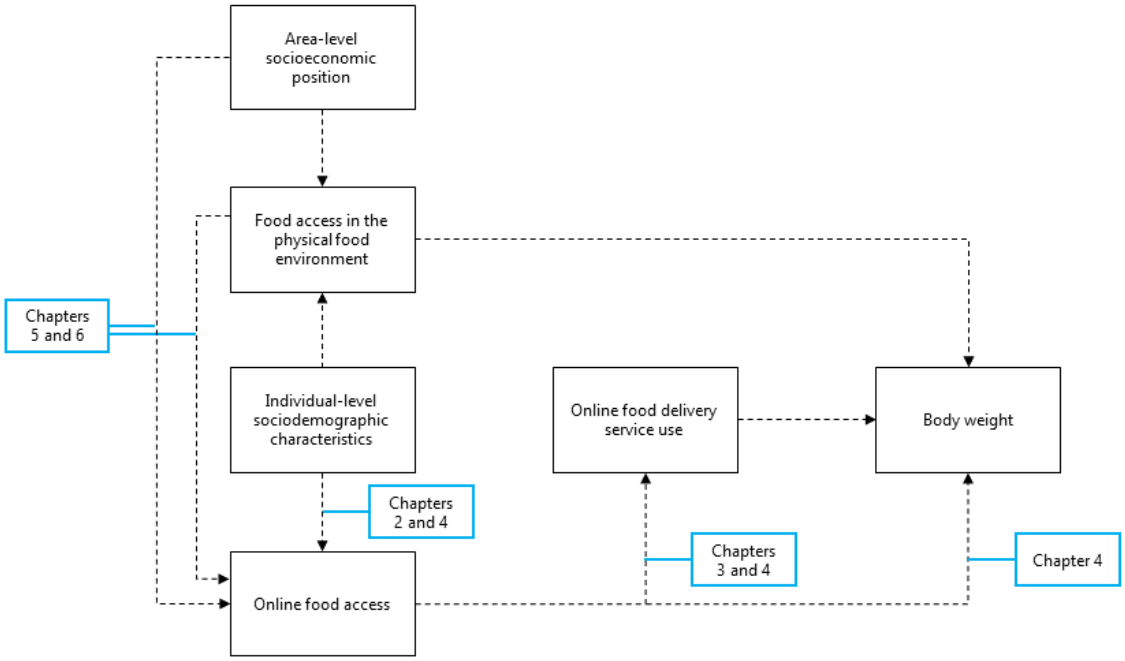

Figure 1.6: Proposed causal pathway between online food access (access to food prepared out-of-home through online food delivery services) and body weight.
Note: Dashed lines indicate hypothesised links.

1.4.5 Online access to food prepared out-of-home

It is a core tenet of my thesis that the domains of food access discussed in Section 1.2.5.2 (availability, accessibility, affordability, accommodation, and acceptability) are relevant to the use of online food delivery services. As such, I have adapted the definitions of these domains to reflect food access through online food delivery services, as shown in Table 1.2. I will discuss current evidence about these domains and elements of the proposed causal pathway (see Section 1.4.4: Figure 1.6) in the next sections. Doing so will help to identify knowledge gaps and provide insight into the potential need for public health concern about access to food through, and the use of, online food delivery services.

Table 1.2: Name and definition of the domains of food access in the context of online food delivery services.

Domain	Original definition [a]	Definition adapted for online food delivery services
Availability	The presence of certain types of food outlet	Online food delivery services present and operating in a given area and individual food businesses registered to accept orders [b]
Accessibility	The location of food outlets and the ease of getting to that location	The interplay between the location of customer-facing outlets of food businesses registered to accept orders [b], their delivery areas, and the location of a given individual that has internet access, an appropriate internet-enabled device, and who is registered as a customer
Affordability	Food prices and people's perceptions of worth relative to cost	The price of food sold and any additional costs incurred when using online food delivery services, and people's perceptions of worth relative to cost
Accommodation	People's attitudes about how well a given food outlets accepts and adapts to their individual needs	People's attitudes about how well online food delivery services and individual food businesses accepts and adapts to their individual needs
Acceptability	People's attitudes about attributes of their local food environment, and how well a given supply of foods meets their personal standards	People's attitudes about attributes of online food delivery services and accessible food businesses, and how well a given supply meets their personal standards

Notes: [a] original definitions were for the physical food environment, reproduced from Caspi et al. (77). [b] registered to accept orders through the online food delivery service operating in a given area.

1.4.5.1 Access to food prepared out-of-home through online food delivery services and inequalities therein

The domains of food access adapted for online food delivery services that I presented in Table 1.2 have not been *explicitly* investigated to date. Nevertheless, there is some relevant evidence related to access to food prepared out-of-home through these services and variation according to area-level socioeconomic position. In terms of availability and accessibility, one study reported that the number of food outlets that could be ordered from through an internationally established online food delivery service was lower in the most, versus least, deprived areas of one city in Australia (477 outlets versus 682 outlets) and one city in the Netherlands (443 outlets versus 1053 outlets) (156). However, the number of food outlets was higher in the most, versus least, deprived areas of one city in the USA (859 outlets versus 809 outlets). Other research has reported that the number of food outlets registered to accept orders through a market leading online food delivery service was higher in less deprived areas across 13 local areas in Sydney,

Australia, yet not different across Auckland, New Zealand (165). Finally, across 24 randomly selected postcodes in Canada's most populated region, the number of food outlets that could be ordered from through a leading online food delivery service ranged from 33 to 472 (166). Although stratification by area-level socioeconomic position was not investigated, the authors noted heterogeneity in online food outlet access within and between cities. Together, this evidence indicates that there is variation in the availability of and accessibility to food prepared out-of-home through online food delivery services, and that this is socioeconomically patterned, albeit not always in the expected direction. Beyond this research, knowledge about online food access in other countries is limited to information that online food delivery services operate. This means that in many countries, the extent to which online food delivery services are available and accessible, and variation according to area-level socioeconomic position, is not yet known. This represents a substantial gap in knowledge since online food access is likely a necessity for online food delivery service use (as I proposed in Section 1.4.4). In Chapter 5, I report the findings from research that helps to address this gap in knowledge for the UK.

In addition, despite the aforementioned evidence that online food delivery services are available and accessible, the extent to which measures of online food access are related to the use of online food delivery services is unclear. I investigate this association in Chapter 4.

Further related to the availability and accessibility domains of food access, the location of food outlets in the physical food environment is important for the business model of online food delivery services. As I discussed in Section 1.2.5.3, the number of food outlets in the physical food environment tends to be higher in more deprived areas of England. Online food delivery services offer an alternative purchasing format without necessarily replacing others (142). As such, food prepared out-of-home can be accessed in multiple ways within both the physical and digital food environments. In turn, variation in online food delivery service availability and accessibility according to socioeconomic position might increase overall access to food prepared out-of-home. This increase might contribute to diet-related inequalities. However, links between the physical food environment and online food access have not yet been investigated. I report the findings from research that investigated plausible links in Chapters 5 and 6.

The density and concentration of food outlets in the physical food environment has increased over time (32, 34, 35). In turn, this might influence online food access as a higher number of food outlets could plausibly register to accept orders through online food delivery services. Given that the popularity of using these services is forecast to increase (39), it is reasonable to suggest that more food outlets will register to accept orders online in the future as a way to

capitalise on perceived demand. Since this is untested, further research is warranted. A better understanding of changes in online food access over time and the extent to which this is socioeconomically patterned would provide insight into market trends, possible implications for customer interactions with the physical food environment, and the potential for food practices and inequalities therein to be influenced. I report the findings from research that investigated changes in online food access over time in Chapter 6.

Finally, unlike the availability and accessibility domains of food access presented in Table 1.2 (see Section 1.4.5), to my knowledge there is no published evidence related to the domains of affordability, accommodation and acceptability. Unique features of online food delivery services, encapsulated within these domains, plausibly influence the use of this purchasing format by ensuring that an individual's standards and needs are met. It has been suggested that online food delivery services are used for their convenience and because they expand food access beyond the traditional physical food environment (148). Nevertheless, experiences of online food delivery service use from the customer perspective are unknown. The research I present in Chapter 3 helps to address this knowledge gap.

1.4.5.2 Online food delivery service use and sociodemographic characteristics of customers

Within the proposed causal pathway that I presented in Figure 1.6 (see Section 1.4.4), I suggest that individual-level sociodemographic characteristics influence online food access and, in turn, online food delivery service use. As it stands, there is limited empirical evidence on the use of online food delivery services and the sociodemographic characteristics of customers. In one study, 28% of a sample of adults in living Australia (n=2010) had used an online food delivery service at least once in the month prior to data collection in 2018 (135). Online food delivery service use was highest amongst younger adults. Moreover, individuals with a higher (university degree) versus lower (compulsory) level of education, and a higher income (compared to less than $9999 per year) had greater odds of online food delivery service use. Despite this research, the prevalence of online food delivery service use in the UK and many other countries, and the sociodemographic characteristics of customers therein, has not been established. This knowledge is vital for a better understanding about individual-level factors that might influence online food access and ultimately, online food delivery service use. I examine the prevalence of online food delivery service use and the sociodemographic characteristics of customers across multiple countries in Chapter 2, and in Great Britain in Chapter 4.

1.4.5.3 Online food delivery service use and body weight

Evidence from multiple countries indicates that food sold and marketed through online food delivery services is high in calories, total fat, saturated fat and salt (159, 162, 165, 167, 168). As shown in Figure 1.5 (see Section 1.4.3), food sold through these services is typically prepared inside of existing customer-facing food outlets located in the physical food environment. Thus, the aforementioned findings might be expected. Nevertheless, this research included only a limited number of the most popular food outlets and most frequently purchased menu items, which possibly misrepresents the full scope of foods sold. It is certainly plausible that by increasing the number and diversity of food outlets that can be ordered from, online food delivery services facilitate access to healthier foods prepared out-of-home than in the physical food environment (141, 148, 169). However, this remains untested. Based on current evidence about the types of food available to purchase through online food delivery services, the association between consumption of food prepared out-of-home and body weight that I discussed in Section 1.2.4.1 might be present. Given that the use of online food delivery services might be a substitute for other ways of purchasing food prepared out-of-home, this is especially important to understand. Therefore, in Chapter 4, I investigate the possible relationship between online food access and body weight.

1.5 Summary of the Introduction

In summary, poor diet is a contributor to poor health and there are socioeconomic inequalities in both. The purchase and consumption of food prepared out-of-home is recognised as a public health concern due to its energy-dense and nutrient-poor composition. Although this food remains accessible in the physical food environment, it is now also accessible through online food delivery services, which are an aspect of food retail within the digital food environment. However, the prevalence of online food delivery service use, and by whom, has not yet been established in the UK and many other countries. Moreover, possible reasons for selecting one purchasing format over another are unclear.

There is evidence that access to food prepared out-of-home in the physical food environment is higher in more deprived areas of the UK, and that this contributes to diet-related inequalities. Food sold through online food delivery services is typically prepared inside of existing customer-facing food outlets located in the physical food environment. As such, access to these services may increase overall access to food prepared out-of-home, especially in more deprived areas, which could contribute to diet-related inequalities. Therefore, research to help better understand access to food prepared out-of-home through online food delivery services, and the extent to which this is socioeconomically patterned and possibly influences health, is required.

1.6 Thesis aims

The aim of my thesis was to provide an improved understanding of the use of online food delivery services to access food prepared out-of-home, specifically with regard to the:

1. Prevalence of online food delivery service use and sociodemographic characteristics of customers.
2. Experiences of online food delivery service use from the perspective of customers.
3. Associations between measures of access to food prepared out-of-home through online food delivery services and online food delivery service use and body weight.
4. Extent to which access to food prepared out-of-home through online food delivery services is socioeconomically patterned, and how this access and any inequality changed over time.

1.7 Thesis structure

After this introductory chapter, I present a series of complementary empirical chapters. Together, these chapters help to deliver the specific aims outlined in the previous section and provide evidence for multiple elements of the proposed causal pathway presented in Figure 1.6 (see Section 1.4.4).

Chapters 2 to 6 are based on research that I led, with support and contributions from co-authors. The research I present in Chapters 2 to 5 has been peer-reviewed and published. The order in which I present the research in these chapters does not reflect the order of publication. Because of this difference, at points I refer to published research despite it not yet being presented in my thesis. For the most part, in Chapters 2 to 5, I present the published manuscripts. As a result, there is overlap across chapters in terms of background content and methods. However, I have made minor amendments to minimise repetition, to provide further information and rationale where appropriate, and to present a coherent structure to my thesis. I present the supplementary material for each empirical chapter in the appendices.

Regarding the aims outlined in Section 1.6, in Chapter 2, I address aim 1 by describing the prevalence of online food delivery service use and sociodemographic characteristics of customers amongst adults living across Australia, Canada, Mexico, the UK, and the USA. In Chapter 3, I address aim 2 by reporting experiences of online food delivery service use from the perspective of customers living in the UK. In Chapter 4, I address aim 3 by providing evidence on the association between online access to food prepared out-of-home and online food delivery service use and body weight amongst adults living in Great Britain. In Chapters 5 and 6, I address aim 4 by examining online access to food prepared out-of-home across England and variation according to socioeconomic position at one time point and over time. Finally, in Chapter 7, I discuss the findings from each of the empirical chapters as a whole, summarise the possible implications for public health and policy, and outline an agenda for future research.

Chapter 2:
Multi-country prevalence of online food delivery service use and sociodemographic characteristics of customers

2.1 Details of author contributions, publication and dissemination

For the research in this chapter, I developed the research questions and conceptualised data analysis with Jean Adams (JA) and Thomas Burgoine (TB), after consultation with David Hammond (DH), Gary Sacks (GS), and Lana Vanderlee (LV). Christine White (CW) provided data management support. I led data analysis. All authors read and provided critical comments on the manuscript that I first drafted and agreed to the final version.

This chapter is published as: Keeble, M., Adams, J., Sacks, G., Vanderlee, L., White, C.M., Hammond, D., Burgoine, T. (2020). Use of online food delivery services to order food prepared away-from-home and associated sociodemographic characteristics: a cross-sectional, multi-country analysis. International Journal of Environmental Research and Public Health. 17(4), 5190. https://doi.org/10.3390/ijerph17145190.

I shared the findings from the research in this chapter during a symposium at the 2020 International Society of Behavioral Nutrition and Physical Activity Annual Congress (held online): "New ways of purchasing (fast) food: are we transitioning away from tradition?".

2.2 Abstract

Background

Online food delivery services like Just Eat and Grubhub facilitate online ordering and home delivery of food prepared out-of-home. It is poorly understood how these services are used and by whom. I aimed to investigate the prevalence of online food delivery service use and sociodemographic characteristics of customers in Australia, Canada, Mexico, the United Kingdom (UK), and the United States of America (USA).

Methods

I used online survey data (n=19,378) from the International Food Policy Study, conducted in 2018. I identified respondents who reported any online food delivery service use in the past week and calculated the frequency of use and number of meals ordered. I used adjusted logistic regression to investigate whether odds of any online food delivery service use in the past week differed by sociodemographic characteristics.

Results

Overall, 15% of respondents (n=2929) reported online food delivery service use, with the greatest prevalence amongst respondents in Mexico (n=895; 26%). Online food delivery services had most frequently been used once and the median number of meals purchased in this way was two. Odds of any online food delivery service use in the past week were lower per additional year of age (odds ratio (OR): 0.95; 95% confidence intervals (CI): 0.94, 0.95) and greater for respondents who were male (OR: 1.50; 95% CI: 1.35, 1.66), that identified with an ethnic minority (OR: 1.57; 95% CI: 1.38, 1.78), were highly educated (OR: 1.66; 95% CI: 1.46, 1.90), or living with children (OR: 2.71; 95% CI: 2.44, 3.01).

Conclusions

Further research is required to investigate how online food delivery service use may influence diet and health.

2.3 Introduction

According to global estimates, 11% of males and 15% of females were living with obesity in 2016 (170, 171). Although the drivers of obesity are complex, excess calorie intake through the consumption of food prepared out-of-home is a recognised contributor (172-174). Food prepared out-of-home is typically served ready-to-consume, is often energy-dense, high in fat and salt, and less healthy than food prepared at home, with more frequent consumption of this food associated with elevated body weight (46, 175-177). Traditionally, this food may have been purchased through `conventional` purchasing formats whereby customers visit food outlets in-person or contact food outlets directly to place orders before collection or delivery. Although food prepared out-of-home can still be purchased in this manner, third-party platforms that facilitate online ordering and delivery, referred to as `online food delivery services`, provide an alternative purchasing format that coexists with conventional purchasing formats (142). Online food delivery services operate as intermediaries between customers and food outlets (39). Customers place orders through online platforms, their orders are forwarded to food outlets where meals are prepared, and once ready, meals are delivered to customers by couriers working for the food outlet or for the online food delivery service (142, 178).

In 2020, prominent online food delivery services such as Just Eat (including subsidiaries such as Menulog in Australia), Uber Eats, and Deliveroo operated internationally, whilst Grubhub was established in many cities across the United States of America (USA) (179-182). Online food delivery service availability and accessibility has been forecast to increase, possibly leading to greater use. In turn, this could increase the consumption of food prepared out-of-home (183). There is currently limited understanding of the nutritional quality of food items sold through online food delivery services. Nonetheless, given that the food sold through these services is typically prepared inside of existing customer-facing food outlets located in the physical food environment (39), it is likely to have a similar nutrient profile to food prepared out-of-home ordered in conventional ways. As such, online food delivery services could contribute to excess calorie intake and poor health (41, 46, 175). Accordingly, interventions to reduce online food delivery service use, or to improve the quality of available food, may be called for in the future.

Previous research into online food delivery services from a public health perspective is limited. A public health focused narrative review concluded that convenience and food outlet variety were potential drivers of online food delivery service use (144). To date, however, aspects of online food delivery service use that might influence diet and health, including the prevalence and frequency, have not been investigated. This knowledge about online food delivery service use will help to establish a baseline against which future patterns of use can be compared and serve

as an indicator of potential public health harm. Moreover, the sociodemographic characteristics of online food delivery service customers are poorly understood. Knowledge about these characteristics might provide vital intelligence for public health intervention development, if required in the future.

2.3.1 Study aims

In my study, I aimed to describe the prevalence and frequency of online food delivery service use, investigate associations between online food delivery service use and sociodemographic characteristics of customers, and describe how online food delivery service customers used other purchasing formats to access food prepared out-of-home in five upper-middle or high-income countries.

2.4 Methods

2.4.1 Data collection

I used cross-sectional data from the International Food Policy Study (IFPS), which is an ongoing annual repeat cross-sectional survey conducted in Australia, Canada, Mexico, the United Kingdom (UK), and the USA. Data collection methods have been described in full elsewhere (184). Briefly, between November and December 2018, data were collected via self-completed online surveys from adults aged 18 years or over, recruited through Nielsen Consumer Insights Global Panel and their partners' panels. Panellists were screened for eligibility and quota requirements based on device type, age, and sex. Email invitations containing links to an online survey in national languages were sent to a random sample of eligible panellists in each country. Respondents provided consent prior to survey completion. The IFPS was reviewed by and received ethics clearance through a University of Waterloo (Canada) Research Ethics Committee (ORE# 21460). Data collection in the UK was approved by the University of Cambridge Humanities and Social Science Research Ethics Committee (Reference: 19/225).

2.4.2 Measures

2.4.2.1 Purchasing format use

In the IFPS survey, all respondents were asked: *"During the past 7-days, how many meals did you get that were prepared away-from-home in places such as restaurants, fast food or takeaway places, food stands, or from vending machines?"*. A similar question has been asked in previous research (185, 186). Respondents who had purchased at least one meal prepared out-of-home were asked to report the number of meals ordered: *"using a food delivery service (e.g.,*

[country-specific examples]*) and delivered"*, *"directly from a restaurant and delivered"*, *"at a restaurant/food outlet within 5 minutes of your home"* and *"at a restaurant/food outlet more than 5 minutes away from your home"*. Country-specific examples of online food delivery services available in each country included Uber Eats (all countries), Just Eat (Canada, Mexico, UK), Deliveroo (Australia, UK), Foodora (Australia), SkipTheDishes (Canada), and Grubhub (USA). I used answers to the second question for my analyses. I collapsed responses for *"at a restaurant/food outlet within 5 minutes of your home"* and *"at a restaurant/food outlet more than 5 minutes away from your home"* into a single category for analyses: *"directly from food outlets in-person"*.

2.4.2.2 Sociodemographic characteristics

In the IFPS survey, all respondents were asked to self-report sociodemographic characteristics. I included sex, age, ethnicity, education, body mass index (BMI), and living with children aged under 18 years as independent variables. Sex at birth was reported as male or female. I treated this as a binary variable for analysis. Food purchasing practices (and plausibly, as a result, online food delivery service use) are a reflection of social norms and expectations (187). This might mean that online food delivery service use is a gendered practice rather than being driven by biological differences. Nevertheless, there is evidence of a correlation between sex at birth and gender in some instances (188). Age was reported in years (continuous). Ethnicity was reported as the group that best described racial or ethnic background, with different categories provided for respondents in each country. I dichotomised respondents into `majority` (selection of a `White` category for respondents living in the USA or the UK, predominantly speaking English at home for those living in Australia, selection of `European` rather than any other category for respondents living in Canada, and `not Indigenous` for those living in Mexico) and `minority` (all other responses, which varied across each studied country). Education was reported as the highest level completed. I categorised respondents as having: `low` (high school completion or lower), `medium` (some post-high school qualifications) or `high` (university degree or higher) levels of education, and used this variable as a marker of socioeconomic position (189). Height and weight were reported in either metric or imperial units. I calculated BMI (kg/m^2) and grouped respondents by World Health Organization categories: `underweight` (BMI <18.5), `normal weight` (BMI 18.5-24.9), `overweight` (BMI 25.0-29.9) or `obesity` (BMI $\geq$30.0) (190). I collapsed the `underweight` and `normal weight` categories into a `not overweight` category (BMI ≤24.9). As individuals living with a higher BMI may not always report their height and weight (191), I included respondents with missing data for this variable. Living with children aged under 18 years was reported as a binary (yes/no) measure.

2.4.3 Study sample

In total, data were available for 22,824 respondents. I removed respondents with missing data for any variable of interest (except BMI), when the total number of meals purchased out-of-home and the number of meals purchased through each purchasing format summed did not match, or when the total number of meals purchased out-of-home in the past week exceeded 21 (I did not consider this to be plausible based on the maximum consumption of three meals per day). The final analytical sample included 19,378 respondents.

2.4.4 Statistical analysis

Following data collection, sample weights for the IFPS were constructed using population estimates from the census in each country based on age, sex, region, ethnicity (except in Canada) and education (except in Mexico) (184, 192). I rescaled sample weights to reflect the number of participants included in the analytic sample. Unless specified, I report weighted findings.

2.4.4.1 Descriptive analyses

For each country, I determined the prevalence of online food delivery service use by identifying respondents who reported that they had used an online food delivery service at least once in the past week. For these `online food delivery service customers`, I identified the frequency of online food delivery service use. I also calculated the number and proportion of all meals purchased out-of-home using each purchasing format (i.e. `online food delivery services`, `directly from food outlets for delivery` and `directly from food outlets in-person`). I also identified respondents who had purchased at least one meal prepared out-of-home directly from food outlets for delivery or in-person but had not used an online food delivery service. For these `non-online food delivery service customers`, I calculated the number and proportion of all meals purchased out-of-home `directly from food outlets for delivery` and `directly from food outlets in-person`.

2.4.4.2 Inferential analyses

I used online food delivery service use as the primary outcome measure. As data were not normally distributed and highly right-skewed, I dichotomised respondents into any online food delivery service use in the past week or not. I used Pearson's χ^2 to compare differences in sociodemographic characteristics of online food delivery service customers in each country. I used logistic regression following a sequential modelling strategy to investigate associations between my primary outcome and each of: sex, age, ethnicity, education, BMI, and living with

children aged under 18 years (across all countries combined). Model 0 was unadjusted, Model 1 was adjusted for all independent variables except education to investigate variation by individual-level socioeconomic position, and finally, Model 2 was as Model 1 but with education included (193, 194).

I used separate logistic regression models, adjusted according to Model 2, with each country as the reference category, to investigate differences in the prevalence of online food delivery service use between countries.

I investigated differences in the prevalence of online food delivery service use and independent variables between countries by adding a two-way interaction term (country x independent variable) to separate logistic regression models (adjusted according to Model 2). I used post-estimation Wald tests to determine interaction term significance. When interaction terms were significant, I stratified analyses by country. I used Stata version 15.1 (StataCorp LLC., College Station, TX, USA) to complete analyses with a significance threshold of $p<0.05$ used throughout.

2.5 Results

Amongst the analytic sample, 78% (n=15,093) had purchased at least one meal prepared out-of-home in the past week; 63% (n=12,163) had purchased food prepared out-of-home directly from food outlets for delivery or in-person but had not used an online food delivery service, whereas 15% (n=2929) had used an online food delivery service at least once. The greatest prevalence of online food delivery service use was amongst respondents in Mexico (n=895; 26%) (see Table 2.1).

2.5.1 Sociodemographic characteristics

Table S1 (see Appendix A) shows the sociodemographic characteristics of the analytic sample. Overall, more than half of the analytic sample were female or identified with an ethnic majority, the median age was 47 years, over 40% had a low level of education, over 20% were living with obesity, and less than 30% lived with children aged under 18 years. Table S2 (see Appendix A) shows the sociodemographic characteristics of non-online food delivery service customers. These respondents were similar in terms of sociodemographic characteristics to the analytic sample.

Table 2.1 shows the sociodemographic characteristics of online food delivery service customers. Overall, more than half of online food delivery service customers were male, identified with an ethnic majority, were highly educated, or living with children aged under 18 years. Around 40%

were living with overweight or obesity, and the median age was 33 years (interquartile range (IQR): 26, 41).

2.5.2 Meals purchased out-of-home

Of the respondents that reported any online food delivery service use, around half had used this purchasing format to purchase one meal, meaning that they had purchased food prepared out-of-home in this way only once in the past week (see Appendix A: Figure S1).

Table 2.2 reports the purchase of meals prepared out-of-home through each purchasing format for online food delivery service customers and non-online food delivery service customers, respectively. Overall, online food delivery service customers ordered a median of 2.0 (IQR: 1.0, 3.0) meals through an online food delivery service, which represented 36% of all meals prepared out-of-home. Online food delivery service customers ordered a median of 1.0 (IQR: 0.0, 2.0) meal directly from food outlets for delivery and 2.0 (IQR: 0.0, 3.0) meals directly from food outlets in-person. Overall, the median number of meals that non-online food delivery service customers ordered directly from food outlets for delivery and from food outlets in-person was 2.0.

Table 2.1: Sociodemographic characteristics of online food delivery service customers amongst the analytic sample (n=19,378) from the 2018 International Food Policy Study.

	Australia (n=3578)	Canada (n=3698)	Mexico (n=3515)	UK (n=4694)	USA (n=3893)	Total (n=19378)	p value for difference [a]
Online food delivery service customers [b c]	498 (13.9)	327 (8.8)	895 (25.5)	747 (15.9)	461 (11.8)	2929 (15.1)	p>0.0001
Variable							
Sex							p>0.0001
Male	305 (61.1)	196 (60.0)	433 (48.3)	422 (56.4)	273 (59.2)	1629 (55.6)	
Ethnicity							p>0.0001
Majority	310 (32.1)	201 (61.3)	662 (73.9)	570 (76.3)	259 (56.1)	2001 (68.3)	
Age (years)							
Median (IQR)	31 (25-40)	33 (26-41)	34 (27-42)	32 (25-41)	33 (26-38)	33 (26-41)	
Education							p>0.0001
Low	136 (27.4)	95 (28.9)	119 (13.3)	320 (42.8)	177 (38.3)	846 (28.9)	
Medium	133 (26.6)	110 (33.7)	90 (10.1)	171 (22.9)	35 (7.6)	538 (18.4)	
High	229 (46.0)	122 (37.4)	686 (76.6)	257 (34.4)	250 (54.4)	1545 (52.7)	
BMI (kg/m^2)							p>0.0001
Not overweight (≤24.9)	255 (51.2)	164 (50.2)	420 (46.9)	321 (42.9)	206 (44.6)	1366 (46.6)	
Overweight (25.0-29.9)	118 (23.7)	77 (23.4)	265 (29.6)	150 (20.1)	135 (29.2)	744 (25.4)	
Obesity (≥30.0)	52 (10.3)	60 (18.2)	145 (16.1)	106 (14.2)	77 (16.7)	439 (15.0)	
Missing	73 (14.7)	27 (8.2)	66 (7.4)	170 (22.8)	44 (9.5)	380 (13.0)	
Child <18 years in home							p>0.0001
Yes	226 (45.4)	131 (40.0)	639 (71.4)	364 (48.7)	240 (51.9)	1600 (54.6)	

Notes: [a] p values from Pearson's $\chi 2$ test represents difference between categories within variable.

[b] Online food delivery service customers had purchased at least one meal prepared out-of-home through an online food delivery service in the past week.

[c] Unless specified, data reported as n (%).

Table 2.2: Purchasing formats used to acquire meals prepared out-of-home in the past week amongst the analytic sample (n=19,378) from the 2018 International Food Policy Study.

Purchasing format	Australia (n=3578)	Canada (n=3698)	Mexico (n=3515)	UK (n=4694)	USA (n=3893)	Total (n=19378)	p value for difference [a]
Online food delivery service customers [b]							
Number (%)	498 (13.9)	327 (8.8)	895 (25.5)	747 (15.9)	461 (11.8)	2929 (15.1)	
Online food delivery services [c]							p>0.0001
Number of meals	2.0 (1.0-2.0)	1.0 (1.0-2.0)	2.0 (1.0-3.0)	1.0 (1.0-2.0)	2.0 (1.0-3.0)	2.0 (1.0-3.0)	
Proportion (%)	40.0 (50.0-57.1)	40.0 (25.0-66.7)	33.3 (23.1-50.0)	50.0 (33.3-100.0)	33.3 (25.0-50.0)	35.7 (25.0-50.0)	
Directly from food outlets for delivery [c]							p>0.0001
Number of meals	0.0 (0.0-1.0)	0.0 (0.0-1.0)	1.0 (0.0-2.0)	0.0 (0.0-1.0)	1.0 (0.0-2.0)	1.0 (0.0-2.0)	
Proportion (%)	0.0 (0.0-28.6)	0.0 (0.0-28.6)	25.0 (0.0-40.0)	0.0 (0.0-25.0)	20.0 (0.0-33.3)	16.7 (0.0-33.3)	
Directly from food outlets in-person [c]							p>0.0001
Number of meals	2.0 (0.0-3.0)	1.0 (0.0-3.0)	2.0 (1.0-4.0)	1.0 (0.0-2.0)	2.0 (1.0-4.0)	2.0 (0.0-3.0)	
Proportion (%)	40.0 (0.0-60.0)	40.0 (0.0-54.5)	40.0 (20.0-52.4)	33.3 (0.0-50.0)	40.0 (20.0-57.1)	40.0 (0.0-50.0)	
Non-online food delivery service customers [d]							
Number (%)	2188 (61.2)	2420 (65.4)	2396 (68.2)	2439 (52.0)	2721 (69.9)	12163 (62.8)	
Directly from food outlets for delivery [c]							p>0.0001
Number of meals	1.0 (1.0-2.0)	1.0 (1.0-2.0)	2.0 (1.0-4.0)	1.0 (1.0-2.0)	2.0 (1.0-3.0)	2.0 (1.0-3.0)	
Proportion (%)	66.7 (50.0-100.0)	100.0 (40.0-100.0)	75.0 (50.0-100.0)	100.0 (50.0-100.0)	100.0 (40.0-100.0)	83.3 (50.0-100.0)	
Directly from food outlets in-person [c]							p>0.0001
Number of meals	2.0 (1.0-3.0)	2.0 (1.0-3.0)	3.0 (2.0-4.0)	2.0 (1.0-3.0)	2.0 (1.0-4.0)	2.0 (1.0-3.0)	
Proportion (%)	100.0 (100.0-100.0)	100.0 (100.0-100.0)	100.0 (66.7-100.0)	100.0 (100.0-100.0)	100.0 (100.0-100.0)	100.0 (100.0-100.0)	

Notes: [a] p value from Pearson's $\chi 2$ test represents difference between categories within variable.

[b] Online food delivery service customers had purchased at least one meal prepared out-of-home through an online food delivery service in the past week.

[c] Data reported as median (IQR) number of meals, and median (IQR) proportion of all meals purchased out-of-home, per person.

[d] Non-online food delivery service customers had purchased at least one meal prepared out-of-home directly from food outlets but not through an online food delivery service, in the past week.

2.5.3 Sociodemographic correlates of online food delivery service use

Table S3 (see Appendix A) reports sociodemographic correlates of online food delivery service use from unadjusted (Model 0) and partially adjusted (Model 1) analyses.

Figure 2.1 reports findings from maximally adjusted analyses (Model 2). Overall, there were greater odds of any online food delivery service use in the past week amongst respondents who were male rather than female (odds ratio (OR): 1.50; 95% confidence intervals (CI): 1.35, 1.66), those that identified with an ethnic minority rather than an ethnic majority (OR: 1.57; 95% CI: 1.38, 1.78), who lived with children (OR: 2.71; 95% CI: 2.44, 3.01) or had a high rather than low level of education (OR: 1.66; 95% CI: 1.46, 1.90). Odds of online food delivery service use were lower per additional year of age (OR: 0.95; 95% CI: 0.94, 0.95). There were no differences by BMI category.

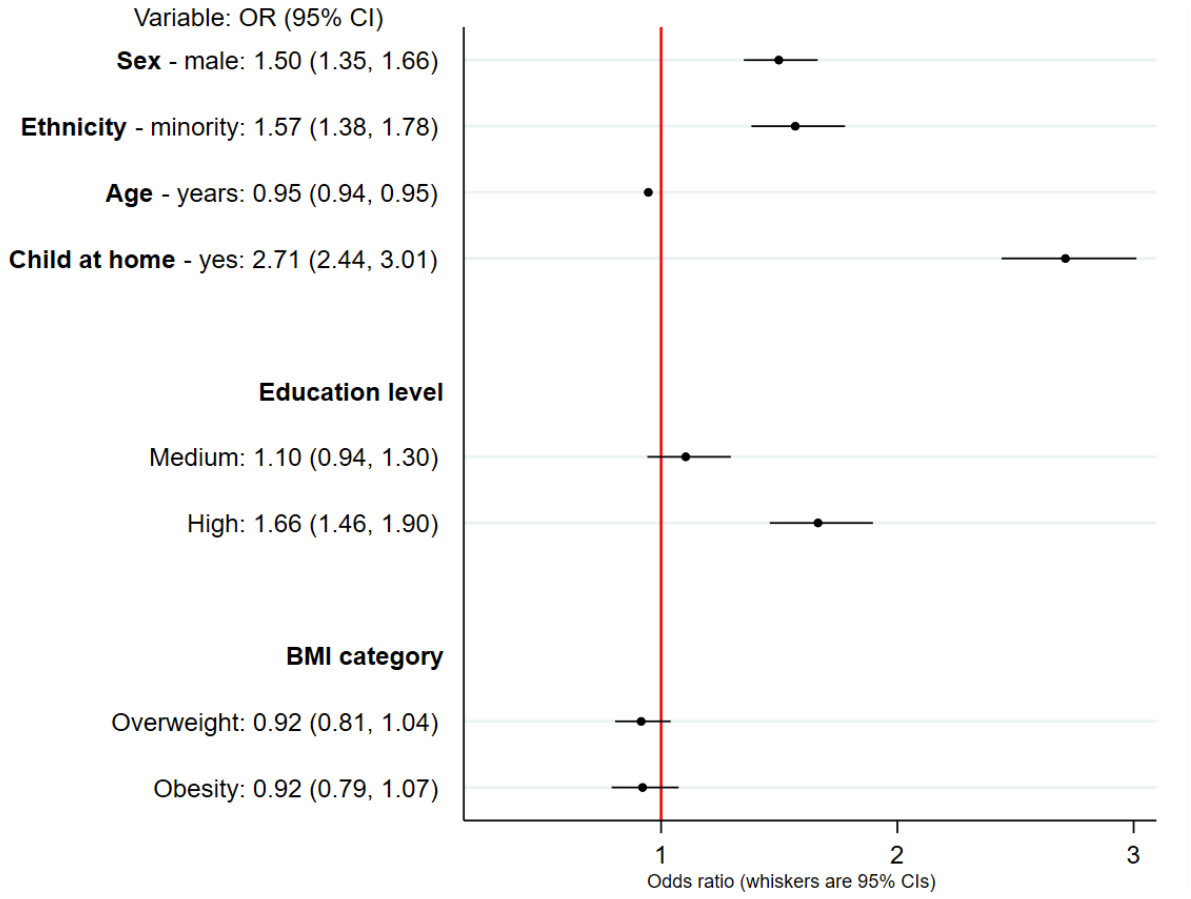

Figure 2.1: Associations between prevalence of any online food delivery service use in the past week and sociodemographic characteristics, amongst the analytic sample (n=19,378) from the 2018 International Food Policy Study.

Note: Data analysed using logistic regression adjusted for independent variables (sex, ethnicity, age, living with children aged under 18 years at home, education, and body mass index (BMI)). Reference groups: ethnicity = majority, education level = low, BMI category = not overweight.

2.5.4 Between country variation

Table 2.3 reports between country variation in the prevalence of online food delivery service use. Respondents in Canada had lower odds of any online food delivery service use in the past week compared with respondents in all other countries. Respondents in the UK and Mexico typically had greater odds compared with respondents in other countries.

Amongst online food delivery service customers in Australia, Mexico and the USA, the median number of meals ordered through online food delivery services per person was 2.0, and in Canada and the UK, the median number per person was 1.0 (with minimal variation in respective IQR values) (see Table 2.2).

Table S4 (see Appendix A) shows that there were significant between-country interactions. The association between online food delivery service use and each of: age ($p<0.0001$), living with children aged under 18 years ($p=0.037$), sex ($p<0.0001$) and education ($p<0.0001$) varied between countries. Figures 2.2 to 2.5 show country-stratified findings for each of: age, living with children aged under 18 years, sex and education. Odds of online food delivery service use were lower per additional year of age (and relatively consistent) amongst respondents in all countries. Respondents who lived with children aged under 18 years had greater odds of online food delivery service use in all countries, with the strongest association observed amongst respondents in the USA (OR: 3.22; 95% CI: 2.49, 4.20). There was no difference in odds of online food delivery service use by sex amongst respondents in Mexico (OR: 1.02; 95% CI: 0.85, 1.23), whereas males in all other countries had greater odds. Respondents with high (versus low) education had greater odds of online food delivery service use in all countries except the UK (OR: 0.87; 95% CI: 0.67, 1.13).

Table 2.3: Associations between country and prevalence of any online food delivery service use in the past week amongst the analytic sample (n=19,378) from the 2018 International Food Policy Study.

Country [a]	OR [b]	95% CI [c]	
Australia (ref)	-	-	-
Canada	0.65	0.54	0.78
Mexico	1.21	1.03	1.43
UK	1.39	1.18	1.64
USA	0.85	0.72	1.02
Australia	1.55	1.29	1.87
Canada (ref)	-	-	
Mexico	1.88	1.58	2.25
UK	2.15	1.79	2.57
USA	1.32	1.10	1.59
Australia	0.82	0.69	0.97
Canada	0.53	0.45	0.63
Mexico (ref)	-	-	-
UK	1.14	0.98	1.33
USA	0.70	0.60	0.82
Australia	0.72	0.61	0.85
Canada	0.47	0.39	0.56
Mexico	0.88	0.75	1.02
UK (ref)	-	-	-
USA	0.61	0.52	0.73
Australia	1.17	0.98	1.40
Canada	0.76	0.63	0.91
Mexico	1.43	1.22	1.67
UK	1.63	1.37	1.93
USA (ref)	-	-	-

Notes: [a] Each country used as reference (ref) in separate adjusted logistic regression models.
[b] Odds ratio.
[c] 95% confidence intervals.

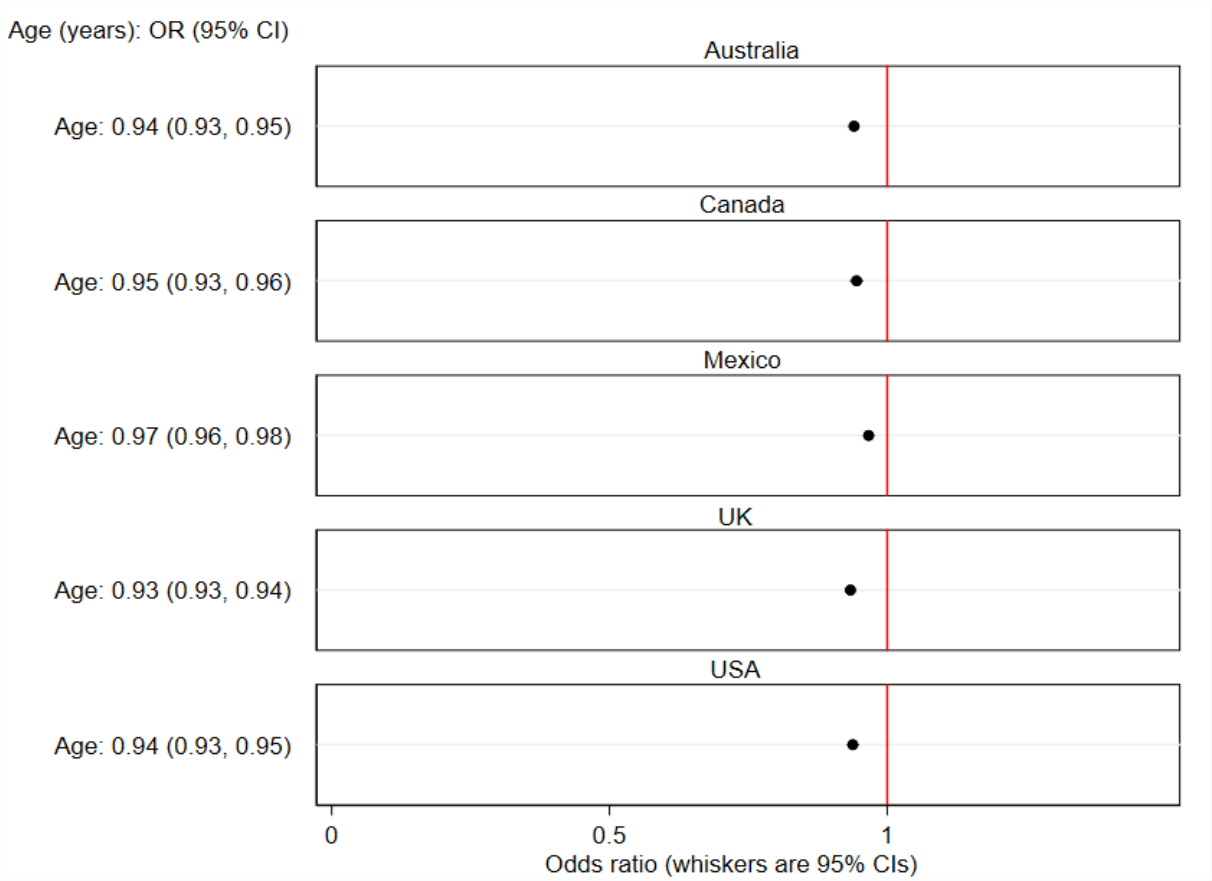

Figure 2.2: Associations between prevalence of any online food delivery service use in the past week and age, amongst the analytic sample (n=19,378) from the 2018 International Food Policy Study.
Note: Data analysed using country-stratified logistic regression adjusted for independent variables (sex, ethnicity, living with children aged under 18 years at home, education, and body mass index (BMI)).

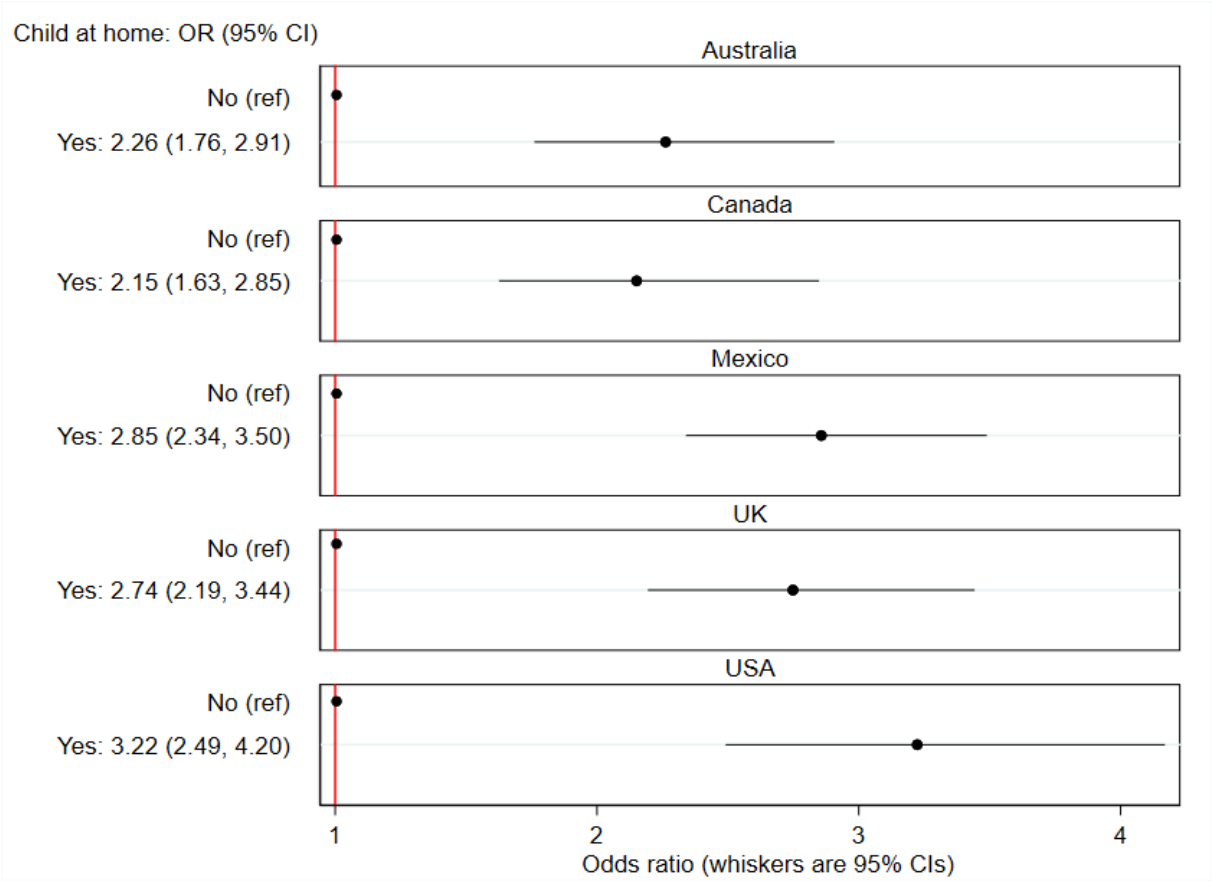

Figure 2.3: Associations between prevalence of any online food delivery service use in the past week and living with children aged under 18 years, amongst the analytic sample (n=19,378) from the 2018 International Food Policy Study.

Note: Data analysed using country-stratified logistic regression adjusted for independent variables (sex, ethnicity, education, and body mass index (BMI)).

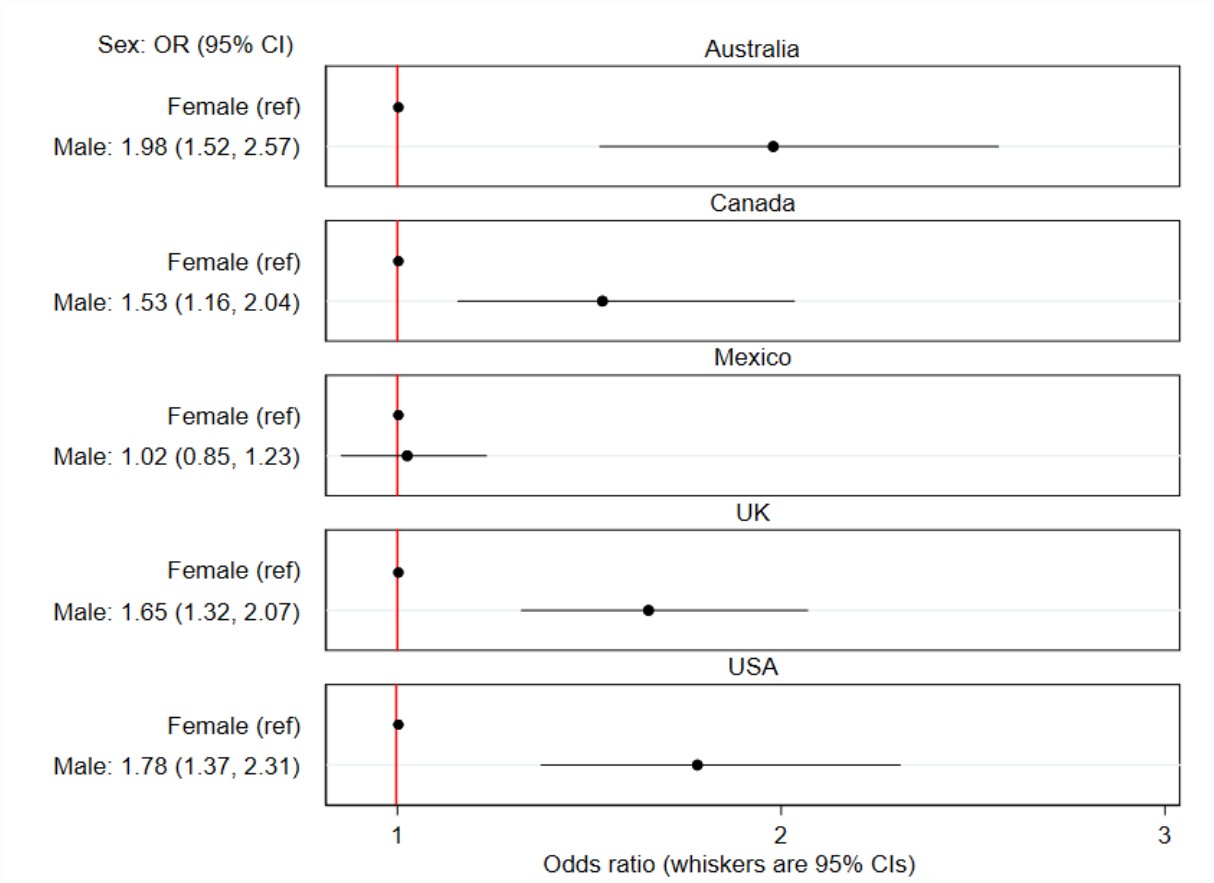

Figure 2.4: Associations between prevalence of any online food delivery service use in the past week and sex, amongst the analytic sample (n=19,378) from the 2018 International Food Policy Study.
Note: Data analysed using country-stratified logistic regression adjusted for independent variables (ethnicity, living with children aged under 18 years at home, education, and body mass index (BMI)).

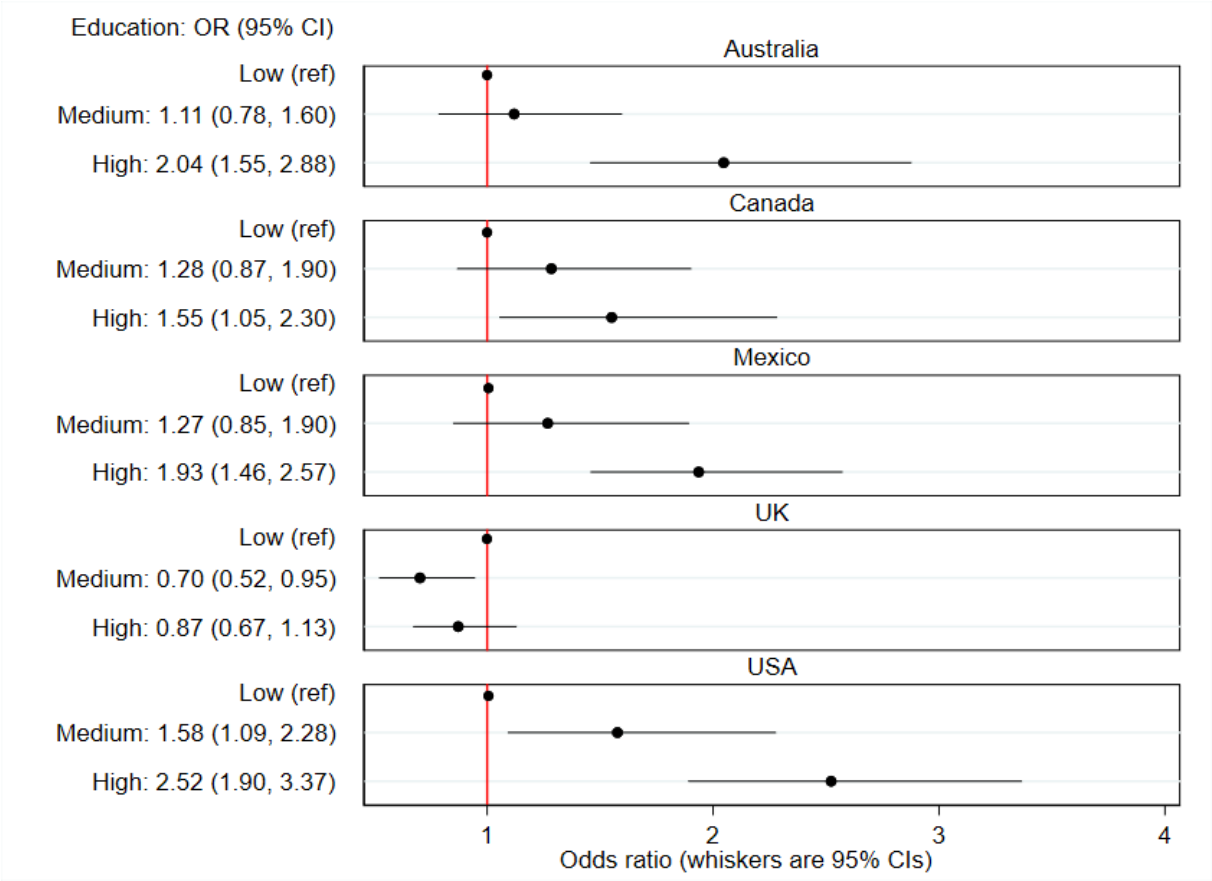

Figure 2.5: Associations between prevalence of any online food delivery service use in the past week and education level, amongst the analytic sample (n=19,378) from the 2018 International Food Policy Study.
Note: Data analysed using country-stratified logistic regression adjusted for independent variables (sex, ethnicity, living with children aged under 18 years at home, and body mass index (BMI)).

2.6 Discussion

2.6.1 Summary of findings

My study included almost 20,000 adults living across Australia, Canada, Mexico, the UK, and the USA. Overall, more than 60% had purchased food prepared out-of-home directly from food outlets in the past week but had not used an online food delivery service, however, 15% reported that they had used an online food delivery service in the past week. Online food delivery services were mostly used once in the past week, however, on occasion they were used more frequently. Overall, the median number of meals purchased through online food delivery services was 2, and the median proportion of all meals purchased out-of-home ordered in this manner exceeded 30%. Adults who were male, younger, with higher rather than lower levels of education, those who lived with children, or identified with an ethnic minority had greater odds

of online food delivery service use. Sociodemographic correlates of online food delivery service use were similar in each country but the strength of associations varied.

2.6.2 Interpretation of findings

As the first study to investigate the prevalence and frequency of online food delivery service use in and across studied countries, I am unable to conclude that identified levels are relatively high or low. As such, my findings provide novel insight into the use of these services. My findings also provide insight into how multiple purchasing formats coexist. Importantly, purchasing food prepared out-of-home in multiple ways may lead to greater total consumption of food sold. In turn, this might lead to increased risk of excess weight and adverse health outcomes. When having food delivered, IFPS respondents who reported any online food delivery service use in the past week appeared to favour this purchasing format. In contrast, non-online food delivery service customers continued to order directly from food outlets. This observation could support the suggestion that online food delivery services have the capacity to displace conventional purchasing formats within out-of-home food retail (155). Nevertheless, some online food delivery service customers reported that they also visited food outlets in-person, indicating that individuals continued to interact with the physical food environment regardless of online food delivery service use.

In my research, males had greater odds of online food delivery service use compared with females. Consistent with my finding, males reportedly purchase more food prepared out-of-home more and cook at home less frequently than females (111, 112). It is unclear how reasons for purchasing food prepared out-of-home might differ based on the purchasing format used, and how these reasons vary by sex. Given that broader social, cultural and environmental factors can influence both food purchasing practices and the gender to which an individual identifies (195), factors other than biology likely contribute. Qualitative research could help better understand reasons for online food delivery service use and factors that influence this purchasing practice.

Additionally, adults that identified with an ethnic minority had greater odds of online food delivery service use. Analyses of data from the National Health and Nutrition Examination Survey in the USA reported that respondents who identified with being Black consumed more fast food than respondents that identified with other ethnic groups (196). However, further research from the USA (197), and from the UK (198), concluded that individuals who identified with an ethnic minority group allocated more time to home food preparation and consumed more home cooked food than individuals that identified with an ethnic majority group. There are differences

in racial and ethnic factors across countries (136), including unique cultures, traditions, beliefs, history and experiences (199). Accordingly, the meaning of identifying with a certain ethnic or racial group is unlikely to be similar for populations living in the studied countries. Since this meaning and possible differences therein would not have been captured in the current study due to category aggregation, future research could seek to better understand how identifying with a certain racial or ethnic group is associated with online food delivery service use on a more granular level.

Online food delivery service use could reduce the prevalence and frequency of home cooking, which in turn, might have implications for overall dietary patterns. Although it is possible to meet dietary guidelines by consuming food prepared out-of-home, it is difficult and more expensive compared with consuming food prepared at home (198, 200), and bound by the types of food outlet that can be accessed (201). The latter makes food outlet access in both the physical and digital food environments particularly important to consider in future research.

In my research, online food delivery service customers were younger, had higher rather than lower levels of education, and often lived with children. For age, one explanation is that older individuals are not inclined to order food online due to technology unfamiliarity and a loyalty towards conventional purchasing formats (202). In contrast, younger individuals have plausibly never experienced purchasing food prepared out-of-home in ways that are not internet-based (i.e. `conventional` purchasing formats). Moreover, both parents and those who are more highly educated often report having limited time, and may purchase food prepared out-of-home to offset pressure from limited time resources (84, 203, 204).

Online food delivery service use did not vary by respondent weight status. This may be due to the use of cross-sectional data and simultaneous exposure and outcome measurement. Further research is necessary to develop a better understanding about plausible associations between online food delivery service use and body weight. Analysis of the National Diet and Nutrition Survey in the UK identified that greater consumption of food from fast-food outlets but not restaurants or cafés was associated with living with obesity (205). However, in my study, it was not possible to disaggregate online food delivery service use by food outlet type during analyses. Moreover, it is necessary to consider the direction of association between online food delivery service use and body weight.

The prevalence of online food delivery service use and the number of meals purchased directly from food outlets in-person by non-online food delivery service customers, were both greatest amongst respondents in Mexico. Together, these findings may reflect cultural norms in Mexico

aligned with the frequent purchase of food prepared out-of-home (206). However, online food delivery service use was apparent across all studied countries supporting that these services are internationally established (144). Individuals with greater access to food outlets through online food delivery services could be inclined to use them more frequently. Indeed, my finding that respondents from Canada had lower odds of online food delivery service use compared with respondents in other countries could indicate that there is currently limited access to food outlets through this purchasing format. This conclusion would help to explain plans from Just Eat, branded as SkipTheDishes, to increase the number of food outlets in Canada registered to accept orders through their platform (181).

Sociodemographic characteristics of online food delivery service customers were similar between countries, however, the strength of associations varied. Notably, a higher (versus lower) level of education was associated with greater odds of online food delivery service use in all countries except the UK. The type of food available through online food delivery services in the UK is currently unclear. Elsewhere, amongst food outlets registered to accept orders through an online food delivery service in Australia, the Netherlands and the USA, common food labels used to describe the type of food sold included `Burgers`, `Pizza` and `Italian`, with `Healthy` food labels less commonly used (156). Although labels appointed by food outlets may not always reflect the food they sell, given the apparent lack of `healthy` options, it is plausible that online food delivery services in the UK do not sell food that accommodates the needs of individuals with higher education, plausibly limiting their use. Further work to validate self-appointed labels against the types of food sold, and the nutritional quality of this food, is warranted.

2.6.3 Strengths and limitations

My research represents the most comprehensive description of online food delivery service use to date. Nonetheless, my findings are subject to limitations, including those common to survey-based research. Respondents in the IFPS were recruited using nonprobability-based sampling, which means that my findings are not necessarily nationally representative. I applied post-stratification sample weights to improve representativeness, however, respondents in Mexico had higher levels of education than census estimates, and average BMI scores were lower than national averages for respondents in all countries (184). Recruitment may have also been biased towards individuals with internet access. However, internet penetration rates across studied countries in 2016 were between 67% (Mexico) and 93% (Australia), with rates of 88% or higher in Canada, the UK and the USA (207).

My analyses were based on cross-sectional data, limiting the ability to draw strong causal inferences. Additionally, data were self-reported. Social desirability bias may have led to the number of meals purchased out-of-home, online food delivery service use, and body weight being under-reported. The risk of this may have been reduced by online data collection, which offers respondents a sense of anonymity when reporting sensitive information (208, 209). Finally, I used education as a marker of socioeconomic position, which may not have been comparable across studied countries (102, 103, 111).

2.7 Conclusions

I found that 15% of a large sample of adults living across Australia, Canada, Mexico, the UK, and the USA had purchased food prepared out-of-home through online food delivery services in the past week. Online food delivery service use was associated with being male, identifying with an ethnic minority, being younger, or having a high level of education, with the strongest associations observed for those living with children. Although sociodemographic characteristics of online food delivery service customers were consistent across countries, there was variation in the strength of associations. Norms surrounding the purchase of food prepared out-of-home, stressors on time that plausibly limit the opportunity for cooking at home, and the number and type of food outlets that can be accessed through online food delivery services may vary internationally and could help to explain observed differences between countries. Further research is needed to understand the extent to which online food delivery service use supplements or substitutes other purchasing formats, the reasons for using these services when alternative options are seemingly available, and implications for diet and diet-related health.

Chapter 3:
Experiences and perspectives of frequent online food delivery service customers in the United Kingdom

3.1 Details of author contributions, publication and dissemination

For the research in this chapter, I conceptualised the research questions and study design along with JA and TB. I was responsible for participant recruitment and data collection and led data analysis. I led data interpretation with support from JA and TB. All authors read and provided critical comments on the initial manuscript and agreed to the final version.

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I shared the findings from the research in this chapter during an oral presentation at the 2021 UK Society for Behavioural Medicine Annual Scientific Meeting (held online), and a poster presentation at the 2022 Society for Social Medicine Annual Scientific Meeting (held in-person, Exeter, United Kingdom). For the latter, the meeting abstract is published as: Keeble, M., Burgoine, T., Adams, J. (2022). P14 Investigating frequent online food delivery service use: a qualitative study in UK adults. Journal of Epidemiology Community Health. 76, A54-A55. https://dx.doi.org/10.1136/jech-2022-SSMabstracts.113.

3.2 Abstract

Background

Food prepared out-of-home is typically energy-dense and nutrient-poor. This food can be purchased from multiple retailers, including restaurants and takeaway food outlets. Using online food delivery services to purchase food prepared out-of-home is increasing in popularity. This may lead to more frequent consumption, which is positively associated with poor diet and living with obesity. Understanding possible reasons for using online food delivery services might contribute to the development of future public health interventions, if deemed necessary. This knowledge would be best obtained by engaging with individuals who use online food delivery services as part of established routines. Therefore, I aimed to investigate customer experiences of using online food delivery services to understand their reasons for purchasing food prepared out-of-home in this way, including any advantages and drawbacks.

Methods and results

In 2020, I conducted telephone interviews with 22 adults living in the United Kingdom (UK) who had used online food delivery services on at least a monthly basis over the previous year. Through codebook thematic analysis, I generated five themes: `The importance of takeaway food`, `Less effort for more convenience`, `Saving money and reallocating time`, `Online food delivery service normalisation` and `Maintained home food practices`. Two concepts were overarching throughout: `Place. Time. Situation.` and `Perceived advantages outweigh recognised drawbacks`. After considering the context of their location and the time of day, participants reported that they typically selected online food delivery services to purchase food prepared out-of-home instead of other purchasing formats. Participants reported that they did not use online food delivery services to purchase healthy food. Participants considered online food delivery service use to be a normal practice that involves little effort due to optimised purchasing processes. As a result, these services were seen to offer convenient access to food aligned with sociocultural expectations. Participants reported that this convenience was often an advantage but could be a drawback. Although participants were price-sensitive, they were willing to pay delivery fees for the opportunity to complete other tasks whilst waiting for meal delivery. Furthermore, participants valued price-promotions and concluded that receiving them justified their online food delivery service use. Despite online food delivery service use, participants considered home cooking to be irreplaceable.

Conclusions

Future public health interventions might seek to increase the healthiness of food available online whilst maintaining sociocultural expectations. Extending restrictions adopted in other retail settings to online food delivery services could also be explored.

3.3 Introduction

Purchasing food that is prepared out-of-home and served ready-to-consume (often referred to as `takeaway food`) is prevalent across the world (29). The physical food environment includes food outlets where individuals can purchase and consume takeaway food, with an increased number of outlets selling this food plausibly contributing to a normalisation of its consumption (210). Purchasing formats represent ways to buy takeaway food. Although the opportunity to purchase this food was once limited to `conventional` purchasing formats like visiting food outlets in-person or placing orders directly with food outlets by telephone, additional options such as online food delivery services now exist (145). Online food delivery services are an aspect of food retail within the digital food environment. On a single online platform, customers receive aggregated information about food outlets they can order from based on their location. Customers then select a food outlet, and place and pay for their order. These orders are forwarded to food outlets with a customer-facing premises in the physical food environment where meals are prepared before being delivered (147). Widespread internet and smartphone access is reported to have increased online food delivery service use, with market revenue in the United Kingdom (UK) estimated at around £11.5 billion in 2021 (211).

Food prepared out-of-home is typically nutrient-poor and served in portion sizes that exceed public health recommendations for energy content (41, 175). More frequent consumption of this food has been associated with poor diet and elevated body weight over time (110). Although it is currently unclear, using online food delivery services might lead to more frequent and greater overall consumption of food prepared out-of-home. In turn, this could lead to increased risk of elevated body weight. Since an estimated 67% of males and 60% of females in the UK were considered overweight or obese in 2019 (13), the possibility that using online food delivery services increases overall consumption of food prepared out-of-home is a public health concern that has been recognised by the European region of the World Health Organization (145, 212).

With respect to the physical food environment, food outlet accessibility (number and proximity (i.e. distance to nearest)) and availability (presence of variety), as well as attitudinal dimensions (acceptability, accommodation and affordability) contribute to food purchasing practices (77). Each of these domains plausibly influences food access through online food delivery services. In 2019, the number of food outlets accessible through the leading online food delivery service (Just Eat) was 50% greater in the most deprived areas of England compared with the least deprived areas (213) (see Chapter 5). Furthermore, adults living in the UK with the highest number of food outlets accessible online had greater odds of online food delivery service use in the past week compared with those who had the lowest number (214) (see Chapter 4). However,

attitudinal dimensions of online food delivery service use are poorly understood. Given the complexity of food purchasing practices, there are likely to be unique and specific reasons for using online food delivery services. Understanding these reasons from the perspective of customers could contribute to more informed public health policies, which is important since public health interventions that include online food delivery services may be necessary as their use becomes increasingly popular (141, 212).

3.3.1 Study aims

In my study, I investigated experiences of using online food delivery services from the perspective of adults living in the UK who use them frequently. I aimed to understand their reasons for using these services, the possible advantages and drawbacks of doing so, and how it coexists with other food-related practices.

3.4 Methods

Between June and August 2020, I used semi-structured telephone interviews to study experiences of using online food delivery services from the perspective of adults living in the UK. I used the Consolidated Criteria for Reporting Qualitative Research (COREQ) checklist to guide study development and reporting (215). The University of Cambridge Humanities and Social Science Research Ethics Committee provided ethical approval (Reference: 19/220).

3.4.1 Methodological orientation

I used a qualitative description methodological orientation to investigate my study aims. Qualitative description has been framed as less interpretative than other orientations as it is often used to explore a phenomenon in its natural state whilst relying on the spoken word of participants during data interpretation (216). Nevertheless, in line with my study aims, qualitative description is theoretically and epistemologically flexible and can facilitate a rich description of perspectives (217).

3.4.2 Participants and recruitment

I used convenience sampling to recruit adults that used online food delivery services frequently. For the purpose of my study, I defined frequent customers as those who had used online food delivery services on at least a monthly basis over the previous year. I believed this level of use would make participants positioned to provide their experiences of using this purchasing format within established purchasing practices, rather than less frequent or only recent use. Guided by the findings from Chapter 2 (218), and from others elsewhere (219), I specifically wanted to

recruit younger rather than older adults. I did not initially specify further individual-level sociodemographic characteristics as inclusion criteria. However, as data collection progressed, I introduced criteria so that participants were not only highly educated (see Figure 3.1).

Able to communicate in English
Aged between 18 and 50 years
Living in the UK
Non-university educated *

Figure 3.1: Inclusion criteria used during frequent online food delivery service customer recruitment between June and August 2020.
Note: * introduced after 12 participants had been recruited so that the study sample included participants with different levels of education.

I used two social media platforms (Twitter and Reddit) to recruit participants. Participant recruitment through social media platforms can be fast and efficient (220-222). If targeted advertising is not used (as in my study), participant recruitment in this way is also free. This approach was appropriate because my aims were related to understanding experiences of online food delivery service use, which requires internet access. For Twitter, users can publish and re-publish information, images, videos, and links to external sites. During recruitment through this platform, I published study information using my personal account and relied on existing connections to re-publish it. For Reddit, users can publish information, images and videos, and discuss topics within focused forums known as `Subreddits`. For recruitment through this platform, I created an alias account (I did not have a personal account at the time of my fieldwork) and published study information in Subreddits for cities in the UK with large populations according to the 2011 UK census, those related to online food delivery services, and those that discuss topics relevant to the UK (223). Box S1 (see Appendix B) reports a complete list of Subreddits.

Published study information asked interested individuals to contact me by email. When contacted, I responded by email with screening questions that asked individuals to self-report their frequency of online food delivery service use over the past year, and their age and level of education (only after 12 participants had been recruited). When eligibility was confirmed, I provided further information about the study by email. This information included the study aims, details about researchers involved, the offer of a £20.00 electronic high street shopping

voucher, and a formal invitation to participate. After five business days with no response to my invitation, I sent a further email. After another five business days, I classified individuals that did not respond as `non-respondents`.

3.4.3 Data collection

3.4.3.1 Before data collection

Before starting data collection, I planned to complete a maximum of 25 interviews. I considered this number realistic within the constraints of conducting research as part of my PhD studentship. I did not target data saturation, partly to reflect that I pre-specified the maximum number of telephone interviews that I would complete. Additionally, food practices, including purchasing and consuming food prepared out-of-home, are highly individual and informed by previous experiences, cultural backgrounds, and preferences (224). As such, I also felt that it would be difficult to conclude that data saturation had been achieved (225, 226). Instead, I prioritised conceptual depth and information strength. This approach was aligned with the qualitative description methodological orientation of my study (see Section 3.4.1) (226).

I wanted to investigate experiences of online food delivery service use from before the Coronavirus Disease 2019 (COVID-19) pandemic, which was a time when there were no restrictions on access to multiple purchasing formats and the opportunity for on-premises food consumption. Therefore, I pre-specified that I would stop data collection if it became difficult for participants to refer to the time before March 2020, which is when COVID-19 pandemic related travel and food outlet access restrictions were first introduced in the UK. I piloted an initial protocol with an eligible individual to confirm this would be possible and then made amendments based on their feedback.

Before starting data collection, I reflected on my position as a public health researcher and my previous training and experience in qualitative research (227). I also reflected on my own consumption of food prepared out-of-home and previous online food delivery service use. As of the start of my fieldwork in June 2020, I consumed this food infrequently and had previously placed one order with an online food delivery service. Although I was not a frequent customer according to my classification, I was familiar with online food delivery services operating in the UK. I concluded that despite understanding why online food delivery services might be used, I could not use my own experiences to provide detailed reasons for favouring this purchasing format over alternative options.

3.4.3.2 Throughout data collection

I completed one-off semi-structured telephone interviews with participants at a convenient time selected by them. At the start of the interview process, I confirmed the rationale for my study, gave participants the opportunity to ask clarifying questions, and asked them to provide verbal consent. I used a topic guide that was developed based on *a priori* knowledge, pilot interview feedback and previous research related to food prepared out-of-home and online food delivery services (36, 50, 218). I amended the topic guide as data collection progressed so that points I had not initially considered could be discussed in future interviews. Interview questions focused on reasons for using online food delivery services, the perceived advantages and drawbacks of using these services, and how their use coexisted with the use of alternative purchasing formats and other food-related practices. Box S2 (see Appendix B) shows the final topic guide.

Although I completed interviews in the context of the COVID-19 pandemic, I did not ask questions related to this. I also asked participants to think about the time before March 2020 so that we could discuss their experiences from before the COVID-19 pandemic. I digitally recorded interview audio and made field notes to track points for discussion within each respective interview.

3.4.3.3 After data collection

Immediately after each interview, I reflected on topics discussed with participants, data collection progress, possible links with existing theory and the ability of participants to think about the time before the COVID-19 pandemic. I used my post-interview reflections to help decide when to stop data collection.

3.4.4 Data analysis

A professional company transcribed interview audio verbatim. Whilst listening to the corresponding audio, I quality assured and anonymised each transcript. Participants did not review their transcripts.

I used codebook thematic analysis. When using this analytic approach, researchers develop a codebook based on the final topic guide used during data collection and data familiarity, which is achieved by reviewing collected data (228, 229). Codebook thematic analysis is aligned with qualitative description methodological orientations as it allows researchers to remain close to the data and facilitates an understanding of a topic through the spoken word of participants (230). In practice, I developed an initial codebook. I then reviewed three transcripts (a 10% sample) alongside co-authors. This number was manageable and allowed us to discuss a sample

of collected data (231). After discussion with co-authors, I refined the initial codebook to collapse codes that overlapped and to add new codes. In doing so, I formed the final codebook. I coded each transcript with the final codebook and reviewed reflections written after each interview. I then studied the coded data to generate themes that were discussed and finalised with co-authors. In the context of my study, themes summarise experiences of using online food delivery services from the perspective of participants. I also identified that across the generated themes, there were overarching concepts. Concepts should be seen to offer an overall and consistent structure that capture the common and overlapping elements of each of the generated themes (232).

I used NVivo (version 12) to manage the data and facilitate interpretation.

3.5 Results

3.5.1 Participant and data overview

I conducted telephone interviews with 22 frequent online food delivery service customers between June and August 2020. Interviews lasted between 35 and 61 minutes. Table 3.1 reports the sociodemographic characteristics of participants and their online food delivery service use. There were 12 males, 13 participants were aged between 20 and 29 years, and 15 participants had completed University (i.e. higher education). Since initial adoption, online food delivery services had mostly been used on a weekly or monthly basis, and in one instance, on a daily basis. Participants consistently referred to using the three largest online food delivery services operating in the UK (Just Eat, Deliveroo, and Uber Eats).

During the 19th interview, conducted in August 2020, I identified that it seemed difficult for the participant to think about the time before the onset of the COVID-19 pandemic in March 2020. I completed three further interviews and then concluded that this difficulty was consistent so stopped data collection. I included data from all completed interviews in analyses since experiences and perspectives of participants from before March 2020 were gathered after appropriate prompting. In addition to the completed interviews, three interviews were scheduled but cancelled by individuals without providing a reason, and there were nine non-respondents.

Table 3.1: Sociodemographic characteristics and online food delivery service use amongst frequent customers (n=22) interviewed between June and August 2020.

Participant number	**Gender**	**Age** (years)	**Highest education** [a]	**Online food delivery service(s) used**	**Typical usage frequency** [b]	**Time since adoption** (years)
1	Female	20-29	Higher	Deliveroo & Just Eat	Monthly	≤5
2	Male	20-29	Higher	Deliveroo, Just Eat & Uber Eats	Fortnightly	>5
3	Female	20-29	Higher	Deliveroo	Weekly	Unknown
4	Female	30-39	Higher	Deliveroo & Just Eat	Weekly	≤5
5	Female	30-39	Higher	Deliveroo & Just Eat	Weekly	≤5
6	Female	20-29	Higher	Deliveroo & Just Eat	Monthly	Unknown
7	Female	20-29	Higher	Deliveroo	Weekly	≤5
8	Female	40-49	Higher	Just Eat	Monthly	≤5
9	Male	30-39	Compulsory	Deliveroo, Just Eat & Uber Eats	Weekly	>5
10	Female	20-29	Further	Deliveroo	Monthly	≤5
11	Male	30-39	Higher	Just Eat	Monthly	>5
12	Female	20-29	Higher	Deliveroo, Just Eat & Uber Eats	Fortnightly	>5
13	Male	20-29	Compulsory	Deliveroo, Just Eat & Uber Eats	Weekly	≤5
14	Female	20-29	Higher	Just Eat	Monthly	>5
15	Male	40-49	Further	Just Eat	Monthly	≤5
16	Male	20-29	Higher	Deliveroo & Uber Eats	Fortnightly	≤5
17	Male	30-39	Higher	Deliveroo	Monthly	>5
18	Male	20-29	Higher	Just Eat	Fortnightly	>5
19	Male	30-39	Further	Deliveroo	Weekly	≤5
20	Male	20-29	Compulsory	Deliveroo & Just Eat	Fortnightly	≤5
21	Male	20-29	Compulsory	Deliveroo & Uber Eats	Daily	≤5
22	Male	30-39	Higher	Deliveroo & Uber Eats	Weekly	>5

Notes: [a] Highest level achieved or underway. `Compulsory` = High school, `Further` = Education after high school, not including a university degree, `Higher` = University degree.
[b] Since initial adoption.

3.5.2 Summary and structure of findings

Two concepts were overarching throughout the data: `Place. Time. Situation.` and `Perceived advantages outweigh recognised drawbacks`. Within these overarching concepts, there were five generated themes: `The importance of takeaway food`, `Less effort for more convenience`, `Saving money and reallocating time`, `Online food delivery service normalisation` and `Maintained home food practices`.

The sections that follow are organised so that I present the findings for each of the overarching concepts, followed by each of the themes. Whilst I discuss each concept and theme individually, elements of each were present throughout the data and should be thought of as dynamic, overlapping, and non-hierarchical. For example, participants consistently reflected on features of online food delivery services according to the context of their location at a specific time. The conclusion of this process determined if a given feature was viewed as an advantage or a drawback and in some cases, if online food delivery services would be used. Table 3.2 at the end of the Results provides examples of this comparison process.

3.5.3 Overarching concepts

3.5.3.1 Place. Time. Situation.

Participants described how their location and the time of day influenced their ability to access different types of food. When choosing one type of food over another, participants had a multi-factorial thought and decision-making process that considered their food at home, their immediate finances available for food, and the food they had already eaten that day.

Although my interview questions focused on the consumption of food prepared out-of-home, which I referred to as `takeaway food` throughout, participants were clear that purchasing this type of food was not always appropriate. As participant 10 (Female: 20-29 years) stated; *"I don't always just go and get a takeaway; sometimes I'll walk to the shop, get some food, and make something"*. This view was shared by participant 11 (Male: 30-39 years); *"some days I'll decide that it's too expensive and I'll either get something else directly from the restaurant or go to the supermarket and then make food"*.

Nonetheless, participants indicated that purchasing takeaway food was preferable in many situations. For example, when acting spontaneously, when meals had not been previously planned for, or when other types of food could not satisfy their needs, then takeaway food was appropriate.

> *"I think you're more likely to get delivery and order online when it's unplanned and you need a pick-me-up, or you need something quick, or you don't have something and you're really hungry."* Participant 15 (Male: 40-49 years)

When participants decided to purchase takeaway food, they recognised that their location and the time of day dictated the purchasing formats they could access and potentially use. Access to multiple purchasing formats created a second decision-making process. Participants considered the cuisine they wanted, delivery times estimated by online food delivery services versus the time it would take for them to travel to a food outlet, the weather, their willingness to leave home, and previous experience with food outlets that would deliver to them. Alongside these factors, choosing one purchasing format over another was often based on what was most convenient.

> *"If I'm out and about, on the way home and I'm passing via an outlet, then I'll pick it up. If I'm at home and just kind of, don't want to leave the house, I'll order via an app or online, because it's just convenient."* Participant 2 (Male: 20-29 years)

Despite having apparently decided how they would purchase takeaway food, participants stated that they were willing to change their mind. In the case of online food delivery services, if estimated delivery times failed to meet their expectations then this purchasing format would not be appropriate and another option or type of food would be selected. Using a specific purchasing format also had to align with other routines and schedules. This was particularly clear when participant 8 (Female: 40-49 years) described that they used online food delivery services when they could *"relax on a Friday night with the whole evening free".* However, if they did not have time to select a food outlet, place their order, and wait for delivery, then they *"normally just have some spaghetti because that takes 10 minutes"*.

Participants referred to online food delivery service marketing in their day-to-day environments. In the context of the physical food environment, this marketing included branded food outlet signs and equipment used by delivery couriers. Participants stated that these things did not

always trigger immediate online food delivery service use, yet their omnipresence reminded them that these services were available.

> *"I don't know if I ever go onto Just Eat after seeing it advertised, I don't think that's ever directly led me to do it. But it certainly keeps it in your mind, it's certainly at the forefront of your mind whenever you think of takeaway food."*
>
> Participant 11 (Male: 30-39 years)

3.5.3.2 Perceived advantages outweigh recognised drawbacks

Throughout the data, participants recognised that a single online food delivery service feature could be an advantage or a drawback based on their location and the time of day. This was clearest when participant 2 (Male: 20-29 years) discussed the number of food outlets accessible online compared with those accessible through alternative purchasing formats. There was value in having access to *"20, 30, 40 food outlets"* through online food delivery services as it meant there was greater choice, otherwise *"you're more limited just by the virtue of where you are or what shops you're passing"*. However, access to a higher number of food outlets was a drawback when it meant that making a selection was difficult. The constant comparison of advantages and drawbacks prompted me to ask participants why they kept using online food delivery services. There was a consensus that these services had unique features that were, more often than not, advantageous. As participants continued to use online food delivery services to access unique features, this practice appears to be self-reinforcing, even if this means accepting that the same feature can sometimes be a drawback. Nevertheless, participants acknowledged that if the overall balance between advantages and drawbacks changed then they would purchase takeaway food in other ways. This solution emphasises that takeaway food can often be accessed through multiple purchasing formats, dependent on place and time. Despite this, as it stands, participants anticipated that they would continue to use online food delivery services indefinitely.

> *"I can't see any reason why I would* [stop using online food delivery services]*, unless something went wrong with Just Eat, you know, the service had a massive problem, but at the moment I can't see any reason why I would."*
>
> Participant 16 (Male: 20-29 years)

3.5.4 Analytic themes

Having discussed the two overarching concepts, I now present each of the five themes generated from analyses. As described, elements of each theme overlapped within the two overarching concepts presented to this point.

3.5.4.1 The importance of takeaway food

Participants emphasised that it was *"the food"* they most valued and led them towards online food delivery services.

> *"It's the food really, that leads me to use* [online food delivery service] *apps."*
>
> Participant 10 (Female: 20-29 years)

Participants reported that they did not use online food delivery services with the intent of purchasing healthy food. In fact, they expected takeaway food and the food available to buy through online food delivery services to be unhealthy. This perspective influenced the types of food that participants were willing to purchase online. For example, pizza (seen as unhealthy) was appropriate but a salad (seen as healthy) was not. Moreover, participants recognised that if they wanted to consume healthy food, they would most likely cook for themselves.

Participants stated that takeaway food had social, cultural, and behavioural value. For many, purchasing and consuming takeaway food at the end of the working week signified the start of the weekend, which was seen as a time for relaxation and celebration. This tradition had been carried forward from childhood, with Friday night referred to as *"takeaway night"*. Using an online food delivery service allowed participants to maintain, yet digitalise, traditions.

> *"It's always a weekend thing, besides it being a convenient, really quick way of accessing food that is filling and tastes nice, for me, it marks the end of a work week."* Participant 4 (Female: 30-39 years)

Participants reported that in some situations, consuming takeaway food as a group could be a way to socialise. This was especially the case during life transitions such as leaving home to start university.

"When you move out, you're concentrating on making friends, and getting a takeaway was quite an easy way for everyone to sit down around the table and socialise and to have drinks." Participant 14 (Female: 20-29 years)

Participants did not value online food delivery services to the same extent that they did takeaway food. This perspective reinforced that online food delivery services were primarily used to satisfy takeaway food purchasing needs.

"If Just Eat as an entity disappeared, or all online takeaways disappeared, I wouldn't be upset [...] *it's a luxury, it makes life easier."* Participant 9 (Male: 30-39 years)

3.5.4.2 Less effort for more convenience

Participants reported that it takes little effort to use online food delivery services because they receive information about each of the food outlets they can order from on a single platform. Participants particularly valued the opportunity to save their payment details, previous orders, and favourite food outlets for future use. Participants also reported that they could order from an increased number of food outlets and a more diverse range of foods compared with other purchasing formats. Due to the number of food outlets accessible online, the selection process was not always fast. Nonetheless, participants indicated that online food delivery services make purchasing takeaway food easier and more convenient than other purchasing formats where information is less readily available.

"You've got all of the different options laid out in front of you, it's like one resource where everything is there, and you can choose and make a decision, rather than having to pull out leaflets from a drawer or Google different takeaways in the area. It's all there and it's all uniform and it's in one place." Participant 3 (Female: 20-29 years)

"I can pick through a whole wide selection rather than being limited to the few takeaways down on my road or having to drive somewhere." Participant 21 (Male: 20-29 years)

Participants emphasised that online food delivery service smartphone applications had been optimised to enhance their purchasing experience.

"I guess it's the convenience of just being able to open the app on my phone, and not having to go searching for menus or phone numbers and checking if places are open. So yeah, it's the convenience." Participant 15 (Male: 40-49 years)

"For me, it's just the ease of going on, clicking what you want, paying for it and it arriving. You don't have to move, you don't have to cook, you don't have to think, it's just there ready to go, someone's doing the hard work for you." Participant 1 (Female: 20-29 years)

However, greater convenience was not always advantageous. Some participants were concerned that convenient and easy access to takeaway food through online food delivery services might have negative consequences for health and other things.

"It's quite addictive in the way that it's just so convenient to order. I'm not making stuff fresh at home, and I'm eating unhealthier." Participant 21 (Male: 20-29 years)

"I think it adds to a general kind of laziness that is not good for people really. If you actually got up and went for a walk to go and get this food, at least there's a slightly positive angle there." Participant 17 (Male: 30-39 years)

"The convenience is not necessarily a positive thing [because] *these apps can be abused because it's so easy to access foods."* Participant 10 (Female: 20-29 years)

3.5.4.3 Saving money and reallocating time

Participants were sensitive to the price of takeaway food and valued the opportunity to save money. When discussing financial aspects of online food delivery service use, participants referred to special offers they had received by email or through mobile device push notifications. Participants reported that direct discounts (e.g. 10% off), free items (e.g. free appetisers on orders over £20.00), free delivery (e.g. on orders over £30.00), or time-limited price-promotions (e.g. 40% off all orders for the next three-hours) justified their online food delivery service use.

"Getting a takeaway is always a treat, every time I do it I know I shouldn't but then basically I'm convinced to treat myself, if there's a discount I'm much more likely to do it because I don't feel like it's such a waste of money." Participant 18 (Male: 20-29 years)

Participants recognised takeaway food as being a distinct food category. Nevertheless, they appreciated that they could use online food delivery services to purchase other types of food, like food from restaurants. Since this food is usually accompanied by a complete dining experience that online food delivery services cannot replicate, participants expected to spend less when purchasing it online.

"Some restaurants deliver through Deliveroo, [these are places] *where you can sit down and have an experience, a dining experience,* [...] *well that's different because you might go there for the dining experience."* Participant 4 (Female: 30-39 years)

"Sometimes I'm deterred from using Uber Eats because I noticed that the restaurants increase their prices if you buy it through them rather than directly [...] *I don't want to pay over £10 for a takeaway dish, whereas I would pay that if I ate at a restaurant."* Participant 3 (Female: 20-29 years)

Although participants were sensitive to the price of takeaway food, they were willing to trade money for time. Participants compared the time they would spend cooking or travelling to customer-facing food outlets with the time taken to place orders through online food delivery services plus the tasks they could complete whilst waiting for meal delivery. Paying a delivery fee to have the opportunity to use time that would not have otherwise been available was acceptable.

"Yeah, it costs money but at the same time we're getting more time with the kids and more time to do other stuff, so it's absolutely fine as far as I'm concerned." Participant 9 (Male: 30-39 years)

However, some participants were unsure about the appropriateness of paying to have food delivered, as it might be unfair to delivery couriers.

"I don't feel like it's necessarily right to make a delivery courier drive two minutes up the road just because I can't be bothered to go and collect something that's not very far away." Participant 10 (Female: 20-29 years)

3.5.4.4 Online food delivery service normalisation

Participants consistently reported having positive previous experiences of using online food delivery services. These experiences influenced future custom and contributed to an overall sense that using this purchasing format was now a normal part of living in a digital society. Some participants referred to watching television online to exemplify this point. The normalisation of using online food delivery services was particularly evident when I asked participants for their first thoughts about the term `takeaway food`. Participants often referred to online food delivery services in the first instance and saw them as synonymous with this type of food.

> *"If you were to say `takeaway food` I'd pull out my phone and I'd open one of the apps and say `okay, what should we order`, I wouldn't say `oh let's go to this road`, or `let's go to that road`, I'd say `yeah, let's look on the app`."*
>
> Participant 21 (Male: 20-29 years)

For participants in my study, using online food delivery services replaced purchasing takeaway food in other ways. This perspective was linked to habitual takeaway food purchasing and sociocultural values. Participants purchased takeaway food within set routines (for example only at the weekend) because they did not always think it was appropriate to do so at other times. As a result, participants reported that they had a limited number of opportunities to use multiple purchasing formats and thus increase existing levels of consumption.

3.5.4.5 Maintained home food practices

Most participants were responsible for cooking at home, enjoyed doing so, and said they were competent at it. Nonetheless, cooking at home required personal effort, and being *"lazy"*, *"tired"*, or *"having nothing in the cupboards"* justified online food delivery service use.

> *"I cook, when I'm not using these apps I cook and prepare food for myself, it's just on the odd occasion I might be feeling tired or want something different* [...] *the rest of the time, I'm quite happy to cook."* Participant 10 (Female: 20-29 years)

Despite the apparent normalisation of using online food delivery services, participants did not feel that these services would eliminate cooking at home. Most participants consumed home cooked food daily, whereas they consumed takeaway food less frequently. This contributed to the view that these two types of food were different. As a result, participants used online food delivery services to purchase food they could not, or would not, cook at home, for a break from normality, and as a *"cheat"* or *"treat"*.

Table 3.2: Examples of how frequent online food delivery service customers (n=22) compared the advantages and drawbacks of features of the online food delivery service business model, identified from data collected between June and August 2020.

Feature	Perceived advantage	Perceived drawback
Food outlet information and menus can be viewed, and orders placed, on one platform	Orders can be placed with little effort	It is *too easy*, and it takes no effort to purchase takeaway food
An increased number of food outlets are accessible compared with other purchasing formats	Food outlets, cuisines, and price points, including those not normally available, can be selected	Selecting a food outlet is difficult because there is *too much* choice
Unique promotional offers can be used	Money can be saved, additional food items can be received, and meals can be delivered for free	It is *too appealing* to place orders when promotional offers are available
Takeaway food can be purchased	The available food meets expectations	The available food is mostly unhealthy
Meals are delivered	Takeaway food can be received without leaving home	Having takeaway food delivered when the food outlet is nearby might be lazy
Delivery typically involves an additional fee	Paying a delivery fee is worth it to carry out other tasks whilst waiting	Delivery fees can be expensive

3.6 Discussion

3.6.1 Summary of findings

To my knowledge, this is the first research in the public health literature to investigate experiences of using online food delivery services from the perspective of frequent customers. Participants recognised that their location and the time of day meant that they often had access to different types of food through multiple purchasing formats at the same time. Participants stated that purchasing takeaway food was appropriate in many situations and typically favoured using online food delivery services. For many participants, using these services was now part of routines in their increasingly digital lives. As such, using online food delivery services appeared to be synonymous with takeaway food purchasing. This meant that participants expected food sold online to be unhealthy, with them reporting that they were not inclined to purchase healthy food in this manner. Participants consistently thought about how features of online food delivery services were an advantage or a drawback within the context of their location at a given point in time. This was a complex and dynamic process. Participants described how the advantages of these services were a strong enough reason to continue use, and that they outweighed drawbacks. Participants reported that using online food delivery services involved little effort as they were provided with food outlet information and menus, and payment facilities on one platform that had been optimised for their use. Moreover, although the cost of food was an important consideration for participants, they were willing to pay a fee in exchange for the opportunity to complete tasks whilst waiting for meal preparation and delivery. Finally, using online food delivery services substituted purchasing takeaway food in other ways. Nevertheless, participants reported that cooking at home was a distinct food practice that occurred more frequently and was irreplaceable.

3.6.2 Interpretation of findings

Participants described sociocultural values assigned to takeaway food. Purchasing this food formed part of weekend traditions and routines to celebrate the end of the working week. Sociocultural values are proposed to develop from previous experiences (86, 115), which might have influenced the perspective of participants. In the past, traditions and routines might have led to visiting food outlets in-person. However, online food delivery services can now be used. Since participants reported that takeaway food in and of itself was a reason for seeking out these services, it is reasonable to conclude that sociocultural values linked to this food are relevant across purchasing formats.

The decision to purchase food has been recognised as being situational and made in the context of place and time (114, 233), with convenience reported as a consistent consideration (234). Participants reported that takeaway food was appropriate in many situations and acknowledged that it could often be accessed through multiple purchasing formats depending on their location at a given time. Selecting one purchasing format over another came after the consideration of multiple factors, including the level of effort required to find a suitable food outlet and to place orders. Using online food delivery services was often most convenient because doing so took little effort. However, participants were clear that although their decision had seemingly been made, it could be changed if an online food delivery service feature that was supposedly an advantage became a drawback. For example, if estimated delivery times were too long or delivery fees were too high then an alternative purchasing format would be considered. My findings support that the decision to purchase takeaway food is dynamic and influenced by place and time (36).

Food access has previously been summarised within the domains of availability, accessibility, affordability, accommodation, and acceptability (77). Broadly speaking, I investigated the acceptability of using online food delivery services, and participants made explicit reference to the domains of food accessibility, availability, and affordability. For example, one particularly valuable aspect of using online food delivery services was the ability to order from a higher number of food outlets compared with other purchasing formats. The experiences reported by participants in my study support the possibility that domains of food access are relevant to the decision to adopt, and maintain, online food delivery service use. Other features of these services, such as having information about each of the food outlets that could be ordered from on one platform, likely amplify the perceived benefit of increased food outlet access. Notably, access to an increased number of food outlets was not always advantageous, which is aligned with awareness about the negative aspects of takeaway food consumption reported by young adults in Australia and Canada (115, 235).

Participants also discussed how the price of food and delivery fees influenced their online food delivery service use. This reflects that food affordability contributes to food purchasing practices (36). This finding also provides insight into actions that retailers registered to accept orders through online food delivery services might take to attract customers. Customers can often select from multiple food outlets at the same time. As a result, food outlets might aim to compete with one another by lowering the price of food sold or by introducing price-promotions. The latter were particularly valued by participants. Elsewhere, price-promotions contribute to food purchasing practices (236, 237). Access to price-promotions through online

food delivery services has not been systematically documented. However, it is possible that their number is positively associated with the number of food outlets accessible online. Since both appear to influence online food delivery service use, the possibility of interaction between them is concerning for overall consumption of food prepared out-of-home, and subsequently, diet and diet-related health.

In some cases, participants reported that they used online food delivery services because they did not have time to cook at home. A number of tasks, including household chores, work, travel and childcare can limit the time available for, and take priority over, cooking at home (238). Using online food delivery services instead of cooking at home allowed participants to complete other tasks whilst waiting for meal preparation and delivery. This would not have necessarily been achievable when using more conventional purchasing formats. Due to sociocultural values and perceived `rules` about how frequently takeaway food `should` be purchased, participants did not see online food delivery services as a complete replacement for cooking at home. Nevertheless, even partial replacement has implications for diet and diet-related health, especially since purchased foods were acknowledged as unhealthy by participants in my study. This perception is aligned with evidence that food consumed at home is often healthier than food consumed out-of-home (239).

3.6.3 Possible implications for public health and future research

Participants reported that using online food delivery services had mostly substituted, not supplemented, the use of other purchasing formats. Given this perspective, food outlets could increasingly register to accept orders through these services to supply an apparent demand. Further research is required to understand the extent to which customer demand is driven by food outlet access through online food delivery services and vice versa. Relatedly, participants reported that despite using online food delivery services frequently, their overall takeaway food consumption had remained the same. It is unclear if this perception would be reflected in objective assessment of overall takeaway food consumption. Further research that quantifies the use of multiple purchasing formats and takeaway food consumption over time is required to understand the potential public health implications of using online food delivery services. Evidence from Australia suggests that food sold through online food delivery services tends to be high in calories, total fat, saturated fat and salt (165). This has not been established in the UK. However, the food is likely to be similar. Nevertheless, the type of food available does not necessarily reflect the balance of the food purchased. Assessment of the nutritional quality of foods available, and purchased, through online food delivery services in the UK would help to understand the extent to which public health concern is warranted.

Price-promotions justified online food delivery service use. Legislation to restrict access to volume-based price-promotions (e.g. buy-one-get-one-free, 50% extra free) on less healthy pre-packaged food sold both in-store and online were due to be introduced in England in October 2022 (240). However, the introduction of this legislation was delayed, and at the time of writing had not been implemented. Regardless, hot food served ready-to-consume (i.e. food prepared out-of-home) was due to be excluded. Given what is known about the association between exposure to price-promotions and food purchasing practices (241), extension of these restrictions to hot food served ready-to-consume might be warranted. Understanding the extent to which price-promotions are associated with online food delivery service use represents a first step to understand the need for related public health intervention in the future.

3.6.4 Strengths and limitations

I recruited participants through two social media platforms, which means that those included were from a subset of all social media users. However, online recruitment was appropriate since I wanted to understand experiences of using a purchasing format that is an aspect of food retail within the digital food environment. The participants I recruited were mostly highly educated, which potentially reflects online food delivery service use amongst this socioeconomic group as I reported in Chapter 2 (although not for the UK) and as has been reported elsewhere (219, 242). I acknowledged this and adjusted my recruitment strategy after 12 telephone interviews to recruit a more balanced sample with respect to level of education. Nevertheless, future research should explore the perspectives of frequent online food delivery service customers with lower levels of education as they possibly have different reasons for using these services. Relatedly, I did not recruit infrequent online food delivery service customers or non-customers, as they would not have been in a position to provide information aligned with my study aims. However, since I have described experiences of using online food delivery services only from the perspective of frequent customers, future work should seek to understand the perspectives of others.

As the first study in the public health literature to investigate customer experiences of online food delivery service use, I used a descriptive methodological orientation. Doing so meant that I did not investigate the underlying meaning of the language used by participants. Nevertheless, my descriptive methodological orientation allowed me to use codebook thematic analysis and include co-authors in this process. Coding a 10% sample of interview transcripts and generating analytic themes together would have been less appropriate with reflexive approaches (228, 229, 243), but assisted with my interpretation of findings.

Finally, I conducted fieldwork during the early stages of the COVID-19 pandemic, which might have altered the recent experiences of online food delivery service use and participant perspectives. However, I asked participants to think about the time before the COVID-19 pandemic during interviews, and reflected on their ability to do so afterwards. My reflective practices are in line with established attempts to ensure qualitative rigour (216, 244), and allowed me to decide when it would be most appropriate to stop fieldwork.

3.7 Conclusions

I used telephone interviews with frequent online food delivery service customers to investigate experiences of using this purchasing format. I found that place and time influenced if and how takeaway food would be purchased. Participants often felt that online food delivery services were the most appropriate way to access this food. In part, this was due to the opportunity to use features not offered by other purchasing formats, including efficient ordering processes that had been optimised for customer convenience. Fundamentally, online food delivery services provide access to takeaway food. Although participants acknowledged that this food is unhealthy, it held strong sociocultural values. Participants were aware that some advantages of online food delivery services might also be drawbacks. Despite this, the drawbacks were not sufficient to stop their use. Finally, participants informed me that price-promotions justified their online food delivery service use. Public health interventions that seek to promote healthier food purchasing online may be increasingly warranted in the future. Interventions might include increasing the healthiness of the food available whilst maintaining sociocultural values and expectations. Restriction of price-promotions for food prepared out-of-home could also plausibly be extended to include online food delivery services.

Chapter 4:
Associations between online access to food prepared out-of-home and online food delivery service use in adults in the United Kingdom

4.1 Details of author contributions, publication and dissemination

For the research in this chapter, I developed the research questions and conceptualised data analysis with support from JA and TB, after consultation with DH and LV. Under the supervision of JA and TB, I led data preparation and analysis, and interpretation of findings. All authors read and provided critical comments on the initial manuscript and agreed to the final version.

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I shared the findings from the research in this chapter during an oral presentation at the 2022 International Medical Geography Symposium (held in-person, Edinburgh, United Kingdom).

4.2 Abstract

Background

Online food delivery services facilitate `online access` to food outlets that typically sell energy-dense nutrient-poor food. Greater online food outlet access might be related to online food delivery service use and living with excess body weight, however, this is not known. I aimed to investigate the association between aspects of online food outlet access and online food delivery service use, and differences according to customer sociodemographic characteristics, as well as the association between the number of food outlets accessible online and body weight.

Methods

I linked data for all food outlets in the United Kingdom (UK) registered with the leading online food delivery service, Just Eat (n=33,204), in 2019 with contemporaneous data on out-of-home food purchasing, body weight, and sociodemographic information collected through the International Food Policy Study (analytic sample n=3067). I used adjusted binomial logistic regression, linear regression, and multinomial logistic regression models to examine associations.

Results

Adults in the analytic sample had access to a median of 85 food outlets (interquartile range (IQR): 34, 181) and 85 unique types of cuisine (IQR: 64, 108) through the online food delivery service, and 15% reported online food delivery service use in the past week. Those with the highest number of food outlets accessible online (quarter four, 182–879) had 71% greater odds of online food delivery service use (odds ratio (OR): 1.71; 95% confidence intervals (CI): 1.09, 2.68) compared to those with the lowest number (quarter one, 0–34). The pattern of this association was evident amongst adults with a university degree (OR: 2.11; 95% CI: 1.15, 3.85), adults aged between 18 and 29 years (OR: 3.27, 95% CI: 1.59, 6.72), those living with children (OR: 1.94; 95% CI: 1.01; 3.75), and females at each increase in the number of food outlets accessible online. I found no association between the number of unique types of cuisine accessible online and online food delivery service use, or between the number of food outlets accessible online and body weight.

Conclusions

In conclusion, the number of food outlets accessible online was positively associated with online food delivery service use. Adults with the highest education, younger adults, those living with children, and females, were particularly susceptible to the greatest online food outlet access. Further research is required to investigate the possible implications of online food delivery service use on diet and diet-related health.

4.3 Introduction

Over the last two decades, the number of food outlets selling food prepared out-of-home has increased globally (31, 32, 34, 35). Whilst purchasing food prepared out-of-home is influenced by many factors (70), the number of food outlets selling this food that are physically accessible is thought to contribute and has been extensively researched (27, 66, 107). Evidence from cross-sectional and longitudinal studies demonstrates that individuals living in areas with greater food outlet access consume food prepared out-of-home more frequently and live with higher body weight and obesity (185, 245). These associations are stronger for those of a lower socioeconomic position (109), with further variation in the strength of associations based on sociodemographic characteristics including age, sex, and household composition (107).

In the past, food prepared out-of-home was conventionally purchased directly from food outlets. However, changing social-norms (142), technological advances (141), widespread internet availability (246), and a desire for greater convenience (247), have contributed to the emergence of alternative purchasing formats. Online food delivery services provide online access to food outlets selling food prepared out-of-home. Based on their location, customers receive aggregated information about the food outlets accessible online (i.e. those that will deliver to them). Customers select a food outlet and place their order through the platform of an online food delivery service. Orders are then forwarded to the food outlet where meals are prepared, and when ready, meals are delivered by couriers who work for the online food delivery service or independently for the food outlet.

Socioecological models propose that an interplay between physical food outlet access and individual-level characteristics influences the purchase of food prepared out-of-home (66, 72, 248, 249). However, little is known about the factors that plausibly influence online food delivery service use. Based on the findings of research investigating the role of physical food outlet access, it is reasonable to suggest that a higher number of food outlets accessible via online food delivery services is associated with more frequent use of this purchasing format, and that the influence of this exposure varies according to customer characteristics. Another possible explanation is that the characteristics of food outlets accessible online in and of themselves are important. Online food delivery services facilitate access to different types of food outlets that sell a range of cuisines (165). As taste preferences contribute to food practices (250), another possible contributor to online food delivery service use is the type of cuisine sold by food outlets. Finally, food available through online food delivery services is typically energy-dense and nutrient-poor (159, 165). Since consumption of such food has been associated with weight

gain over time (110), it is plausible that greater online food outlet access is associated with having elevated body weight on a distal basis.

4.3.1 Study aims

In my study, I aimed to investigate the association between the number of food outlets and the number of unique types of cuisine accessible online and online food delivery service use. Additionally, where an association was present, I aimed to examine differences according to known sociodemographic characteristics of online food delivery service customers. In secondary analyses, I aimed to investigate the association between the number of food outlets accessible online and body weight.

4.4 Methods

4.4.1 Study design

This was a cross-sectional data-linkage study.

4.4.2 Study sample

The International Food Policy Study (IFPS) is an ongoing annual repeat cross-sectional survey conducted in Australia, Canada, Mexico, the United Kingdom (UK), and the United States of America (USA). I used data collected between November and December 2019 from respondents living in the UK. I described data collection methods in Chapter 2, and they have also been described elsewhere (251). Briefly, respondents were recruited through Nielsen Consumer Insights Global Panel and their partners' panels. Panellists were screened for eligibility and quota requirements based on device type, age, and sex. Email invitations with links to an online survey were sent to a random sample of eligible panellists aged 18 years or over. Informed consent was obtained from all respondents prior to survey completion. The IFPS received ethics clearance through a University of Waterloo Research Ethics Committee (ORE# 21460). Data collection in the UK was approved by the University of Cambridge Humanities and Social Science Research Ethics Committee (Reference: 19/225).

4.4.3 Measures

4.4.3.1 Exposures: online food outlet access and unique type of cuisine access

Just Eat has been available in the UK since around 2006 and in 2020 was the online food delivery service market leader in terms of the number of food outlets registered to accept orders (around 35,000) and annual order volume (over 120 million) (252, 253). Unlike competitors that

tend to focus on operating only in large cities, Just Eat reports that it has outlets registered to accept orders through their service across all parts of the UK (254). My pilot work in one area in England, identified that 95% of food outlets registered to accept orders through the next largest online food delivery service operating in the UK (Deliveroo) were also registered with Just Eat (see Appendix C: Figure S1). Therefore, I used data from Just Eat (referred to as `the online food delivery service` hereafter) as a proxy for online food outlet access.

In November 2019, I used a web-browser extension to automate the collection of data on food outlets accessible online across England, Scotland, and Wales. First, on one weekday, I identified all food outlets registered to accept orders. Second, within 72-hours, I visited the profile of each food outlet on the online food delivery service website and collected information on their physical location, the types of cuisine sold (classifications self-determined by outlet owners), and their delivery area, which is all postcode districts to which they would deliver. A postcode district is the first half of a full postcode, for example, for the *postcode* `CB2 0QQ`, the *postcode district* is `CB2`. Postcode districts are used for mail and delivery routing purposes and have an average size of 33 mi^2 (255). Based on data from the 2011 census, the median postcode district population was 23,610 (interquartile range (IQR): 13,320-34,560) (223).

In the IFPS survey, respondents were asked to report their residential postcode. From this, I extracted the postcode district and identified the number of food outlets in data collected from the online food delivery service that listed the same postcode district in their delivery area. This was the number of food outlets accessible online. From these food outlets, I summed the number of unique types of cuisine that could be accessed.

4.4.3.2 Primary outcome: online food delivery service use

In the IFPS survey, all respondents were asked *"During the past 7-days, how many meals did you get that were prepared out-of-home in places such as restaurants, fast food or takeaway places, food stands, or from vending machines?".* Respondents who had purchased at least one meal prepared out-of-home were then asked to report the number of meals that were *"ordered using a food delivery service (e.g., Uber Eats, Just Eat, Deliveroo) and delivered"*. I used answers to the second question for my primary outcome. As data were not normally distributed and right-skewed, I dichotomised respondents into those who reported any online food delivery service use in the past week and those who did not.

4.4.3.3 Secondary outcomes: body mass index and weight status

In the IFPS survey, all respondents were asked to self-report their height and weight in either metric or imperial units. I used this data to calculate body mass index (BMI; kg/m^2, continuous), and used World Health Organization BMI cut-offs to classify respondents as being: `not overweight` (BMI ≤24.9 kg/m^2); `overweight` (BMI 25.0-29.9 kg/m^2); or `obese` (BMI ≥30.0 kg/m^2). I included respondents in a `not available` category when I was unable to calculate BMI due to body weight non-report, which is a possible reflection of social-desirability bias (256), or when calculated BMI was <14.0 kg/m^2 or >48.0 kg/m^2.

In accordance with findings from research investigating the relationship between food outlet access in the physical food environment and body weight (110, 245), it is plausible that greater online access to food prepared out-of-home is positively associated with BMI and weight status. However, the primary focus of my study was on the association between online food outlet access and online food delivery service use, which is more proximal and potentially less susceptible to bias from unmeasured confounding (107, 257). I have previously shown this potential pathway in Figure 1.6 (see Section 1.4.4). Given the above, I report the findings for my secondary outcomes in Appendix C.

4.4.3.4 Potential confounders: sociodemographic characteristics and neighbourhood food outlet access

In the IFPS survey, all respondents were asked to report sociodemographic information. I included potential confounders based on evidence regarding the purchase of food prepared out-of-home (64). Sex at birth was reported as male or female. I treated this as a binary variable for analysis. As I discussed in Chapter 2 and Section 1.2.5.4, although food purchasing practices are considered gendered, there is evidence of a correlation for responses to survey questions on sex and gender (188). Age was reported in years. Due to the possible non-linear influence on food purchasing, I grouped respondents into four age categories for analysis: 18-29 years, 30-44 years, 45-59 years, ≥60 years. Ethnicity was reported as the group that best described racial or ethnic background. I grouped respondents into a binary variable for analysis: `majority` (all `White` ethnicities) or `minority` (all other ethnicities, e.g. Asian, Black, Indian), which reflects that the majority of IFPS respondents in the UK identified with a White ethnic group (251). I used education and perceived income adequacy as markers of socioeconomic position (102, 103). Education was reported as the highest level completed. I categorised respondents as having a: `low` (high school completion or lower), `medium` (some post-high school qualifications), or `high` (university degree or higher) level of education for analysis. Perceived income adequacy

was reported based on how well total monthly incomes allowed needs to be met. I grouped respondents into two groups: `not easy` (don't know, refuse to answer, very difficult, difficult, or neither easy nor difficult responses) or `easy` (easy or very easy responses). Living with children under the age of 18 years and smoking status in the past 30 days were binary (yes/no) measures. I maintained the dichotomous nature of these measures for analysis.

Food sold through online food delivery services is typically prepared inside of existing customer-facing food outlets located in the physical food environment (39). Therefore, online food outlet access is predicated on the presence of food outlets in the physical food environment. I used Ordnance Survey Points of Interest (OS POI) data from June 2019 to determine the number of food outlets physically accessible. This is commercial data containing information about retailers across multiple sectors, collated from over 170 suppliers, is one of the most complete sources of food outlet location data available for the UK, and has been used in previous research investigating food outlet access in the physical food environment (258-260). I extracted information for the following categories as they include food outlets predominantly registered to accept orders through online food delivery services: `Fast food and takeaway outlets` (food outlets selling food prepared out-of-home for off-premises consumption), `Fast food delivery services` (food outlets selling food prepared out-of-home for delivery, not explicitly through online food delivery services), `Fish and Chip shops` (food outlets selling a traditional British cuisine, prepared out-of-home, typically for off-premises consumption) and `Restaurants` (food outlets selling food prepared out-of-home for on-premises consumption) (261). I used coordinates supplied in OS POI data, which have a stated accuracy of one metre (262), to map food outlets in a geographic information system (GIS) (ArcGIS version 10.7.1; ESRI Inc., Redlands, CA). I primarily used Doogal (a free web-based resource) to obtain coordinates for the postcodes of IFPS respondents (263). I used the GeoConvert tool (maintained by the UK Data Service) when this was not successful (264). I mapped obtained coordinates in the GIS and created a 1600 m (1-mile) Euclidean (straight-line) radius around postcode coordinates. I then counted the number of food outlets listed in OS POI data located within the 1-mile boundary to determine neighbourhood food outlet access (the number of physically accessible food outlets). A distance of 1600 m has been shown to reflect the spatial extent of an individual's typical shopping practices, and can reasonably be walked by an adult in less than 20 minutes (265, 266).

4.4.4 Exclusion criteria

Data were available for 4139 IFPS respondents living in the UK. I removed respondents with missing postcode information; covariate (except BMI and perceived income adequacy) or outcome data; when they lived in Northern Ireland (OS POI data does not include this country);

or when the total number of meals purchased out-of-home in the past week exceeded 21 (as I did not consider this to be plausible based on the maximum consumption of three meals per day). The final analytical sample included 3067 respondents (74% of all respondents).

4.4.5 Statistical analysis

I used Stata version 16.1 (StataCorp LLC., College Station, TX, USA) to complete statistical analysis with a significance threshold of $p<0.05$ throughout. I applied post-stratification sample weights constructed based on population estimates of age, sex, ethnicity and education from the 2011 UK census to reduce non-response and selection bias (251). I rescaled sample weights to reflect the number of participants included in the analytic sample. Unless specified, I report weighted findings.

Residuals for all measures were not normally distributed. Therefore, I categorised exposure measures (the number of food outlets accessible online and the number of unique types of cuisine accessible online) as quarters (Q). For each exposure measure, Q1 was the quarter with the lowest number and used as the reference category. I used binomial logistic regression models to investigate the association between each exposure and online food delivery service use in the past week (none or any). I completed unadjusted analyses and analyses adjusted for potential confounders (sex, age, education, perceived income adequacy, living with children and ethnicity, and neighbourhood food outlet access). Where the exposure was the number of unique types of cuisine accessible online, I additionally adjusted for the number of food outlets accessible online, due to a positive association.

I added a multiplicative interaction term (number of food outlets accessible online x respective sociodemographic characteristic) to separate adjusted binomial logistic regression models (not adjusted for the respective sociodemographic characteristic). Doing so allowed me to investigate if the association between the number of food outlets accessible online and online food delivery service use varied according to IFPS respondent education level, age, sex, or if they lived with children. I used post-estimation Wald Tests to determine interaction significance. When significant, I completed further analyses stratified by the respective sociodemographic characteristic.

4.4.5.1 Sensitivity analyses

In sensitivity analyses, I wanted to test that I had appropriately defined neighbourhood food outlet access. Therefore, when I constructed this potential confounder, I included additional categories from OS POI data alongside those initially included (`Fast food and takeaway outlets`,

`Fast food delivery services`, `Fish and Chip shops` and `Restaurants`). First, I included the number of supermarkets (as these outlets can provide access to food prepared out-of-home). Second, I included the number of: `Cafés, snack bars and tea rooms`, `Convenience stores`, `Supermarkets`, `Bakeries` and `Delicatessens`. As outlined in Section 4.4.3.4, I counted the number of food outlets in these categories that were within 1600 m of a given respondent's postcode and created quarters of exposure. I included these newly constructed measures of neighbourhood food outlet access in adjusted analyses.

4.4.5.2 Secondary outcomes

I used linear regression models to investigate the association between online food outlet access and BMI (continuous), and multinomial logistic regression models to investigate the association between online food outlet access and weight status. I completed unadjusted analyses and adjusted analyses that included potential confounders (sex, age, education, perceived income adequacy, living with children, ethnicity, and smoking status, which is negatively associated with body weight, and neighbourhood food outlet access) (267). Due to the exploratory nature of these analyses, I did not complete sensitivity analyses or explore interactions.

4.5 Results

4.5.1 Sample characteristics

Table 4.1 summarises sociodemographic characteristics, access to food prepared out-of-home and online food delivery service use for respondents in the analytic sample. The median number of food outlets and the median number of unique types of cuisine accessible online was 85.0 (IQR: 34.0, 181.0 and IQR: 64.0, 108.0, respectively). Around one in six respondents (15.1%) had used an online food delivery service in the past week. The average BMI of online food delivery service customers was 26.7 kg/m^2 and 48.1% were living with overweight or obesity. Table S1 and Table S2 (see Appendix C) report the sociodemographic characteristics, access to food prepared out-of-home and food purchasing practices of IFPS respondents not included in final analyses. These were not materially different to respondents in the analytic sample.

Table 4.1: Prevalence of online food delivery service use, exposure to food prepared out-of-home, and sociodemographic characteristics of the analytic sample (n=3067) from the 2019 International Food Policy Study.

Measure	N [a]	%
Online food delivery service use in the past week		
None	2604	(84.9)
Any	464	(15.1)
Food exposures (count): median (IQR)		
Online		
Outlet number	85	(34.0-181.0)
Unique cuisine type number	85	(64.0-108.0)
Neighbourhood		
Outlet number	25	(9.0-57.0)
Sex		
Male	1513	(49.3)
Female	1554	(50.6)
Age		
18-29 years	479	(15.6)
30-44 years	716	(23.4)
45-59 years	823	(26.8)
≥60 years	1048	(34.2)
Ethnicity		
Minority	267	(8.7)
Majority	2800	(91.3)
Education level		
Low	1570	(51.2)
Medium	652	(21.3)
High	845	(27.5)
Ability to make ends meet		
Not easy	1790	(58.4)
Easy	1277	(41.6)
Child at home		
No	2268	(74.0)
Yes	799	(26.0)
Regular smoker		
No	2417	(78.8)
Yes	650	(21.2)
BMI: mean (standard deviation) [b]	26.7	(5.3)
Weight Status (BMI: kg/m^2)		
Not overweight (≤ 24.9)	1077	(35.1)
Overweight (25-29.9)	877	(28.6)
Obesity (≥ 30)	597	(19.5)
Not available	517	(16.9)

Notes: [a] Data presented as weighted number of respondents (%) unless stated. May not always equate to 3067 due to rounding.

[b] 2551 respondents included in calculation.

4.5.2 Associations between online food outlet access and online food delivery service use in the past week

In the unadjusted model, the number of food outlets accessible online was positively associated with online food delivery service use in the past week, with suggestion of a dose response relationship (see Appendix C: Table S3). Figure 4.1 shows that associations were attenuated in the adjusted model, however, the positive association persisted for those with the greatest online food outlet access (Q4). Those with the highest number of food outlets accessible online (182-879 outlets) had 71% greater odds of online food delivery service use (odds ratio (OR): 1.71; 95% confidence intervals (CI): 1.09, 2.68) compared with those in Q1, who had the lowest number (0-34 outlets).

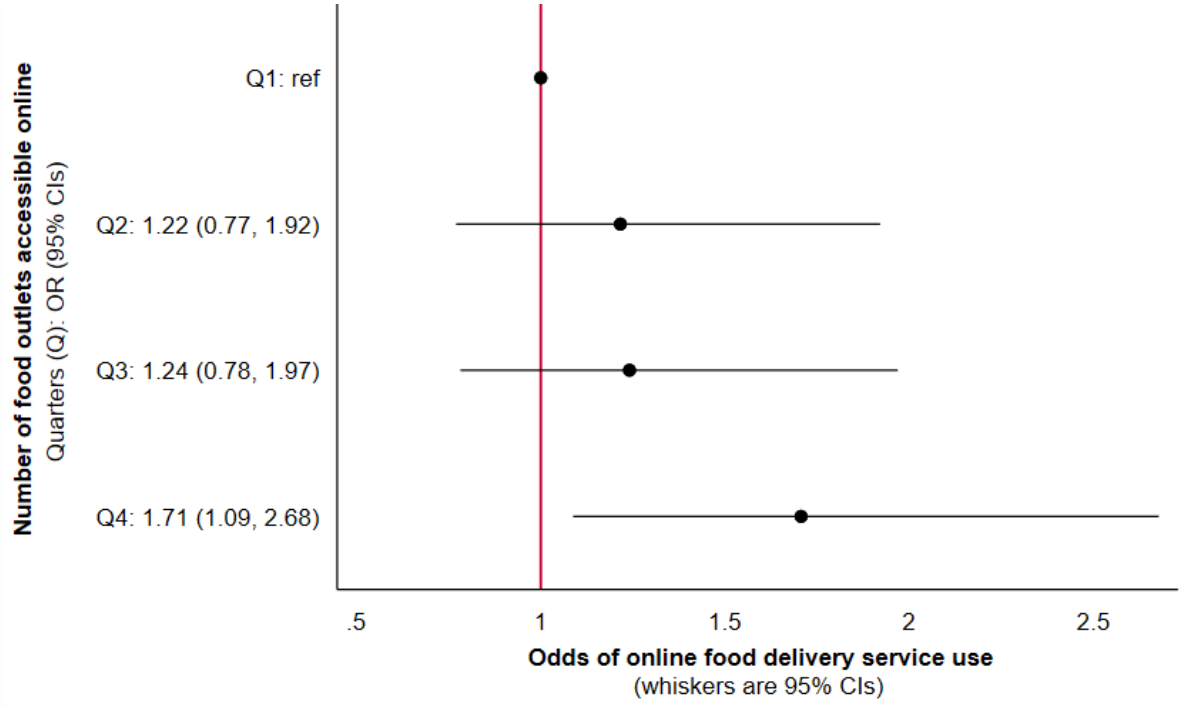

Figure 4.1: Odds of any online food delivery service use in the past week per quarter of online food outlet access amongst the analytic sample (n=3067) from the 2019 International Food Policy Study.
Note: Data collected in 2019, analysed using adjusted binomial logistic regression. Analysis adjusted for the following potential confounders: neighbourhood food outlet access, sex, age, education level, perceived income adequacy, living with children and ethnicity. The number of food outlets accessible online for each quarter (Q) were; Q1: 0–34, Q2: 35–85, Q3: 86–181, Q4: 182–879.

4.5.3 Interactions between online food outlet access and sociodemographic characteristics

There was evidence that the association between the number of food outlets accessible online and online food delivery service use in the past week varied by sociodemographic characteristics of customers: education ($p=0.0015$), age ($p<0.0001$), living with children ($p<0.0001$) and sex ($p<0.0001$) (see Appendix C: Table S4). Figure 4.2 presents findings from stratified analyses. The positive association between the highest number of food outlets accessible online and online food delivery service use was evident amongst respondents with the highest education (OR: 2.11; 95% CI: 1.15, 3.85), those aged between 18-29 years (OR: 3.27; 95% CI: 1.59, 6.72), and those living with children (OR: 1.94; 95% CI: 1.01, 3.75), but not those in other strata of these variables. The positive association increased at each level of exposure for female respondents but was entirely absent in males.

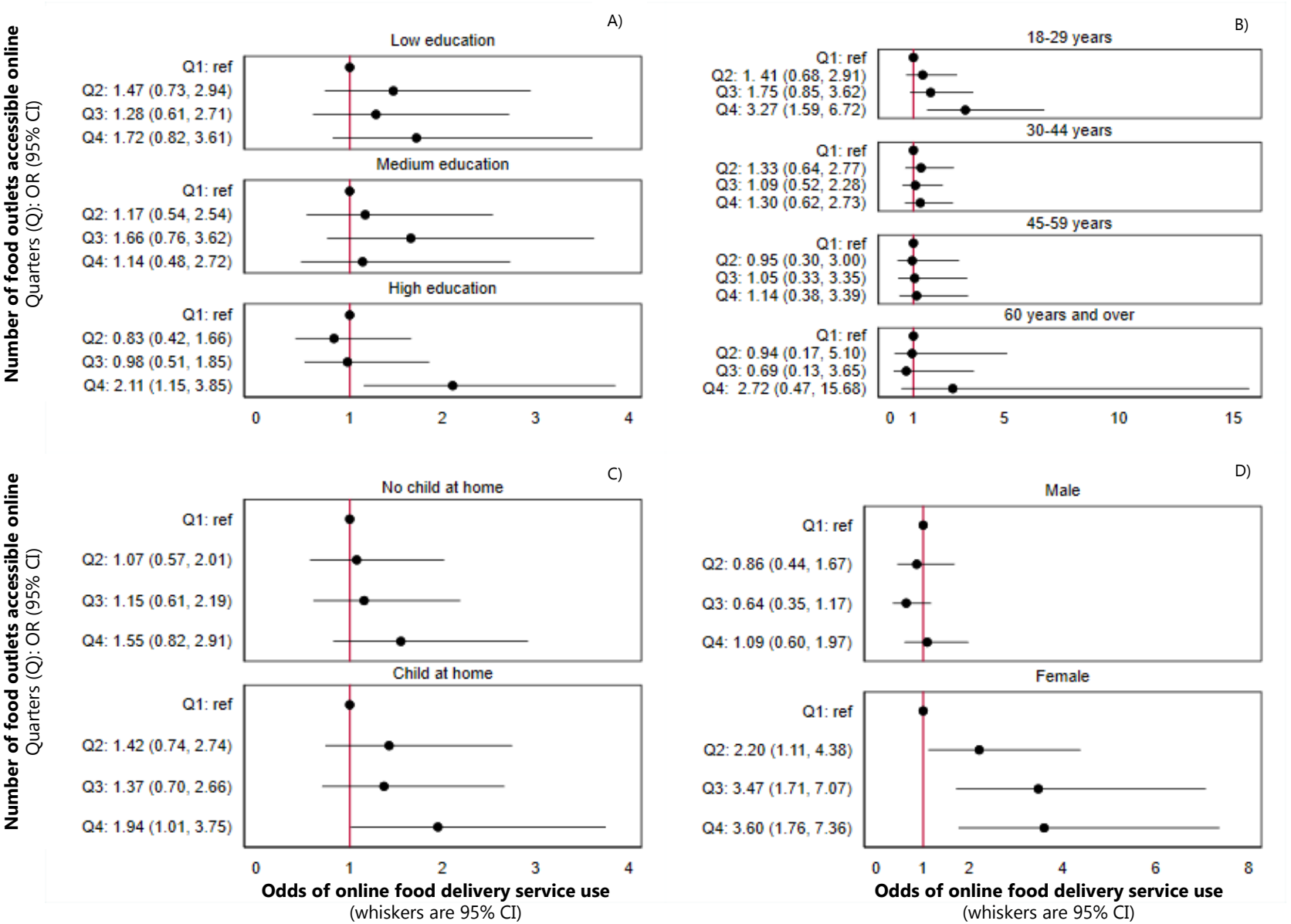

Figure 4.2: Odds of any online food delivery service use in the past week per quarter of online food outlet access amongst analytic sample (n=3067) from the 2019 International Food Policy Study, stratified by sociodemographic characteristics.

Note: Data collected in 2019, analysed using separate adjusted logistic regression stratified by: A) education level; B) age; C) living with children; and D) sex. Analyses adjusted for the following potential confounders: neighbourhood food outlet access, sex, age, education level, perceived income adequacy, living with children and ethnicity. The number of food outlets accessible online for each quarter (Q) were; Q1: 0–34, Q2: 35–85, Q3: 86–181, Q4: 182–879.

4.5.4 Sensitivity analyses

Including neighbourhood access to supermarkets and a broader range of food outlets in the adjusted model revealed similar patterns to the main analyses (see Appendix C: Table S5).

4.5.5 Associations between unique types of cuisine accessible online and online food delivery service use

I found no evidence of an association between the number of unique types of cuisine accessible online and online food delivery service use in the past week in the unadjusted (see Appendix C: Table S6) and adjusted models (see Figure 4.3).

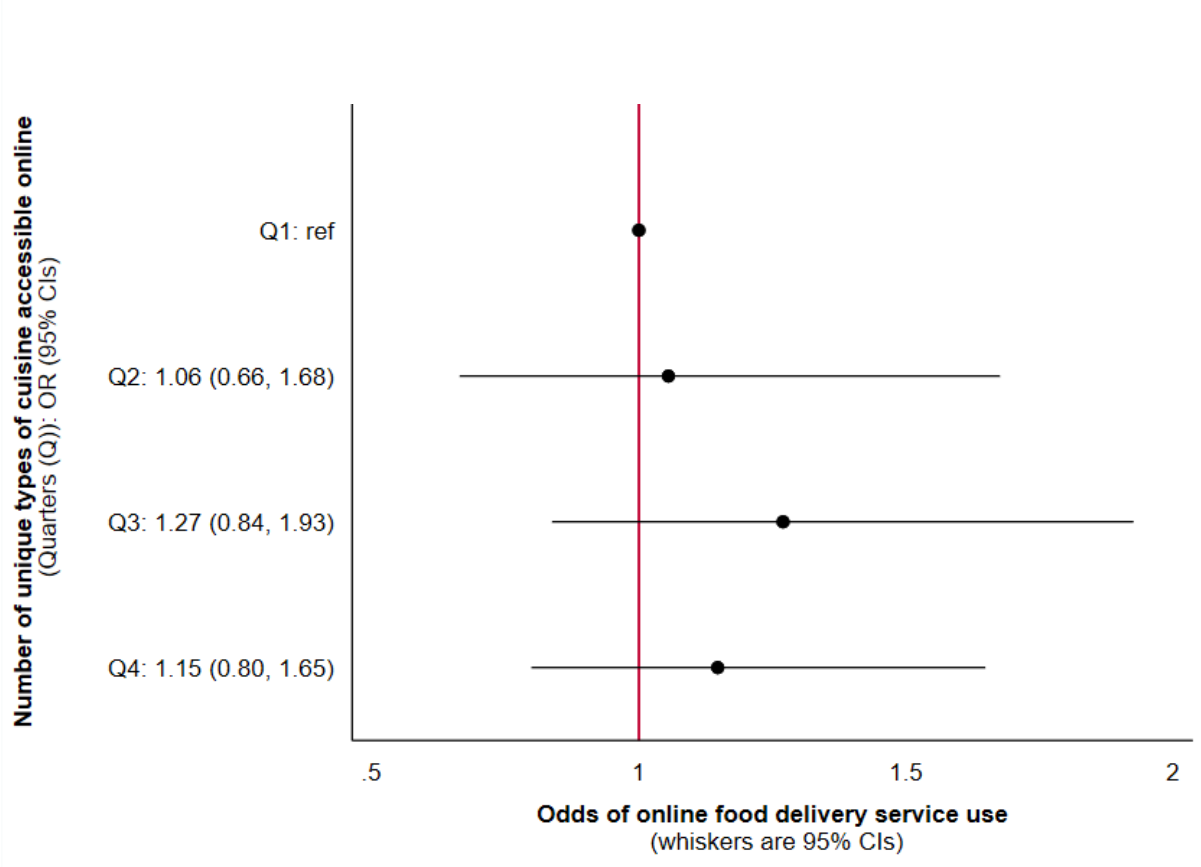

Figure 4.3: Odds of any online food delivery service use in the past week per quarter of online access to unique types of cuisine amongst the analytic sample (n=3067) from the 2019 International Food Policy Study.

Note: Data collected in 2019, analysed using adjusted binomial logistic regression. Analysis adjusted for the following potential confounders: neighbourhood food outlet access, online food outlet access, sex, age, education level, perceived income adequacy, living with children and ethnicity. The number of unique types of cuisine accessible online for each quarter (Q) were; Q1: 0–64, Q2: 65–85, Q3: 86–108, Q4: 109–148.

4.5.6 Secondary analyses: associations between online food outlet access and body weight

Table S7 (see Appendix C) reports findings from secondary analyses. In the unadjusted model, the number of food outlets accessible online was inversely associated with BMI for respondents with the highest number. Respondents with the highest number of food outlets accessible online also had lower odds of living with obesity compared with not being overweight. These associations were attenuated to extinction in adjusted models.

4.6 Discussion

4.6.1 Summary of findings

For the first time in the international published literature, I investigated the association between multiple measures of access to food prepared out-of-home through an online food delivery service and the use of this purchasing format. After adjustment for potential confounders, I found that adults living in the UK with the highest number of accessible food outlets (i.e. that they could order from) had 71% greater odds of reporting any online food delivery service use in the past week compared with those who had the lowest number. This positive association was evident amongst those who were more highly educated, those aged between 18-29 years, those living with children, and females. I found no evidence of an association between the number of unique types of cuisine accessible online and online food delivery service use, or between the number of food outlets accessible online and BMI or weight status.

4.6.2 Interpretation of findings

Amongst adults living in the UK, those with the highest number of food outlets accessible online (between 182 and 879 outlets) had greater odds of self-reporting online food delivery service use in the past week. As my study was the first investigation into the relationship between online food outlet access and online food delivery service use, there is no existing evidence with which to directly compare my findings. Nonetheless, socioecological models propose that exposure to food outlets is an environmental cue that can influence food purchasing practices (66, 268). Indeed, previous research has reported that access to a higher number of food outlets in the physical food environment is associated with purchasing food prepared out-of-home more frequently (52, 245). As food sold through online food delivery services is typically prepared inside of existing customer-facing food outlets, the number of food outlets accessible online is likely to be closely linked to the number of food outlets in the physical food environment (39). As I controlled for this in analyses, it is plausible that seeking out this

purchasing format is a response to other environmental cues not necessarily captured by measures of food outlet density. These cues may include the presence of food delivery couriers (101), or digital cues from targeted marketing (269), both of which are likely to be more prominent when a higher number of food outlets are present in the physical food environment (270).

The positive relationship between online food outlet access and online food delivery service use was specific to adults with the highest education, younger adults, those living with children, and females. In Chapter 2, I reported that online food delivery services are used by individuals with these sociodemographic characteristics (218), with similar findings reported amongst Australian adults (219). Younger adults and those in higher socioeconomic positions spend more time using the internet (271), and have the greatest odds of self-reporting exposure to marketing from online food delivery services (272). Additionally, social roles suggest that females and parents seek out food for others (233, 273). As a result, these individuals in particular might be prone to receiving and acting on cues to visit online food delivery services. Intentionally seeking out this purchasing format reflects shifting sociocultural norms regarding the way that food prepared out-of-home is purchased (169, 246). Indeed, engagement with online food delivery services likely leads to and promotes exposure to multiple aspects of these services, including the food outlets that will deliver to a given location. In contrast, those who do not use these services are not exposed to, and thus influenced by, the number of food outlets that would deliver to them if they were a customer. Therefore, the decision to visit platforms provided by online food delivery services and to become a customer appears critical.

Future research might seek to understand why the number of unique types of cuisine accessible online was not associated with online food delivery service use. It seems intuitive that having access to a higher number of cuisines facilitates access to greater food choice (274). However, it is also plausible that access to a higher number of cuisines results in choice overload, which in turn could lead to the use of an alternative purchasing format (275). This was alluded to by frequent online food delivery service customers who reported that too much choice was seen as a drawback of these services (see Chapter 3) (242).

4.6.3 After adjustment for potential confounders, there were no significant associations between the number of food outlets accessible online and either BMI or weight status. Whilst an association is plausible, my findings might reflect that this relationship has not yet had time to develop. Although online food delivery services have been available in the UK since around 2006, their use is reported to have only become an established practice more recently (39). A relationship may emerge in the future. Furthermore, online food delivery services are one aspect of food retail within the digital food environment and the broader food system. Unmeasured factors such as food access through other purchasing formats, including within the neighbourhood food environment, lifestyle preferences, and established purchasing routines might have contributed to my findings, yet were not captured in my measure of food access. Possible implications for public health and future research

Individuals living across England, Scotland and Wales who had the highest education were particularly susceptible to greater online food outlet access in terms of online food delivery service use. As such, these services may have a negative influence on overall dietary patterns in population groups who currently tend to have the best (276), which is a public health concern.

Alternative purchasing formats that exist alongside online food delivery services include independent food outlet websites and small-scale online food delivery services. However, these are less prominent and offer access to a limited number and range of food outlets compared with internationally established online food delivery services. Nevertheless, their emergence suggests a normalisation towards accessing food prepared out-of-home in a digital manner. This normalisation is reflected in the forecasted increase in frequency of online food delivery service use and purchasing food in the digital food environment (141).

The food available through online food delivery services is typically energy-dense and nutrient-poor (159, 162). Public health interventions that aim to improve the nutritional quality of food prepared out-of-home have previously been adopted (277, 278). As these interventions are often implemented inside of customer-facing food outlets, which is where food sold through online food delivery services tends to be prepared, they are well placed to improve the nutritional quality of food accessible online.

4.6.4 Strengths and limitations

A major strength of my study was the use of automated data collection. This approach allowed unprecedented nationwide collection of exposure data contemporaneous with outcome data collected from a large sample of adults. The use of exposure and outcome data collected at different time points is common in research investigating associations between food outlet

access and purchasing food prepared out-of-home (279). This temporal mismatch could result in exposure misclassification that was absent in my work. Moreover, I investigated online food delivery service use as my primary outcome. This outcome is most proximal to online food outlet access and improves the specificity of my investigations (280, 281). Finally, the IFPS survey was developed from existing measures that have been validated, are accurate, and are used in national surveys (251).

Nonetheless, my findings should be interpreted in light of methodological limitations. If food outlets were registered with the online food delivery service but not identified during data collection, exposure could have been underestimated and misrepresented (282). I identified that 33,204 food outlets were registered to accept orders online in November 2019. This is similar to the *"over 30,000"* reported as being registered to accept orders in contemporaneous reports from the data source (283), which provides confidence in the completeness of my data. Furthermore, my data were collected in November 2019, which pre-dates purported changes in food purchasing practices during the COVID-19 pandemic. I will further discuss this period of time in Chapter 6.

My cross-sectional analysis is unable to infer a strong causal relationship between the number of food outlets accessible online and online food delivery service use. Moreover, data for online food delivery service use were self-reported, which introduces the possibility of under-reporting due to social-desirability bias. These limitations are not unique to my research, yet could help understand my somewhat counterintuitive finding of no association between the number of food outlets accessible online and online food delivery service use.

Finally, I used 1600 m straight-line buffers to define the neighbourhood food environment of respondents. The use of this buffer size may have influenced the number of food outlets identified as being physically accessible. Although previous research has operationalised neighbourhood boundaries ranging from 400 m to 3200 m (26, 284), 1600 m buffers reflect the spatial extent of an individual's typical shopping practices, and this distance can be walked by an adult in around 20 minutes (265).

4.7 Conclusions

More frequent online food delivery service use could increase the consumption of food prepared out-of-home, which has known implications for diet and diet-related health. My study is the first to investigate the association between the number of food outlets and the number of unique types of cuisine accessible online and online food delivery service use. After adjusting for potential confounders, adults in the UK with the highest number of food outlets accessible

online had greater odds of online food delivery service use compared with those who had the lowest number. This association was particularly evident in adults who were more highly educated, younger adults, those who lived with children, and amongst females. I did not find evidence that the number of unique types of cuisine accessible online was associated with online food delivery service use. Moreover, the number of food outlets accessible online was not associated with body weight.

Chapter 5:
The socioeconomic patterning of online access to food prepared out-of-home in England

5.1 Details of author contributions, publication and dissemination

For the research in this chapter, I developed the research questions alongside JA and TB. I developed data collection protocols, and collected data alongside Tom Bishop (TRPB). I led data analysis and interpretation of findings with support from JA and TB. All authors read and provided critical comments on the initial manuscript and agreed to the final version.

This chapter is published as: Keeble, M., Adams, J., Bishop, T.R.P., Burgoine, T. (2021). Socioeconomic inequalities in food outlet access through an online food delivery service in England: a cross-sectional descriptive analysis. Applied Geography. 133, 102498. https://doi.org/10.1016/j.apgeog.2021.102498.

I shared the findings from the research in this chapter during oral presentations at the 2021 American Association of Geographers Annual Meeting (held online), the 2021 Public Health Research and Science Conference (held online), and the 2022 International Medical Geography Symposium (held in-person, Edinburgh, United Kingdom).

5.2 Abstract

Background

Online food delivery services facilitate `online` access to food outlets selling food prepared out-of-home. Systematic differences in online food outlet access could exacerbate existing health inequalities, which is a public health concern. However, this is not known since online food outlet access has not previously been investigated anywhere in England or across a whole country.

Methods

Across postcode districts in England (n=2118), I identified and described the number of food outlets and unique cuisine types accessible through the market leading online food delivery service (Just Eat). I investigated associations with area-level deprivation using adjusted negative binomial regression models. I also compared the number of food outlets accessible online with the number physically accessible in the neighbourhood (1600 m Euclidean buffers of postcode district geographic centroids) and investigated associations with deprivation using an adjusted general linear model. For each outcome, I predicted means and 95% confidence intervals (CI).

Results

In November 2019, 29,232 food outlets were registered to accept orders online. Overall, across England as a whole, the median number of food outlets accessible online per postcode district was 63.5 (interquartile range (IQR): 16.0, 156.0). For the number of food outlets accessible online expressed as a percentage of the number accessible within the neighbourhood, the median per postcode district was 63.4% (IQR: 35.6, 96.5). Analysis through adjusted negative binomial regression models showed that the number of food outlets accessible online was highest in the most deprived postcode districts (n=106.1; 95% CI: 91.9, 120.3). The number of food outlets accessible online expressed as a percentage of those accessible within the neighbourhood was highest in the least deprived postcode districts (n=86.2%; 95% CI: 78.6, 93.7).

Conclusions

In England, online access to food prepared out-of-home is socioeconomically patterned. Further research is required to understand how online food delivery service use varies according to area-level deprivation and implications for diet and health inequalities.

5.3 Introduction

In 2018, half of food expenditure in the United States of America (USA) was on food prepared out-of-home (285), and between 2008 and 2012, over one in four adults in the United Kingdom (UK) consumed at least one meal prepared out-of-home each week (40). Food available out-of-home is often characterised by high levels of energy, fat and salt, and on the whole, is less healthy than food prepared at home (46, 175, 286). Decisions related to when and where this food is purchased are complex and multifaceted (72, 174), with the physical food environment having a recognised influence (79). The number of physically accessible food outlets is a geographical measure of `food access`, whereby exposure to customer-facing premises is suggested to act as an environmental purchasing cue (73, 77). Accordingly, physical food environments that provide abundant access to food outlets selling food prepared out-of-home have been referred to as obesity promoting (287). Moreover, it has been consistently reported across multiple countries that a higher number of food outlets selling food prepared out-of-home are located in more deprived areas (31, 99, 288-290), which may contribute to inequalities in diet and health.

A growing body of cross-sectional and longitudinal evidence from research investigating food outlet access at the individual level now exists (27, 77). Evidence of an association between physical food environment exposures and outcomes such as the purchase and consumption of food prepared out-of-home is mixed (29, 53). In part, this is a reflection of methodological heterogeneity across the existing evidence base, which includes the use of different geographical measures of food outlet access and different conceptualisations of neighbourhood food environments, as well as varying food environment contexts across countries (26, 291). Nonetheless, in two UK studies that used similar methods, exposure to fast-food outlets was positively associated with fast food consumption (109, 245). This food practice has been associated with excess weight gain over time (110). In addition to the aforementioned methodological heterogeneity, although acquiring food prepared out-of-home is no longer restricted to physical food outlet access, previous research has rarely considered alternative purchasing formats.

Online food delivery services facilitate online access to food outlets selling food prepared out-of-home. Unlike visiting food outlets in-person, online food delivery service use is internet based (39). When using online food delivery services, customers receive information about each of the food outlets that will deliver to them based on their entered location. Customers then select a food outlet and place their order. Orders are then forwarded to individual food outlets

where meals are prepared. When ready, meals are delivered by couriers who work for either the online food delivery service or the food outlet.

In 2020, prominent online food delivery services, Deliveroo and Uber Eats were available in multiple countries, and Grubhub was established in many cities across the USA (179-182). Just Eat (including subsidiaries such as Menulog in Australia) was available in 23 countries (253), and was the market leader in the UK in terms of the number of food outlets registered to accept orders (around 30,000) and the annual number of orders processed (almost 170 million) (252, 292). Like food outlet access in the physical food environment (248, 293), it is possible that access to a higher number of food outlets through online food delivery services leads to an increased number of opportunities to purchase food prepared out-of-home. Indeed, in Chapter 4, I reported that a higher number of accessible food outlets was positively associated with online food delivery service use (214). As mentioned, there are known differences in access to food outlets selling food prepared out-of-home in England, with outlets selling this food more prevalent in the physical food environments of more deprived areas (31). Food sold through online food delivery services is typically prepared inside of existing customer-facing food outlets located in the physical food environment (39). As such, differences in physical food outlet access may be reflected in online food outlet access. However, this has not been investigated in the UK. Moreover, research completed elsewhere has been conducted in a limited number of cities (156, 165). In turn, the full extent of nationwide variation in online food outlet access and potential differences across the full socioeconomic gradient that might only be observed across a whole country has not been investigated. This variation is important to understand since certain sociodemographic groups may be disproportionately influenced by greater cumulative food outlet access across multiple purchasing formats.

Other factors could also influence online food delivery service use beyond the number of food outlets accessible online (i.e. that can be ordered from). Broadly speaking, customers select food outlets based on the foods (i.e. cuisine) they sell (77, 294). Within the context of online food delivery services, access to a higher number of unique types of cuisine could facilitate more choice, resulting in customer needs being accommodated and in turn, online food delivery service use. In Chapter 3, I reported that access to a variety of food was important to frequent online food delivery service customers (242). However, in Chapter 4, I reported that the number of unique types of cuisine accessible online was not associated with online food delivery service use (214). Nevertheless, variation in access to types of cuisine through online food delivery services is important to understand given the differences in nutritional quality between them (295).

5.3.1 Study aims

In this cross-sectional, area-based study, I aimed to describe online access to food outlets and unique cuisines across England; compare online food outlet access with physical food outlet access in the neighbourhood; and examine whether and to what extent these measures were associated with socioeconomic position.

5.4 Methods

5.4.1 Study setting and analytic scale

The study setting was England. The analytic scale was the postcode district level. This analytic scale reflects how food outlets registered to accept orders through Just Eat delineate their `delivery area` (see Section 5.4.3.1). A postcode district is the first half of a full postcode and is formally known as the outward code (255). For the *postcode* `CB2 0QQ`, the *postcode district* is `CB2`. Postcode districts are used for mail and delivery routing purposes and have an average size of 33 mi^2 (255). Based on data from the 2011 census, the median postcode district population was 23,610 (interquartile range (IQR): 13,320-34,560) (223).

For analyses, I used boundary data from 2012, provided by the UK data service (296), to map postcode districts in England in a geographic information system (GIS) (ArcGIS version 10.7.1; ESRI Inc., Redlands, CA). I included 2118 postcode districts, which were those entirely within the border of England, as well as those in Scotland or Wales with an intersecting boundary (food outlets could be located in these countries yet deliver to locations in England).

5.4.2 Exposure measure

I used data from the 2019 Index of Multiple Deprivation (IMD) to measure relative deprivation. This is a compound measure of deprivation that includes metrics across seven domains: income deprivation, employment deprivation, crime levels, health deprivation and disability, education, skills and training deprivation, barriers to housing and associated services and living environment deprivation (297). Relative deprivation scores are available for lower super output areas (LSOAs) in England, which are administrative boundaries with a mean residential population of 1500 people (298). As LSOAs are typically geographically smaller than postcode districts, I aggregated LSOAs within and intersecting the boundary of each postcode district and calculated the mean IMD score (297). For analyses, I split postcode districts into deciles based on IMD score, with decile 10 containing the most deprived.

5.4.3 Outcome measures

Table 5.1 summarises each of the outcome measures I investigated in my study.

5.4.3.1 Online food access

Information about all food outlets registered to accept orders through the UK market leader (Just Eat), including their opening hours, menus, delivery fees, and customer reviews, is publicly available. As I stated in Chapter 4, my pilot work for one area in England identified that 95% of food outlets registered to accept orders through the next largest online food delivery service (Deliveroo) were also registered to accept orders through Just Eat (see Appendix C: Figure S1). Moreover, unlike competitors, food outlets registered to accept orders through Just Eat are reported to be accessible in almost all areas of England (254). Like Chapter 4, I used data from Just Eat as a proxy for online food outlet access. Given that the aims of my study were related to online food delivery services in a general sense, I refer to Just Eat as the `online food delivery service` hereafter. As I described in Chapter 4 (see Section 4.4.3.1), in November 2019, I used a web-browser extension to collect information about all food outlets registered to accept orders through the online food delivery service across England, Scotland and Wales (299). First, on one weekday, I identified all food outlets registered to accept orders. Second, within 72-hours, I visited the profile of each outlet on the online food delivery service website and collected information on their physical location, the types of cuisine sold (classifications self-determined by outlet owners), and their delivery area, which is a list of all postcode districts to which they would deliver.

For each food outlet registered to accept orders through the online food delivery service, I primarily used Doogal, which is a free web-based resource, to geocode the postcode of customer-facing premises in the physical food environment (263). When geocoding through Doogal was not successful, I used the GeoConvert tool, which is maintained by the UK Data Service (264). I was unable to geocode seven food outlets (0.02%). This left 29,232 food outlets. I used supplied coordinates to map the physical location of food outlets in the GIS.

I used the number of food outlets accessible online and the number of unique cuisine types accessible online as outcome measures. From the data I collected from the online food delivery service, I counted the number of food outlets registered to accept orders through the online food delivery service that listed each postcode district in their delivery area to identify the number of food outlets accessible online. For each postcode district, I counted the number of unique cuisine types used by accessible food outlets. Food outlets can select multiple cuisines to

describe the food they sell. As a result, the number of unique cuisine types accessible online could be greater than the number of food outlets.

5.4.3.2 Percentage of food outlets registered to accept orders online

For this outcome, I used Ordnance Survey Points of Interest (OS POI) data, which is commercial data containing information about retailers across multiple sectors, collated from over 170 suppliers (260). This dataset is one of the most complete sources of food outlet location data available for England (259), and has been used in previous research that investigated aspects of the physical food environment (258). I used data from June 2019 and extracted information for the following food outlet categories: `Fast food and takeaway outlets` (food outlets selling food prepared out-of-home for off-premises consumption), `Fast food delivery services` (food outlets selling food prepared out-of-home for delivery, not explicitly through online food delivery services), `Fish and Chip shops` (food outlets selling a traditional British cuisine, prepared out-of-home, typically for off-premises consumption) and `Restaurants` (food outlets selling food prepared out-of-home for on-premises consumption) (261). I selected these categories based on *a priori* knowledge that they included food outlets typically registered to accept orders through online food delivery services. I mapped the locations of food outlets using coordinates supplied in OS POI data that are reported to be accurate up to one metre (262), and then identified the postcode district in which they were located.

I compared the number of food outlets located in each postcode district that were registered to accept orders through the online food delivery service with the number of food outlets in each postcode district listed in OS POI data. Doing so allowed me to calculate the percentage of food outlets registered to accept orders online. I did not identify and match individual food outlets listed in both datasets. The number of food outlets registered to accept orders through the online food delivery service should not exceed the number of food outlets located in each postcode district, therefore, I used a bounded (between 0-100%) outcome measure in analyses.

5.4.3.3 Percentage of neighbourhood food outlets accessible online

I expressed the number of food outlets accessible online (see Section 5.4.3.1) as a percentage of the number listed in OS POI data that could be accessed in the neighbourhood food environment for a given (pseudo) population. I defined the neighbourhood food environment for each given population as a 1600 m (1-mile) Euclidean (straight-line) radius around the geographic centre of each postcode district. Food outlet access within this distance has been associated with food-related practices (265, 266). I did not identify and match individual food outlets listed in both datasets. The number of food outlets accessible online may exceed the

number physically accessible in the neighbourhood, therefore, for this outcome measure, the percentage could be greater than 100%.

Although I report the percentage of food outlets registered to accept orders online and the percentage of neighbourhood food outlets accessible online, I acknowledge that in the strictest sense these outcomes have not been calculated as such.

5.4.4 Covariates

5.4.4.1 Physical food outlet access

Food sold through online food delivery services is typically prepared inside of existing customer-facing food outlets located in the physical food environment. These outlets tend to concentrate in highly populated areas, which possibly reflects a perception of greater demand amongst business owners (34). As online food outlet access might be a function of physical food outlet access, I used the four categories from OS POI data described in Section 5.4.3.2 to identify the number of food outlets within the physical food environment of each postcode district. I included this number as a covariate when it was not used in the calculation of the outcome measure.

5.4.4.2 Online food outlet access

The number of unique cuisine types accessible online was positively associated with the number of food outlets accessible online. Therefore, I used the number of food outlets accessible online as a covariate when the outcome was the number of unique cuisine types accessible online.

5.4.4.3 Rural Urban classification and population density

I used the 2011 rural urban classification to categorise postcode districts as: `rural` when LSOAs within or intersecting their boundary were most frequently rural (populations less than 10,000 people within combined settlements, where the majority live in rural-related areas); `urban` when LSOAs were most frequently urban (populations greater than 10,000 people within combined settlements, where the majority live in urban-related areas); or `balanced` when the number of rural and urban LSOAs was equal (300). I included usual residential and workday population from the 2011 UK census (301, 302). The usual residential population is the number of individuals, including students and schoolchildren not living away from home during term-time, who usually reside in a postcode district. The usual workday population is the number of individuals working in a postcode district on a given day, in addition to residents who are unemployed. Data for population density were available for 2088 postcode districts.

Table 5.1: Summary of measures and the exposure: outcome relationships investigated.

Exposure	Outcome	Outcome description	Geography	Covariates added to adjusted model
Postcode district relative deprivation IMD score modelled as deciles: Decile 1 = least deprived.	Percentage of food outlets registered to accept orders online	The number of food outlets registered to accept orders online, expressed as a percentage of the number of food outlets in a postcode district (bounded, 0-100%).	Postcode district	Postcode district rural urban classification Postcode district population density: usual residential and usual workday
	Number of food outlets accessible online	The number of food outlets accessible online based on a postcode district being listed in the delivery area of a food outlet registered to accept orders online.	Postcode district	Postcode district rural urban classification Number of food outlets in postcode district Postcode district population density: usual residential and usual workday
	Number of unique cuisine types accessible online	The number of unique cuisine types accessible online from food outlets that were accessible.	Postcode district	Postcode district rural urban classification Number of food outlets in postcode district Postcode district population density: usual residential and usual workday Number of food outlets accessible online
	Percentage of neighbourhood food outlets accessible online	The number of food outlets accessible online expressed as a percentage of the number physically accessible in the neighbourhood (unbounded, may exceed 100%).	1600 m Euclidean radius `neighbourhood` buffer of postcode district geographic centroid	Postcode district rural urban classification Postcode district population density: usual residential and usual workday

5.4.5 Statistical analysis

I used Stata version 16.1 (StataCorp LLC., College Station, TX, USA) to complete statistical analyses, with a significance threshold of $p<0.05$ throughout. For each exposure: outcome relationship investigated (see Table 5.1), I included postcode districts with complete data for all relevant variables. I completed unadjusted and adjusted analyses.

Data on the number (count) of food outlets and unique cuisine types accessible online were not normally distributed and were over-dispersed. Therefore, I used negative binomial regression to investigate associations with postcode district relative deprivation. Negative binomial regression reports incidence rate ratios (IRR) and 95% confidence intervals (CI). In the context of my research, IRR are the expected change in the outcome measure at each level of deprivation compared with the least deprived (decile 1). For analyses where the outcomes were the number of food outlets accessible online and the number of unique cuisine types accessible online, adjusted models included the number of food outlets in a postcode district, postcode district rural urban classification, and population density as covariates. When the number of unique cuisine types accessible online was the outcome, adjusted models additionally included the number of food outlets accessible online as a covariate. When the outcome was the percentage of food outlets registered to accept orders online or the percentage of neighbourhood food outlets accessible online, I used general linear models to investigate associations with postcode district deprivation. For these outcomes, model coefficients are the difference in the percentage at each level of deprivation compared with the least deprived. For these outcomes, adjusted models included postcode district rural urban classification and population density as covariates. I used the `margins` command to estimate the marginal means and 95% CI calculated from the coefficients or IRR from adjusted analyses. To aid interpretation of outcomes, I present these in the Results. I present the coefficients and IRR from unadjusted and adjusted analyses in Appendix D.

5.4.5.1 Sensitivity analyses

In sensitivity analyses, I wanted to test the sensitivity of my findings to the food outlet categories originally selected from OS POI data (`Fast food and takeaway outlets`, `Fast food delivery services`, `Fish and Chip shops`, `Restaurants`). Therefore, I used the same approach as described in Section 5.4.3.2 to construct measures that included the number of food outlets from additional categories listed in OS POI data: `Cafés, snack bars and tea rooms`, `Convenience stores`, `Supermarkets`, `Bakeries`, `Delicatessens`. I included the newly constructed measure in unadjusted and adjusted models.

5.5 Results

In November 2019, 29,232 food outlets across England were registered to accept orders through the online food delivery service (see Appendix D: Table S1).

5.5.1 Food outlet access across England

Table 5.2 provides descriptive statistics summarising online and physical food outlet access. Overall, the median number of food outlets accessible online per postcode district was 63.5 (IQR: 16.0, 156.0). Figure 5.1 shows that access to food outlets through the online food delivery service was widespread. I observed clusters of postcode districts in the North East, North West, West-Midlands regions and the Greater London area that had a high number of food outlets accessible online. Returning to Table 5.2, the median number of unique cuisine types accessible online was 39.0 (IQR: 16.0, 68.0). The median number of food outlets located in the physical food environment of postcode districts was 30.0 (IQR: 14.0, 52.0). The median number of food outlets registered to accept orders online and located in postcode districts expressed as a percentage of food outlets in postcode districts was 30.0% (IQR: 10.0, 40.0). When the number of food outlets accessible online was expressed as a percentage of the number physically accessible in the neighbourhood of a given population, the median was 63.4% (IQR: 35.6, 96.5). The median number of food outlets accessible online (186.0 outlets; IQR: 102.0, 294.0), and the percentage of food outlets in a postcode district registered to accept orders online (50.0%; IQR: 40.0, 60.0) were highest in postcode districts in decile 10 of deprivation. The median number of food outlets accessible online expressed as a percentage of the number physically accessible in the neighbourhood of a given population was also highest in these postcode districts (77.4%; IQR: 62.2, 107.7).

Table 5.2: Summary of measures for the online food delivery service and the physical food environment across postcode districts in England (n=2118), stratified by deprivation decile.

	Deprivation decile [a]										
Measure	1 (least deprived) n=214	2 n=210	3 n=213	4 n=211	5 n=211	6 n=212	7 n=212	8 n=212	9 n=212	10 (most deprived) n=211	All n=2118
Online food delivery service											
Food outlets registered (count) [b]	3.0 (1.0-7.0)	3.0 (0.0-10.0)	3.0 (1.0-9.0)	5.0 (1.0-13.0)	5.0 (0.0-14.0)	6.0 (1.0-18.0)	9.5 (1.0-23.5)	14.5 (5.0-26.0)	21.5 (10.0-37.5)	24.0 (14.0-37.0)	7.0 (1.0-21.0)
Accessible food outlets (count)	41.0 (18.0-68.0)	31.0 (12.0-74.0)	30.0 (11.0-89.0)	44.0 (11.0-101.0)	41.0 (8.0-106.0)	62.0 (9.0-121.0)	76.0 (4.0-176.5)	92.5 (30.5-208.5)	143.0 (80.0-247.0)	186.0 (102.0-294.0)	63.5 (16.0-156.0)
Unique cuisine types accessible (count)	31.0 (18.0-43.0)	26.5 (13.0-47.0)	27.0 (12.0-47.0)	32.0 (13.0-55.0)	29.0 (10.0-54.0)	36.0 (10.0-59.5)	44.0 (6.5-72.0)	49.0 (24.0-83.5)	59.5 (40.5-84.0)	71.0 (48.0-95.0)	39.0 (16.0-68.0)
Physical food environment											
Food outlets in postcode district (count) [c]	18.0 (9.0-31.0)	21.0 (10.0-38.0)	24.0 (10.0-39.0)	25.0 (11.0-45.0)	24.0 (12.0-43.0)	28.0 (11.0-52.5)	34.5 (18.5-56.5)	41.5 (21.5-68.0)	50.5 (29.5-81.0)	50.0 (29.0-76.0)	30.0 (14.0-52.0)
Food outlets in neighbourhood (count) [c]	45.0 (26.0-93.0)	52.5 (24.0-97.0)	55.0 (26.0-129.0)	67.0 (29.0-142.0)	75.0 (29.0-154.0)	90.5 (31.0-169.0)	112.0 (34.0-223.5)	123.5 (49.0-274.5)	191.0 (105.5-290.5)	212.0 (146.0-343.0)	90.0 (36.0-200.0)
Percentage registered (%) [d]	20.0 (10.0-30.0)	20.0 (0.0-30.0)	10.0 (0.0-30.0)	20.0 (10.0-40.0)	20.0 (0.0-40.0)	20.0 (10.0-40.0)	30.0 (0.0-50.0)	40.0 (20.0-50.0)	40.0 (30.0-50.0)	50.0 (40.0-60.0)	30.0 (10.0-40.0)
Percentage accessible online (%) [e]	70.9 (40.4-115.1)	59.4 (33.3-100.0)	49.7 (27.3-91.3)	59.2 (29.2-96.4)	53.3 (26.3-97.1)	56.8 (28.3-88.4)	52.7 (23.1-82.4)	67.3 (40.1-91.9)	72.1 (52.6-95.0)	77.4 (62.2-107.7)	63.4 (35.6-96.5)

Notes: [a] Decile 1 was least deprived. Decile 10 was most deprived. Data reported as median (IQR).

[b] `Registered` = registered to accept orders online, through the online food delivery service.

[c] Food outlet categories included: Fast food and takeaway outlets; Fast food delivery services; Fish and Chip shops; Restaurants. `Neighbourhood` = 1600 m Euclidean radius buffer of postcode district geographic centroid.

[d] The number of food outlets registered to accept orders online expressed as a percentage of the number of food outlets in a postcode district.

[e] The number of food outlets accessible online expressed as a percentage of the number physically accessible in the neighbourhood.

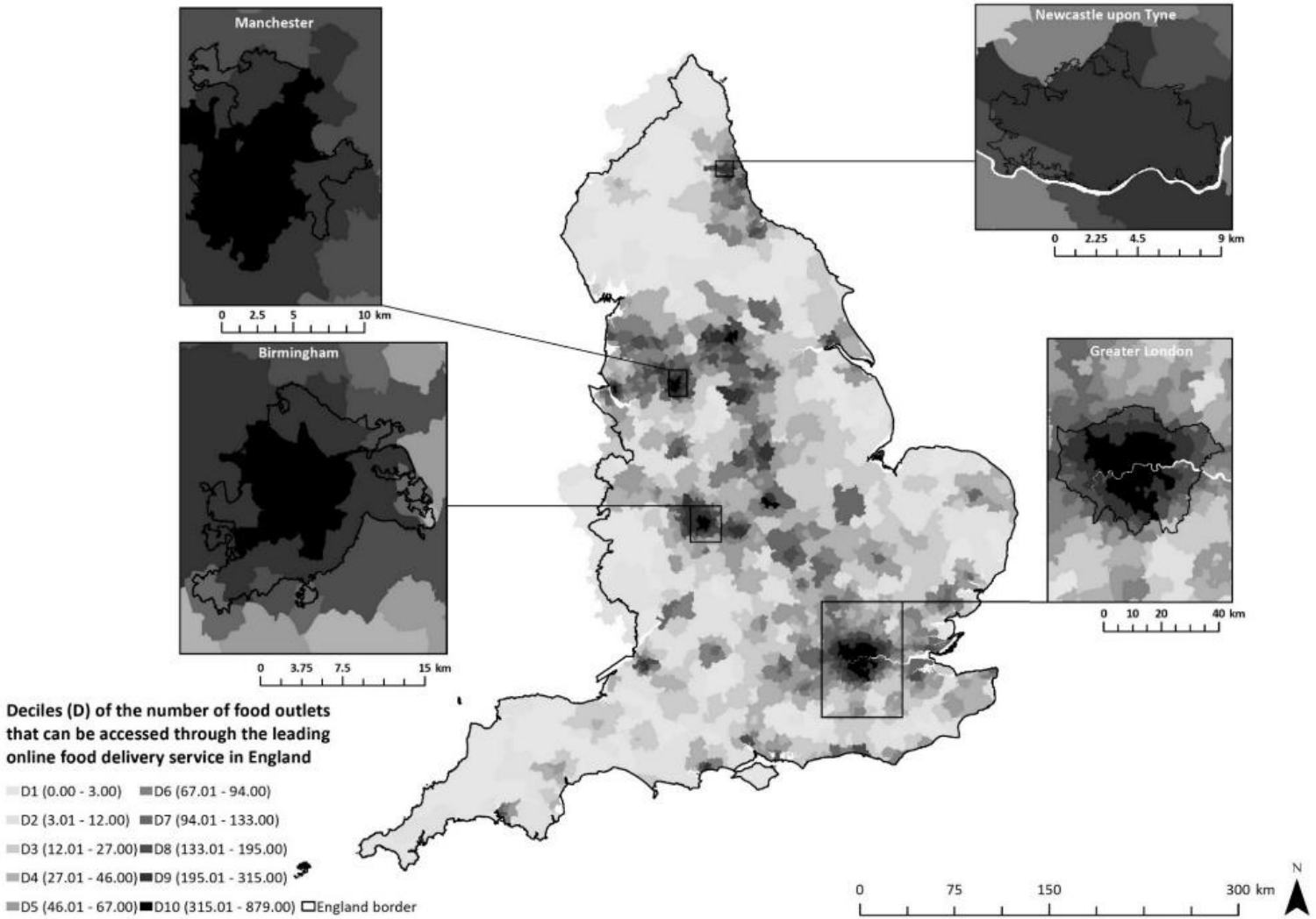

Figure 5.1: Deciles of the number (count) of food outlets accessible online across postcode districts (n=2118) in England in November 2019.

5.5.2 Association between deprivation and the percentage of food outlets registered to accept orders online

In the adjusted model, I observed evidence suggestive of a positive dose-response association between deprivation and the percentage of food outlets located in postcode districts registered to accept orders online (see Appendix D: Table S2). Figure 5.2 reports predicted means with 95% CI, calculated from the coefficients of the adjusted model. Postcode districts in deciles 8-10 of deprivation (i.e. more deprived areas) had significantly higher percentages of food outlets registered to accept orders online than those in decile 1 (the least deprived). In the most deprived postcode districts, 42.9% (95% CI: 40.7, 45.1) of food outlets were predicted to be registered to accept orders online, compared with 22.8% (95% CI: 20.7, 25.0) in the least deprived.

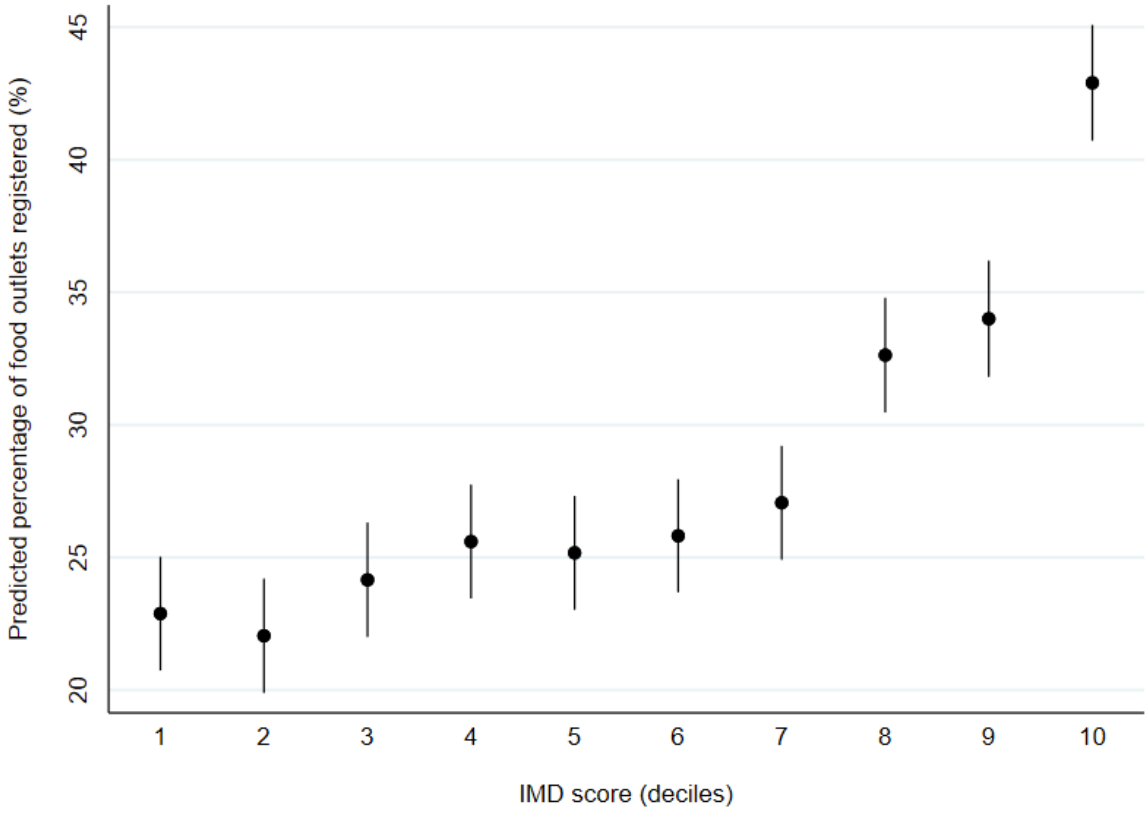

Figure 5.2: Percentage of food outlets registered to accept orders online across postcode districts (n=2084) in England in 2019.
Note: Data points are predicted means with 95% CI, calculated from coefficients estimated using a general linear model adjusted for rural urban classification and population density. IMD = Index of Multiple Deprivation.

5.5.3 Association between deprivation and online food outlet access

In the adjusted model, there was limited evidence of a trend in online food outlet access across deprivation deciles (see Appendix D: Table S3). Nevertheless, as shown in Figure 5.3, the predicted number of food outlets accessible online in the most deprived postcode districts (decile 10) was significantly higher compared with the least deprived postcode districts (106.1 outlets; 95% CI: 91.9, 120.3 and 70.4 outlets; 95% CI: 60.8, 80.1, respectively). Figure S1 (see Appendix D) shows the predicted number of food outlets accessible online across postcode districts in England, calculated from the IRR of the adjusted model. The clusters of postcode districts in the North East, North West, West-Midlands regions and in the Greater London with a high number of food outlets accessible online persisted.

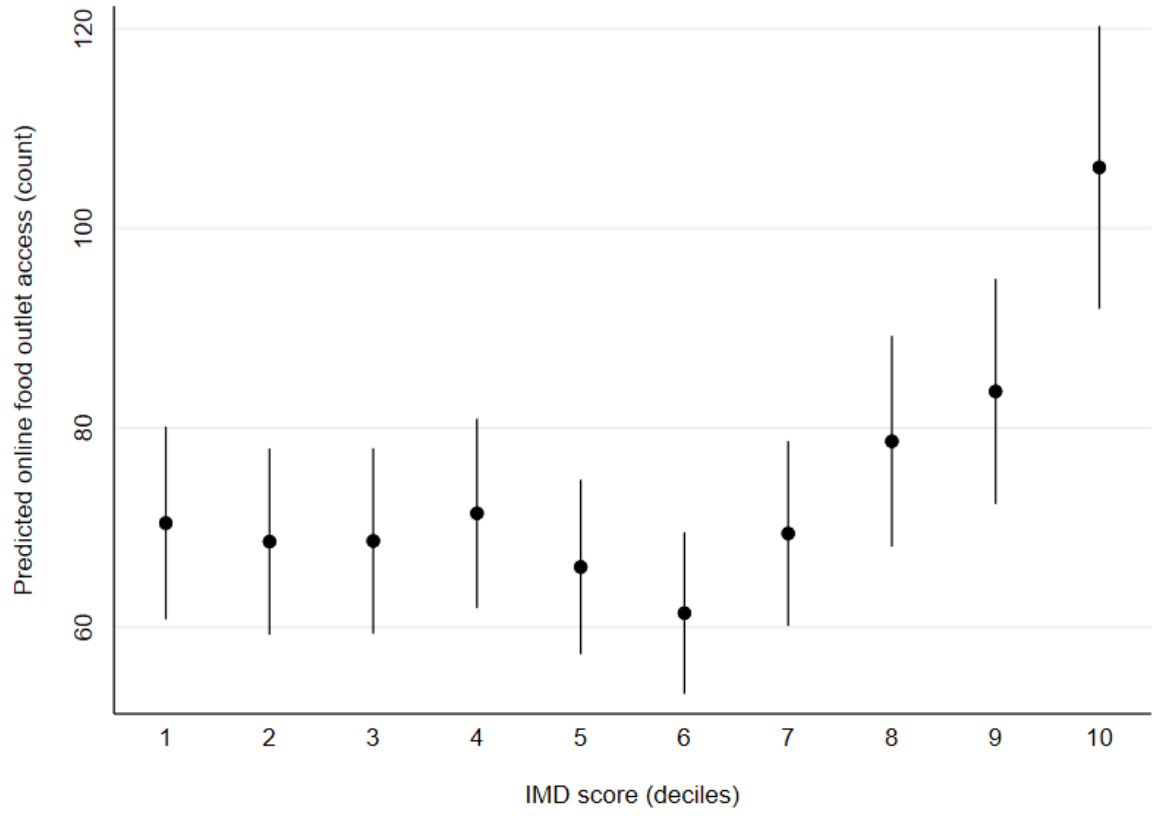

Figure 5.3: Number of food outlets accessible online across postcode districts (n=2088) in England in 2019.
Note: Data points are predicted means with 95% CI calculated from IRR estimated using negative binomial regression adjusted for rural urban classification, population density, and the number of food outlets in the physical food environment. IMD = Index of Multiple Deprivation.

5.5.4 Association between deprivation and unique cuisine type access

In the adjusted model, there was an inverse association between deprivation and the number of unique cuisine types accessible online (see Appendix D: Table S4). Figure 5.4 reports the predicted means with 95% CI, calculated from the IRR of the adjusted model. I observed evidence of a curvilinear relationship. The least deprived postcode districts had access to the greatest number of unique cuisine types (42.1; 95% CI: 39.1, 45.0).

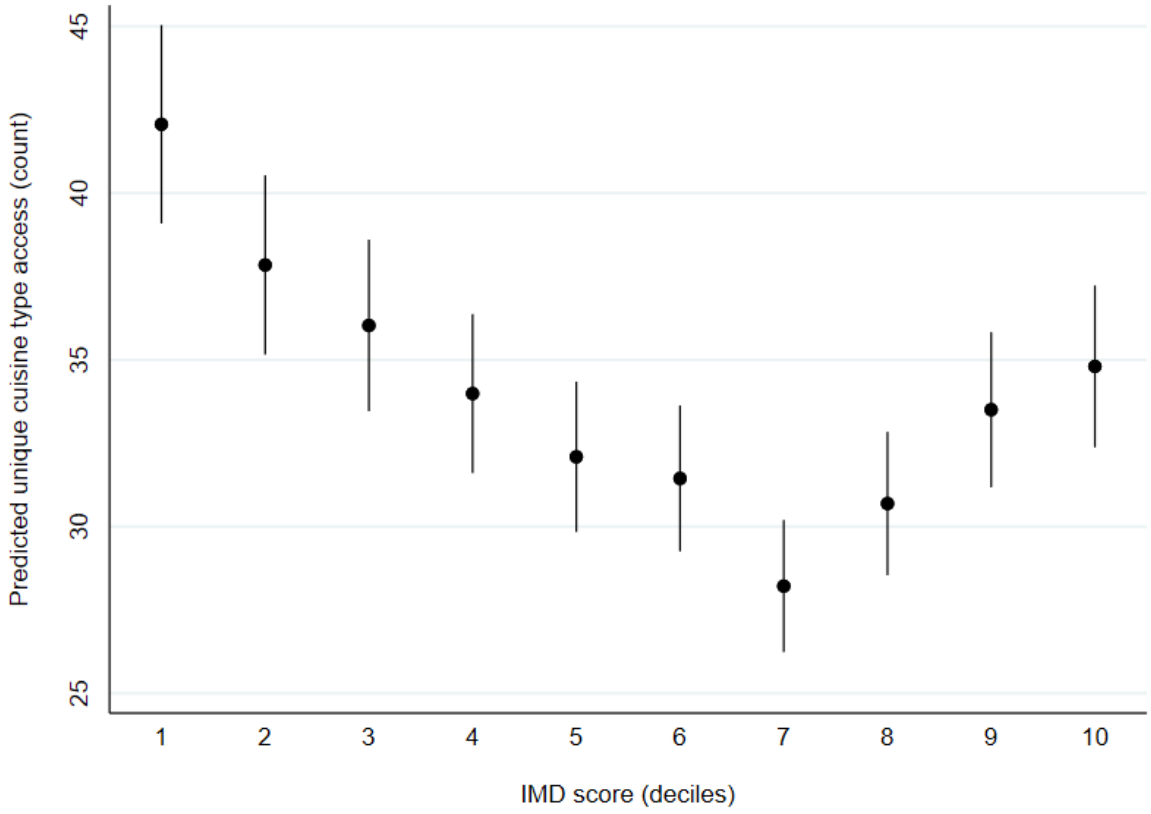

Figure 5.4: Number of unique cuisine types accessible online across postcode districts (n=2088) in England in 2019.
Note: Data points are predicted means with 95% CI, calculated from IRR estimated using negative binomial regression adjusted for rural urban classification, the number of food outlets in the physical food environment, population density and the number of food outlets accessible online. IMD = Index of Multiple Deprivation.

5.5.5 Association between deprivation and the percentage of neighbourhood food outlets accessible online

In the adjusted model, I observed evidence of a curvilinear relationship between deprivation and the number of food outlets accessible online expressed as a percentage of the number physically accessible in the neighbourhood (see Appendix D: Table S5). Figure 5.5 shows predicted means with 95% CI, calculated from the coefficients of the adjusted model. Postcode districts in deciles 3-9 of deprivation had a significantly lower percentage than the least deprived postcode districts. In the least deprived postcode districts, the number of food outlets accessible online as a percentage of the number of food outlets physically accessible in the neighbourhood was 86.2% (95% CI: 78.6, 93.7). This was greater than postcode districts in any other decile of deprivation.

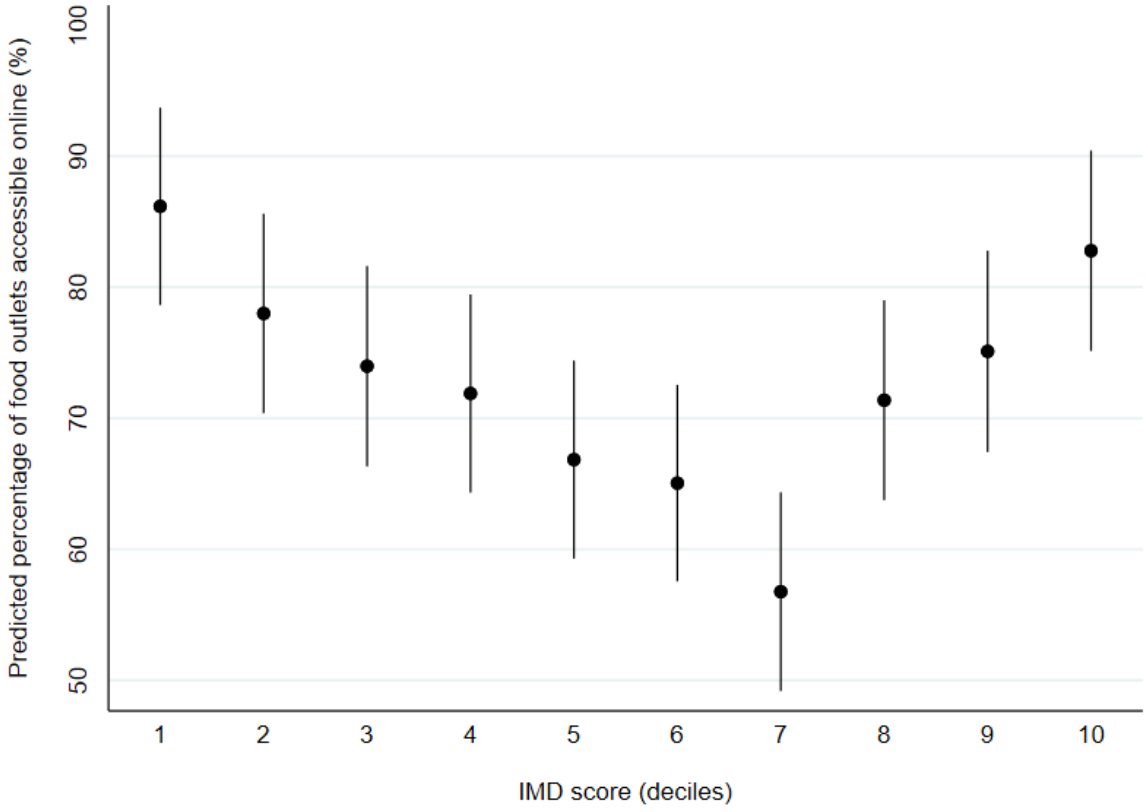

Figure 5.5: Number of food outlets accessible online expressed as a percentage of the number physically accessible in the neighbourhood across postcode districts (n=2076) in England in 2019.
Note: Data points are predicted means with 95% CI, calculated from coefficients estimated using a general linear model adjusted for rural urban classification and population density. IMD = Index of Multiple Deprivation.

5.5.6 Sensitivity analyses

Tables S6-S9 (see Appendix D) show that the strength of associations in sensitivity analyses were either similar or slightly attenuated compared with the main analysis. The percentage of food outlets registered to accept orders online located in postcode districts continued to be positively associated with deprivation when additional food outlet types were included in the denominator. The number of food outlets and unique types of cuisine accessible online continued to be greatest in the most deprived postcode districts when I adjusted for additional food outlet types. Similarly, the curvilinear relationship between deprivation and the number of food outlets accessible online expressed as a percentage of the number physically accessible in the neighbourhood persisted.

5.6 Discussion

5.6.1 Summary of findings

To the best of my knowledge, I have described online food outlet access across a whole country for the first time in the international published literature. I found that in 2019, almost 30,000 food outlets in England were registered to accept orders online, which was around a third of the number of outlets that predominantly sell food prepared out-of-home. A median of 64 food outlets and 39 unique cuisine types were accessible online per postcode district. Moreover, the median number of food outlets accessible online expressed as a percentage of the number physically accessible in the neighbourhood was 63%. I observed evidence of socioeconomic patterning. Although the number of food outlets accessible online was highest in the most deprived areas, it was widespread across England. Additionally, the number of food outlets registered to accept orders online, expressed as a percentage of the number in the physical food environment that predominantly sell food prepared out-of-home, increased with deprivation. The number of unique cuisine types accessible online and the number of food outlets accessible online expressed as a percentage of the number physically accessible in the neighbourhood were both greatest in the least deprived areas. However, I observed evidence of a curvilinear relationship for these measures.

5.6.2 Interpretation of findings

The number of food outlets registered to accept orders online, expressed as a percentage of the number in the physical food environment that predominantly sell food prepared out-of-home, increased with deprivation. In the most deprived areas, the percentage was around two times greater than in the least deprived areas. As far as I am aware, possible reasons for registering

with online food delivery services from the perspective of food outlet owners, and differences in levels of registration according to neighbourhood socioeconomic position, have not been investigated. The physical food environment is vital to the business model of online food delivery services. Food outlets serving food prepared out-of-home cluster together in more deprived areas (31, 303), which perhaps reflects lower retail unit rental costs, or because food business owners believe there will be increased demand due to greater population density (304). In the context of my research, registering to accept orders through an online food delivery service may be one way to `compete` with others. Although business owners must pay initial registration fees and ongoing commission to online food delivery services (169), it seems that even in more deprived areas, this does not outweigh the possible benefits. For example, being registered to accept orders online likely leads to a larger potential customer base and a greater volume of orders. This would allow revenue to be maximised compared with relying on customers visiting customer-facing premises. However, if and how this is the case remains unclear. Regardless, the findings I have presented demonstrate that there remains considerable scope for growth in the number of food outlets registered to accept orders online, including in the most deprived areas.

The absolute number of food outlets accessible online was 50% greater in the most deprived areas of England, compared with the least deprived areas, with evidence of a dose-response association. Online food delivery services plausibly allow food prepared out-of-home to be ordered from food outlets not accessible through other purchasing formats. In turn, this might change perceived access to food outlets in the physical food environment and influence purchasing practices. In contrast to my finding, in one city in each of Australia, the Netherlands and the USA, the number of food outlets accessible through an online food delivery service was not related to area-level socioeconomic position (156). This previous research included 10 locations sampled from the least and most deprived areas of each city. I completed the research in the current chapter on a national scale and included all areas from across the socioeconomic gradient. In doing so, I provide a more comprehensive assessment of online food outlet access.

The number of food outlets accessible online compared with the number of food outlets physically accessible in the neighbourhood of a given population was similarly high in the least and most deprived areas of England. If online food outlet access represents a health risk in addition to that posed by physical food outlet access, my finding suggests that all areas might be affected. However, absolute numbers of food outlets are typically greater in more deprived areas (31, 288-290). Since online food delivery services are a complementary way that food prepared out-of-home can be accessed, online food outlet access compounds access through

other purchasing formats. This might mean that populations living in areas with the highest number of food outlets accessible online and the highest number of physically accessible food outlets experience a `double-burden` of disadvantage. Indeed, purchasing food prepared out-of-home might be an increasingly natural response to enduring exposure across both the physical and digital food environment (141, 146).

The number of unique cuisine types accessible online was inversely associated with deprivation and highest in the least deprived areas. However, these areas also had the lowest absolute number of food outlets accessible online. As a result, the number of food outlets available *within* each unique cuisine category would be lower than elsewhere. This is particularly important to consider in the context of more deprived areas where the number of food outlets accessible online was highest. When registering to accept orders online, food outlets self-select the cuisine category that reflects the food they sell. To gain an advantage in a saturated market, food outlets may select a cuisine believed to differentiate them from others or one that would mean they appear in customer search results more frequently. My evidence from Chapter 4 suggested that the number of unique types of cuisine was not associated with online food delivery service use (214). However, food purchasing practices are complex and influenced by multiple factors (50), and frequent online food delivery service customers indicated that they were aware of the opportunity to access a variety of food online, which they felt was advantageous (242) (see Chapter 3). As such, it remains plausible that access to different types of cuisine is one of many factors that influences the use of online food delivery services.

5.6.3 Possible implications for public health and future research

As with physical access to food outlets that predominantly sell food prepared out-of-home, online food outlet access was greatest in the most deprived areas of England. For populations living in these areas, greater access to food prepared out-of-home through online food delivery services could be cause for public health concern since they may use this purchasing format more frequently. Indeed, in Chapter 4, I demonstrated that a higher number of food outlets accessible online was positively associated with online food delivery service use (214). In turn, this could contribute to existing diet-related inequalities. Exploring variation in levels of online food delivery service use based on area measures of socioeconomic position would extend the research in this chapter and complement the findings I presented in Chapter 4.

5.6.4 Strengths and limitations

As I understand it, this is the first study in the international published literature to investigate online food outlet access on a national scale. Nonetheless, my study is not without limitations. I

generated a novel dataset through an automated data collection approach. If food outlets were registered to accept orders through the online food delivery service but not returned in searches, it is possible that the data were incomplete. However, according to annual reports published by the data source, around 30,000 food outlets were registered to accept orders at the time of data collection (181). This number was similar to the number I identified, increasing confidence in the completeness of the data.

I used postcode districts as the unit of analysis. As such, my analyses may be subject to the modifiable areal unit problem (MAUP), whereby findings are sensitive to the shape of the spatial units or the scale of analysis, which has the potential to introduce bias (305). Although the MAUP is not unique to my study (26), in the context of my research, aggregating measures at the postcode district level would mean that I am unable to identify variation *within* studied areas studied. However, postcode districts were used by the online food delivery service so that food outlets could delineate their delivery areas, which helps to justify my approach. Using postcode districts as the unit of analysis also meant that I was limited to using boundary data from 2012. Although boundaries are subject to change over time, the inferences and conclusions drawn from my study are based on contemporaneous exposure and outcome data collected in 2019.

Finally, I operationalised neighbourhoods of given populations as a 1600 m radius around the geographic centroid of postcode districts. My use of a 1600 m radius may have influenced the magnitude of physical food outlet access in the neighbourhood. Although neighbourhoods are not consistently operationalised in this research area (25), a 1600 m radius has been shown to reflect the spatial extent of an individual's typical shopping practices, and this distance could be reasonably walked by an adult in around 20 minutes (265).

5.7 Conclusions

As far as I know, my study is the first to investigate online food outlet access on a national scale. Around one-third of food outlets that predominantly sell food prepared out-of-home were registered to accept orders online in November 2019. The number of food outlets accessible online was highest in the most deprived areas of England. Online food delivery services do not replace the opportunity to use other purchasing formats meaning that they increase overall access to food prepared out-of-home. This increased access could drive more frequent purchasing of food prepared out-of-home and widen existing diet and health inequalities. Despite having a lower number of food outlets accessible online, the number of unique cuisine types accessible online was highest in the least deprived areas.

Chapter 6:
Changes in online access to food prepared out-of-home in England over time and associations with socioeconomic position

6.1 Details of author contributions, publication status and dissemination

For the research in this chapter, I developed the research questions with guidance from JA and TB. I was responsible for data collection, preparation and analysis, and led the interpretation of findings with support from JA and TB. All authors read and provided critical comments on the initial manuscript and agreed to the version that is currently under peer review at JMIR Public Health and Surveillance. For my thesis, I present an extended version of the manuscript that is currently under peer review.

I presented the findings from this chapter during an oral presentation at the 2022 International Medical Geography Symposium (held in-person, Edinburgh, United Kingdom), and a poster presentation at the 2022 UK Public Health Science National Conference (held in-person, Glasgow, United Kingdom). For the latter, the conference abstract is published as: Keeble, M., Adams, J., Burgoine, T. (2022), Changes in online food access during the COVID-19 pandemic and associations with deprivation: a longitudinal analysis. The Lancet. https://doi.org/10.1016/S0140-6736(22)02264-4. I will also share the findings at the 2023 American Association of Geographers Annual Meeting during an oral presentation (held in-person, Denver, United States of America).

6.2 Abstract

Background

Food prepared out-of-home is typically energy-dense and nutrient-poor. Online food delivery services have become a popular way to purchase this food. The number of food outlets that can be accessed online (i.e. ordered from through these services) can influence how frequently they are used. Online food access reportedly increased in England between 2020 and 2022, in the context of the Coronavirus Disease 2019 (COVID-19) pandemic. However, the extent to which this changed is not currently clear. I aimed to investigate changes in online access to food prepared out-of-home over time, compared with a time before the onset of the COVID-19 pandemic. I also aimed to understand the extent to which any changes were associated with deprivation.

Methods

In November 2019, and monthly between June 2020 and March 2022, I used automated data collection to construct a dataset containing information about all food outlets in England registered to accept orders through the leading online food delivery service. Across postcode districts (n=2118), I identified the number and percentage of food outlets registered to accept orders online and the number of food outlets accessible online. I used generalised estimating equations (adjusted for population density, the number of food outlets in the physical food environment and rural urban classification) to investigate changes in each outcome compared to levels from before the COVID-19 pandemic (November 2019). I stratified analyses by area-level socioeconomic position (deprivation quintile (Q)).

Results

Across England, the number of food outlets registered to accept orders online increased from 29,232 in November 2019 to 49,752 in March 2022. The median percentage of food outlets registered to accept orders online increased from 14.3% (interquartile range (IQR): 3.8, 26.0) in November 2019 to 24.0% (IQR: 6.2, 43.5) in March 2022. The median number of food outlets accessible online decreased from 63.5 outlets (IQR: 16.0, 156.0) in November 2019 to 57.0 outlets (IQR: 11.0, 163.0) in March 2022. However, I observed variation across deprivation quintiles. In March 2022, the median number of outlets accessible online was 175.0 outlets (IQR: 104.0, 292.0) in the most deprived areas (Q5) compared to 27.0 outlets (IQR: 8.5, 60.5) in the least deprived (Q1). In adjusted analyses, I estimated that the number of outlets accessible online in the most deprived areas was 10% higher in March 2022, compared to November 2019 (incidence rate ratios (IRR): 1.10; 95% confidence intervals (CI): 1.07, 1.13). In contrast, in the least deprived areas, I estimated a 19% decrease (IRR: 0.81; 95% CI: 0.79, 0.83).

Conclusions

The number of food outlets accessible online increased only in the most deprived areas of England. Future research might attempt to understand the extent to which changes in online food outlet access that I observed were associated with changes in online food delivery service use and, in turn, possible implications for diet and health.

6.3 Introduction

Purchasing and consuming food prepared out-of-home has become increasingly popular in many countries (29). This food accounted for over 50% of total food expenditure in the United States of America (USA) in 2018 (285), and over one quarter of total food expenditure in the United Kingdom (UK) between 2015 and 2017 (306). Food prepared out-of-home is often high in calories (41, 175), and the majority of items served by large chain restaurants exceed recommended levels for salt, total fat, saturated fat, or sugars (45). More frequent consumption of this food has been positively associated with body weight (110). Online food delivery services such as Uber Eats are now an established way of purchasing food prepared out-of-home (307), and it is plausible that the use of these services has implications for diet and diet-related health (147).

When using online food delivery services, customers receive aggregated information about all food outlets they can order from based on an entered location (i.e. food outlets that are accessible). Customers then select a food outlet and place and pay for their order on a single platform. Orders are forwarded to food outlets where meals are prepared before being delivered by couriers working for them or the online food delivery service (147). As in the physical food environment (77), there is evidence that the number of food outlets accessible online can influence online food delivery service use at the individual level (214) (see Chapter 4). Moreover, before the Coronavirus Disease 2019 (COVID-19) pandemic, the potential for online food delivery service use was not equally distributed across England (213) (see Chapter 5). The estimated mean number of food outlets accessible online in 2019 was over 100 in the most deprived areas, compared with 70 in the least deprived areas (213), which could contribute to known inequalities in overall dietary patterns and diet-related health (308).

6.3.1 Access to food prepared out-of-home during the first two years of the COVID-19 pandemic

In March 2020, the UK government published guidance stating that individuals must remain at home if they had symptoms of COVID-19, or had tested positive for COVID-19 or been in contact with others who had. This was followed by a national `lockdown` that restricted non-essential travel and limited physical and social contact (309). Similar action was taken in other countries. Specifically with respect to out-of-home food retail, the Supplemental Nutrition Assistance Program was extended to include digital food retail in the USA (310), whilst rules around the delivery of food prepared out-of-home and alcohol were relaxed in Australia (311). As part of the national lockdown in the UK, the UK government forced the closure of outlets

serving food for on-premises consumption (312, 313). This meant that bars, cafés, pubs and restaurants could no longer operate with their `primary` function (the primary function of a pub is a drinking establishment, for example). However, at the same time, the UK government introduced emergency regulations that allowed bars, cafés, pubs and restaurants to temporarily operate in a manner that was not their primary function by offering an expanded hot food takeaway service. Before the introduction of these emergency regulations, a pub would have been able to offer only a limited hot food takeaway service in addition to their primary function. Under the emergency regulations, however, they could primarily offer a hot food takeaway service (314). Emergency regulations ended in March 2022. Therefore, after March 2022, bars, cafés, pubs and restaurants should have reverted to their primary function and stopped offering an expanded hot food takeaway service. However, planning professionals from one region in the North East of England reported that due to limited resources during the early stages of the COVID-19 pandemic, the number of outlets that operated with an expanded hot food takeaway service under the emergency regulations was unclear (315). Figure 6.1 provides a timeline of the aforementioned events and information about periods of time when on-premises consumption of food prepared out-of-home would and would not have been possible.

Pre-March 2020		Food outlets in the physical food environment operated with a `primary use` based on their core business operations. The primary use of hot food takeaway outlets would be to serve food prepared out-of-home for off-premises consumption, after previously receiving Local Authority [a] planning permission to operate. Other establishments (bars, cafés, pubs and restaurants) could offer a hot food takeaway service in addition to their primary use, but would need Local Authority planning permission to do so. All food outlets with a customer-facing premises in the physical food environment could feasibly register to accept orders online regardless of their primary use, without Local Authority planning permission [b].
2020	March	Bars, cafés, pubs and restaurants forced to close for on-premises food consumption as part of **first** national lockdown [c]. Emergency regulations to allow bars, cafés, pubs and restaurants to offer a hot food takeaway service in addition to their primary use introduced.
	July	Bars, cafés, pubs and restaurants allowed to reopen for on-premises food consumption, but only with table service and with restricted capacity.
	August	`Eat Out to Help Out` scheme that offered a 50% discount on meals, up to £10 per person, every Monday, Tuesday and Wednesday between 3 and 31 August introduced (for on-premises food consumption only).
	November	Bars, cafés, pubs and restaurants forced to close for on-premises food consumption as part of **second** national lockdown [c]. Emergency regulations introduced in March 2020 extended until March 2022.
	December	Bars, cafés, pubs and restaurants allowed to reopen for on-premises food consumption, but only with table service and with restricted capacity.
2021	January	Bars, cafés, pubs and restaurants forced to close for on-premises food consumption as part of **third** national lockdown [c].
	April	Bars, cafés, pubs and restaurants allowed to reopen for on-premises food consumption, but only with table service and with restricted capacity.
	July	End of restrictions necessitating table service only and capacity limits for on-premises food consumption inside bars, cafés, pubs and restaurants.
2022	March	End of emergency regulations introduced in March 2020.
Post-March 2022		Bars, cafés, pubs and restaurants *should* revert to their primary use, and *should* stop offering a hot food takeaway service if adopted as part of emergency regulations. To continue offering an additional hot food takeaway service, Local Authority planning permission required. All food outlets with customer-facing premises in the physical food environment can feasibly register to accept orders online regardless of their primary use, without Local Authority planning permission.

Figure 6.1: Details of selected emergency regulations introduced, action taken, and broader events in England in relation to the COVID-19 pandemic and food outlets selling food prepared out-of-home.

Notes: [a] Local Authorities are administrative bodies that operate at a sub-national and sub-regional level.
[b] Registration to accept orders online through online food delivery services remained viable regardless of any subsequent action or change.
[c] As part of `lockdown` orders in England, individuals were instructed to `remain at home`.

6.3.2 Possible implications for access to food prepared out-of-home through online food delivery services

It is plausible that food outlets operating with an additional hot food takeaway service under the aforementioned emergency regulations registered to accept orders through online food delivery services. From a business perspective, on-premises food consumption was restricted at times throughout 2020 and 2021 (see Figure 6.1), and therefore, accepting orders through these services could have been an important source of income. Reflective of this, each of Just Eat, Deliveroo and Uber Eats reported an increase in the number of food outlets registered with their services or increased revenue in the UK between 2020 and 2021 (316-318). Focusing on Just Eat as the market leader in the UK, the number of food outlets registered to accept orders across the UK and Ireland in 2021 reportedly increased by 21%, compared with 2020, exceeding 60,000 in total (316). The extent to which these increases were driven by the uptake of emergency regulations is unclear. It is equally possible that the reported increase reflects existing hot food takeaway outlets that were not yet registered to accept orders online choosing to do so. Nevertheless, the reported increase suggests that online access to food prepared out-of-home increased over this period of time. Food sold through online food delivery services is typically prepared inside of existing customer-facing food outlets located in the physical food environment (147). As I discussed in Chapter 1 (see Section 1.2.5.3), the number of food outlets located in the physical food environment is typically higher in more deprived areas of England (31, 319). As such, there was greater potential for existing food outlets to operate under the emergency regulations introduced in March 2022 and to register to accept orders through online food delivery services in more deprived areas compared with less deprived areas. Furthermore, the research I presented in Chapter 5 demonstrated that even before the COVID-19 pandemic, the number of food outlets accessible online was highest in the most deprived areas of England (213). If food outlets that could have potentially registered to accept orders online did so, the number of accessible outlets would plausibly increase further. Given that the number of food outlets accessible online was associated with online food delivery service use amongst adults living across Great Britain (214) (see Chapter 4), greater access might lead to more frequent use amongst existing customers and prompt others to become customers. In turn, this could widen diet-related inequalities.

6.3.3 Study aims

My primary aim was to investigate changes in online access to food prepared out-of-home in England between 2020 and 2022, within the context of the COVID-19 pandemic. Second to this, I aimed to identify the extent to which any changes were associated with area-level socioeconomic position.

6.4 Methods

In this chapter, I build on the research from Chapter 5, where I investigated cross-sectional associations between deprivation and online food outlet access in England.

6.4.1 Study setting, period, and analytic scale

The study setting was England. The study period was November 2019 to March 2022, which coincided with the end of the emergency regulations introduced in March 2020 (see Section 6.3.1: Figure 6.1). Data were not collected between December 2019 and May 2020, meaning that the first available data after November 2019 were from June 2020.

I completed analyses at the postcode district level. This analytic scale reflected the delivery areas of food outlets registered to accept orders online in November 2019 (213, 214) (see Chapters 4 and Chapter 5). Postcode districts are the first half of full postcodes. For the *postcode* `CB2 0QQ`, the *postcode district* is `CB2`. Postcode districts have an average size of 33 mi^2 (255), and a median population of 23,610 (interquartile range (IQR): 13,320, 34,560) (298).

I used boundary data from 2012, sourced from the UK data service (296), to map postcode districts in a geographic information system (GIS) (ArcGIS version 10.7.1; ESRI Inc., Redlands, CA). Like Chapter 5, I included 2118 postcode districts, which were those entirely within the border of England, as well as those in Scotland or Wales with an intersecting boundary (food outlets could be located in these countries yet deliver to locations in England).

6.4.2 Exposure measure

The exposure was time. I characterised the exposure as `month` because I collected data for outcome measures on a monthly basis, as I will discuss in the next sections.

6.4.3 Outcome measures: data source and collection

I collected data from an online food delivery service widely recognised as the UK market leader (Just Eat) to construct each outcome measure. In 2019, around 30,000 food outlets in the UK

were registered to accept orders through Just Eat, and there were almost 170 million orders placed by customers (252, 292). In pilot work (see Appendix C: Figure S1), only a minority of food outlets registered to accept orders through Deliveroo (the next largest online food delivery service in the UK) were not also registered to accept orders through Just Eat in 2020 (213, 214) (see Chapters 4 and 5). Therefore, I used data from Just Eat as a proxy for online food delivery services. I refer to my data source as `the online food delivery service` hereafter.

I used the same automated data collection approach as outlined in Chapters 4 and 5. Briefly, monthly between June 2020 and March 2022, I used a web-browser extension to identify and collect information about all food outlets registered to accept orders through the online food delivery service across England, Scotland and Wales (299). I completed data collection at the same time each month, with the process taking around 72 hours.

6.4.3.1 Number of food outlets registered to accept orders online

I used Doogal (a free web-based resource) to geocode the postcode of each food outlet identified during data collection (263). When geocoding through Doogal was not successful, I used the GeoConvert tool (maintained by the UK Data Service) (264). I excluded food outlets that could not be geocoded (monthly range: 0.1 to 1.4%). I then mapped the locations of food outlets in a GIS based on supplied coordinates and counted the number located inside each postcode district boundary.

6.4.3.2 Number of food outlets accessible online

In November 2019, June 2020, and July 2020, food outlets registered to accept orders online published the postcode districts that they would deliver to as their `delivery areas`. I collected this information during the data collection described in Section 6.4.3. After July 2020, the online food delivery service no longer published this information. Therefore, between August 2020 and March 2022, I manually identified and counted the number of food outlets that were accessible for each postcode district. Although I used two approaches, the data used in outcome measure construction were the same.

6.4.3.3 Percentage of food outlets registered to accept orders online

I compared the number of food outlets registered to accept orders online to the number located in the physical food environment of the same postcode district. In doing so, I calculated the percentage of food outlets registered to accept orders online.

For the denominator (the number of outlets located in the physical food environment within postcode districts), I used Ordnance Survey Points of Interest (OS POI) data. This is commercial data containing information about retailers across multiple sectors, collated from over 170 suppliers (262). I extracted information for the following food outlet classifications: `Fast food and takeaway outlets` (food outlets selling food prepared out-of-home for off-premises consumption), `Fast food delivery services` (food outlets selling food prepared out-of-home for delivery, not explicitly through online food delivery services), `Fish and Chip shops` (food outlets selling a traditional British cuisine, prepared out-of-home, typically for off-premises consumption), `Restaurants` (food outlets selling food prepared out-of-home for on-premises consumption), `Pubs, Bars, Inns` (establishments primarily serving alcohol, that can also sell prepared out-of-home for on-premises consumption), and `Cafe, Snack Bars & Tea Rooms` (food outlets selling food prepared out-of-home with no distinguishable consumption location). I selected these classifications based on *a priori* knowledge that they included food outlets typically registered to accept orders online, and to reflect the types of food outlets that emergency regulations introduced in March 2020 allowed to operate with an additional hot food takeaway service (see Section 6.3.1: Figure 6.1). I used coordinates supplied in OS POI data to map the locations of food outlets in the GIS. These coordinates are reported to be accurate up to one metre (262).

I matched monthly data from the online food delivery service with OS POI data that is collected quarterly (see Appendix E: Table S1). I did not match individual food outlets listed in each dataset, meaning that this outcome is the number of food outlets registered to accept orders online (based on data from the online food delivery service) as a percentage of the number of food outlets in the physical food environment (based on OS POI data). Although I report a percentage, I acknowledge that in the strictest sense it has not been calculated as such. As the number of food outlets registered to accept orders online should not exceed the number of food outlets in the physical food environment, I bounded this measure to between 0% and 100%. When the percentage exceeds 100% it represents that retailers not classified as a food outlet in OS POI data were registered to accept orders online. I excluded postcode districts when this occurred (n=3; 0.14%).

6.4.4 Covariates

The following covariates were `time invariant`, meaning that they did not change over the study period.

6.4.4.1 Index of multiple deprivation

I used data from the 2019 Index of Multiple Deprivation (IMD) to measure relative deprivation. This is a compound measure of deprivation that includes metrics across seven domains: income deprivation, employment deprivation, crime levels, health deprivation and disability, education, skills and training deprivation, barriers to housing and associated services and living environment deprivation (297). Deprivation values are available for lower super output areas (LSOAs) in England, which are administrative boundaries with a mean residential population of 1500 people (298). As LSOAs are typically geographically smaller than postcode districts, I aggregated LSOAs within and intersecting the boundary of each postcode district and calculated the mean IMD score. For analyses, I split postcode districts into quintiles (Q) of deprivation, where Q5 contained the most deprived.

6.4.4.2 Rural Urban classification and population density

I used data from the 2011 rural urban classification to categorise postcode districts as: `rural`, when LSOAs within or intersecting their boundary were most frequently rural (populations less than 10,000 people within combined settlements, the majority of which live in rural-related areas) or `urban` when intersecting LSOAs were most frequently urban (populations greater than 10,000 people within combined settlements, the majority of which live in urban-related areas) (300). Data for rural urban classification were available for 2097 postcode districts (99.0%).

I used data from the 2011 UK census (301) to identify the usual residential population of each postcode district. This is the number of individuals that usually reside in a postcode district, including students and schoolchildren not living away from home during term-time. Data for population density were available for 2088 (98.6%) postcode districts.

6.4.5 Statistical analysis

I used the longitudinal-analysis (`xt`) suite of tools in Stata version 16.1 (StataCorp LLC., College Station, TX, USA) to complete statistical analysis (320). I report findings from the start (November 2019) and end (March 2022) of the study period in the Results. Findings for all time points (November 2019, and then monthly between June 2020 and March 2022) are available in Appendix E.

6.4.5.1 Descriptive statistics

As data for each outcome were not normally distributed, I calculated the median and interquartile range (IQR). I also calculated the percent change from baseline (i.e. November 2019) at each time point.

6.4.5.2 Inferential statistics

I used generalised estimating equations (GEE) to investigate changes in each outcome over time. Generalised estimating equations fit generalised linear regression models that estimate a population (i.e. postcode district) average (320). Models were first unadjusted and then adjusted for covariates. I report findings from adjusted models in the Results and unadjusted models in Appendix E. For each set of respective analyses, I included postcode districts with complete data on all relevant measures. Moreover, I specified an `exchangeable` correlation structure to assess monthly changes compared with baseline (November 2019). Due to non-data collection between December 2019 and May 2020, I was unable to use other correlation structures.

Data for count-based outcomes (the number of food outlets registered to accept orders online and the number of food outlets accessible online) were not normally distributed and were over-dispersed. I used negative binomial GEE to account for this. Negative binomial GEE report incidence rate ratios (IRR) and 95% confidence intervals (CI). In the context of my research, IRR are the expected change in the outcome at each time point compared with baseline (November 2019). For the percentage of food outlets registered to accept orders online, I rescaled the data to between 0 and 1 and specified a binomial distribution (321). Model coefficients for this outcome are the change in percentage at each time point compared with baseline. For each outcome, I used the `margins` command to estimate the marginal mean count from IRR and the mean percentage from coefficients and report these in the Results. I report the respective IRR and coefficients in Appendix E.

6.4.5.3 Associations with deprivation

For each outcome, I included an interaction term (time x deprivation) in the adjusted GEE to investigate how changes over time varied by level of deprivation and completed a post-hoc test for significance (with statistical significance set at $p<0.01$ to account for multiple testing). When interaction terms were significant, I completed analyses stratified by deprivation quintile.

In November 2019, there were inequalities in access to food outlets selling food prepared out-of-home in the digital food environment (213) (see Chapter 5). For each outcome, I calculated a slope index of inequality measure at baseline (November 2019) and at the end of the study

period (March 2022) to investigate how inequalities changed over time. This measure of inequality is the difference in the respective outcome between the least and most deprived areas, estimated using linear regression (322, 323).

6.5 Results

6.5.1 Number of food outlets registered to accept orders online

Figure 6.2 reports changes in the number of food outlets registered to accept orders online in England. I observed an increase from 29,232 in November 2019 to 49,752 in March 2022, equating to 70.2% growth.

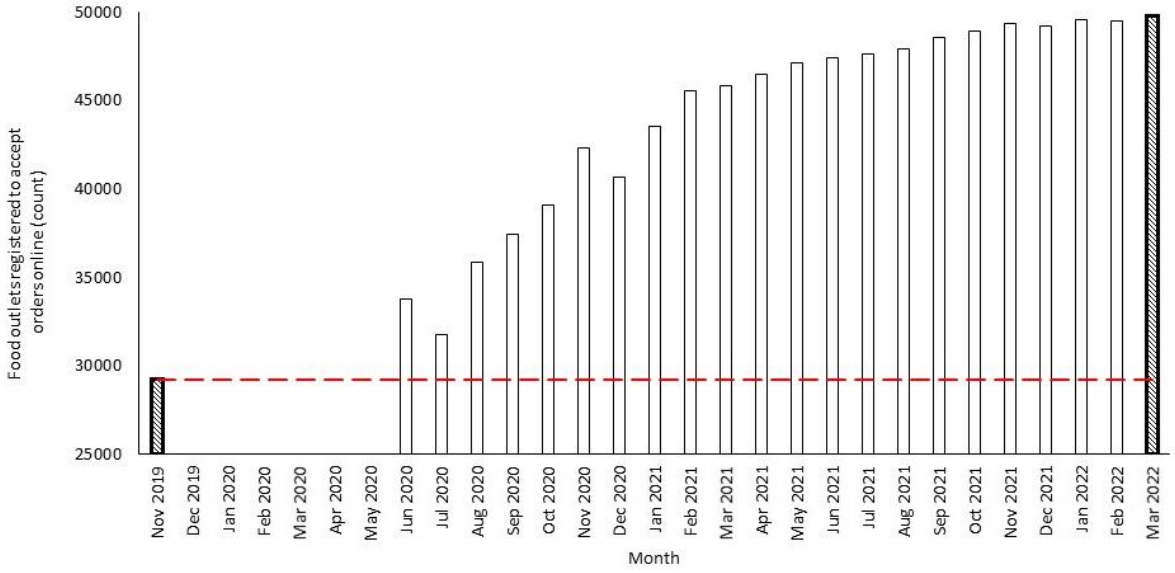

Figure 6.2: Count of food outlets registered to accept orders online in England between baseline (November 2019) and the end of the study period (March 2022).
Notes: shaded bars represent time points reported in the Results. Data for all time points are reported in Appendix E. No data were available from December 2019 to May 2020.

Table 6.1 and Tables S2-S9 (see Appendix E) summarise online access to food prepared out-of-home in England. The median number of food outlets registered to accept orders online per postcode district was 7.0 (IQR: 1.0, 21.0) in November 2019 and 13.0 (IQR: 3.0, 34.0) in March 2022. The median percent change from baseline (November 2019) per postcode district was 65.4 (IQR: 33.3, 100.0) in March 2022 (see Table 6.1).

The increase in the number of food outlets registered to accept orders online across England as a whole was significant at each time point (see Appendix E: Table S11), and there was a significant effect modification by deprivation quintile on time ($p<0.001$).

Figure 6.3 shows the estimated mean number of food outlets registered to accept orders online, calculated from the IRR of the adjusted negative binomial GEE. At each level of deprivation, I observed that the estimated mean number of food outlets registered to accept orders online had initially increased from baseline levels (November 2019), decreased after June 2020, and then consistently increased, except between November 2020 and December 2020. The estimated mean number was highest in the most deprived areas (Q5) and lowest in the least deprived (Q1) throughout the study period. Absolute growth over time was highest in the most deprived areas, where the estimated mean number was 39.1 outlets at the end of the study period compared with 24.6 outlets at baseline. For the least deprived areas, the number was 6.6 and 3.5 outlets, respectively. The slope index of inequality between the least and most deprived areas was 5.0 outlets (95% CI: 4.5, 4.5) at baseline, and 7.8 outlets (95% CI: 7.0, 8.6) in March 2022.

Table 6.1: Descriptive summary of online access to food prepared out-of-home across postcode districts in England (n=2118), at baseline (November 2019) and the end of the study period (March 2022), stratified by deprivation quintile.

	Deprivation quintile					
	1 (least deprived)	2	3	4	5 (most deprived)	England
Number of food outlets registered to accept orders online [a b]						
Count						
November 2019	3.0 (1.0, 8.0)	4.0 (1.0, 12.0)	6.0 (1.0, 18.0)	13.0 (3.0, 25.0)	24.0 (12.0, 39.0)	7.0 (1.0, 21.0)
March 2022	5.0 (1.0, 15.0)	8.0 (1.0, 21.0)	10.0 (2.0, 29.0)	21.0 (4.0, 41.0)	35.0 (20.0, 59.0)	13.0 (3.0, 34.0)
Change from baseline (%) [c]						
March 2022	80.0 (22.2, 120.0)	69.0 (33.3, 120.0)	66.7 (30.0, 106.3)	62.8 (33.3, 100.0)	57.9 (34.0, 87.5)	65.4 (33.3, 100.0)
Number of food outlets accessible online [d]						
Count						
November 2019	37.0 (14.0, 70.5)	38.0 (10.0, 96.0)	62.0 (8.5, 134.5)	86.0 (12.0, 190.0)	164.0 (87.0, 273.0)	63.5 (16.0, 156.0)
March 2022	27.0 (8.5, 60.5)	27.0 (6.0, 103.0)	50.0 (6.5, 133.5)	95.0 (13.0, 217.0)	175.0 (104.0, 292.0)	57.0 (11.0, 163.0)
Change from baseline (%) [c]						
March 2022	-12.7 (-48.6, 20.0)	-7.5 (-48.8, 28.6)	-1.1 (-35.0, 33.2)	13.8 (-18.2, 52.5)	13.1 (-7.9, 33.8)	0.0 (-32.0, 33.3)
Percentage of food outlets registered to accept orders online [e]						
Percent (%)						
November 2019	7.9 (2.2, 14.9)	8.7 (1.5, 19.0)	12.5 (1.9, 23.5)	20.4 (6.5, 30.8)	27.8 (19.7, 37.4)	14.3 (3.8, 26.0)
March 2022	13.2 (4.7, 25.9)	14.9 (4.1, 33.3)	20.5 (5.3, 36.6)	30.8 (11.3, 46.6)	41.9 (30.7, 52.4)	24.0 (7.7, 41.0)
Change from baseline (%) [c]						
March 2022	70.7 (16.7, 116.0)	62.0 (25.0, 106.2)	55.1 (24.0, 98.9)	53.0 (24.8, 88.9)	44.8 (22.4, 75.8)	55.3 (23.0, 96.1)

Notes: [a] Data are reported as Median (IQR). Postcode districts are small geographical units used for mail and delivery routing in England.
[b] Food outlets in the physical food environment registered to accept orders through the UK market leading online food delivery service.
[c] Baseline = November 2019.
[d] Food outlets registered to accept orders online through the UK market leading online food delivery service that would deliver to a given postcode district.
[e] Calculated as the number of food outlets registered to accept orders online through the UK market leading online food delivery service compared with the number in the physical food environment, expressed as a percentage.

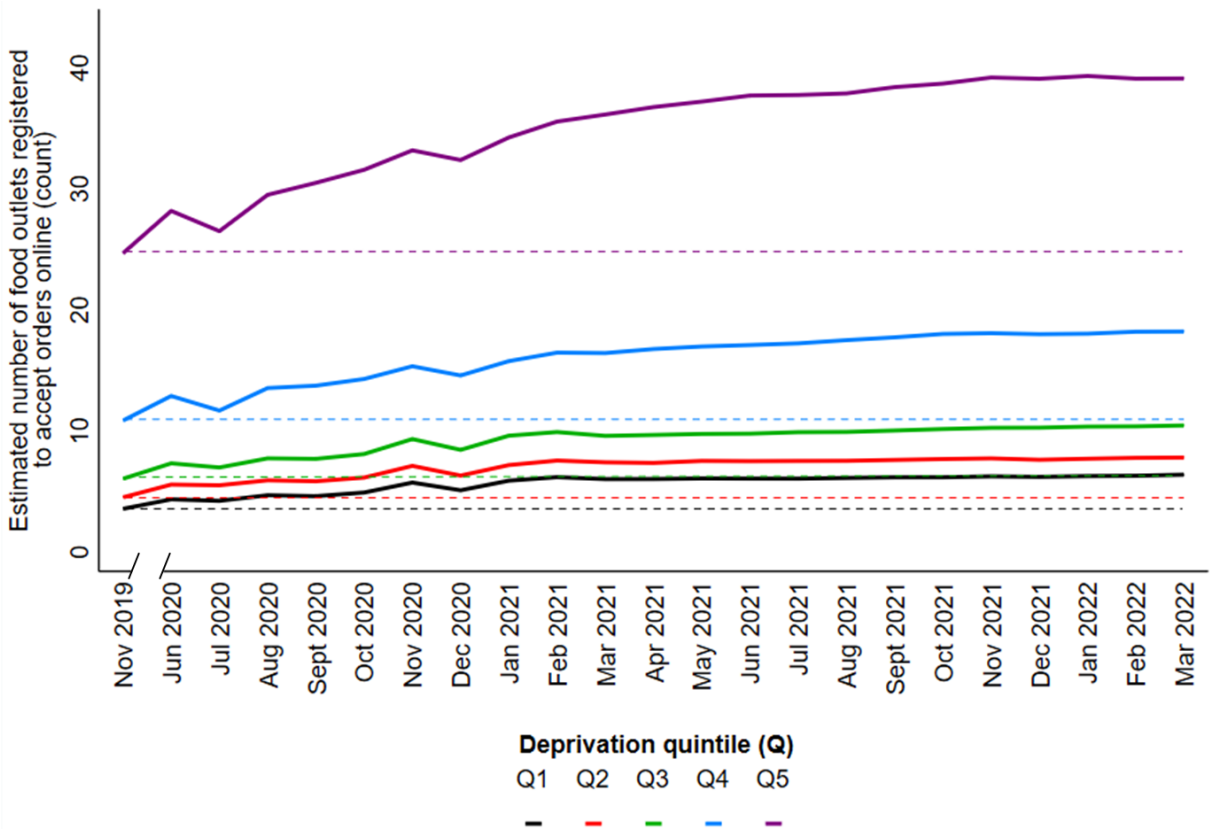

Figure 6.3: Estimated mean number (count) of food outlets registered to accept orders online in England between November 2019 and March 2022, stratified by deprivation quintile.
Notes: 2067 postcode districts included. Quintile (Q) 5 are the most deprived postcode districts. Dashed lines are the baseline (November 2019) number. No data were available from December 2019 to May 2020. Estimated mean number calculated from Incidence Rate Ratios (IRR) of a negative binomial generalised estimated equation adjusted for population density, rural urban classification and the number of food outlets in the physical food environment.

6.5.2 Number of food outlets accessible online

The median number of food outlets accessible online per postcode district was 63.5 (IQR: 16.0, 156.0) in November 2019 and 57.0 (IQR: 11.0, 163.0) in March 2022. The median percent change from baseline per postcode district was 0.0 (IQR: -32.0, 33.3) in March 2022 (see Table 6.1).

The decrease in the number of food outlets accessible online across England as a whole was significant at each time point (see Appendix E: Table S13), and there was a significant effect modification by deprivation quintile on time ($p<0.001$).

Figure 6.4 reports estimated means calculated from the IRR of the adjusted negative binomial GEE. At each level of deprivation, I observed that the estimated number of food outlets accessible online had decreased from baseline in June 2020. Although this was followed by an upward trajectory, the estimated number remained lower than baseline in less deprived areas (Q1-Q3), but surpassed baseline in areas in the two upper quintiles of deprivation (Q4 and Q5).

This increase was significant for the most deprived areas only (see Appendix E: Table S13). For the most deprived areas, the estimated number increased from 181.9 outlets in November 2019 to 200.0 outlets in March 2022, which contributed to an increasing gap in online food outlet access between the least and most deprived areas. The slope index of inequality between the least and most deprived areas was 32.0 outlets (95% CI: 28.1, 35.9) at baseline, and 37.3 outlets (95% CI: 31.8, 42.9) in March 2022.

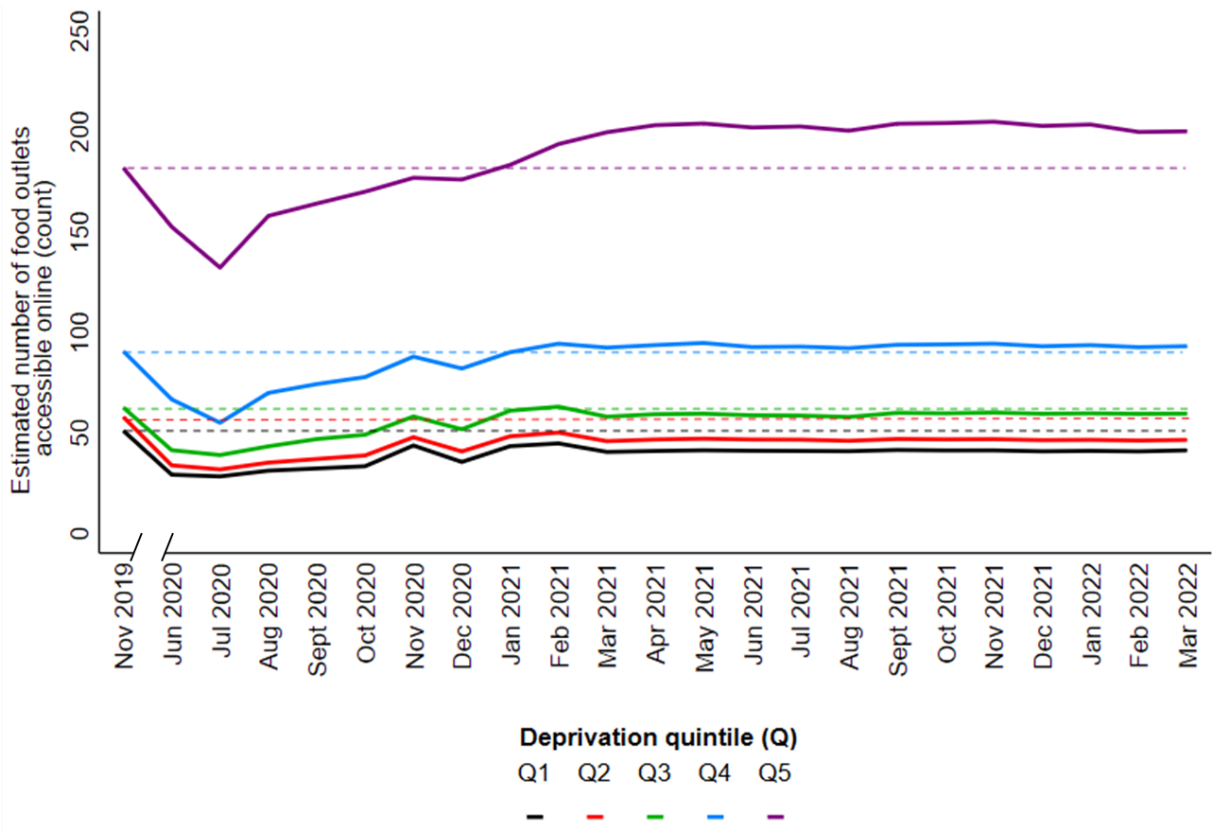

Figure 6.4: Estimated mean number (count) of food outlets accessible online in England between November 2019 and March 2022, stratified by deprivation quintile.
Notes: 2067 postcode districts included. Quintile (Q) 5 are the most deprived postcode districts. Dashed lines are the baseline (November 2019) numbers. No data were available from December 2019 to May 2020. Estimated mean number calculated from the Incidence Rate Ratios (IRR) of a negative binomial generalised estimated equation adjusted for population density, rural urban classification and the number of food outlets in the physical food environment.

6.5.3 Percentage of food outlets registered to accept orders online

The median number of food outlets registered to accept orders online as a percentage of the number of food outlets in the physical food environment per postcode district was 14.3 (IQR: 3.8, 26.0) in November 2019 and 24.0 (IQR: 7.7, 41.0) in March 2022. The median percent change from baseline per postcode district was 55.3 (IQR: 23.0, 96.1) in March 2022 (see Table 6.1).

The increase in the percentage of food outlets registered to accept orders online across England as a whole was significant at each time point (see Appendix E: Table S15), and there was a significant effect modification by deprivation quintile on time ($p<0.001$).

Figure 6.5 reports estimated means calculated from the coefficients of the adjusted GEE. At each level of deprivation, I observed an initial increase from baseline in June 2020 that was followed by a decline, a second increase that equalled or surpassed previous levels, and then another decline before a somewhat more stable increase. Although this trend was evident across all levels of deprivation and the estimated percentage was significantly increased at each level of deprivation by the end of the study period, the magnitude varied. Nevertheless, the estimated mean percentage was highest in the most deprived areas (40.0% in March 2022 compared with 27.4% in November 2019), with these areas also having a higher growth over time in absolute terms, compared with less deprived areas. The slope index of inequality between the least and most deprived areas was 4.5% (95% CI: 4.1, 4.9) at baseline, and 5.9% (95% CI: 5.4, 6.5) in March 2022.

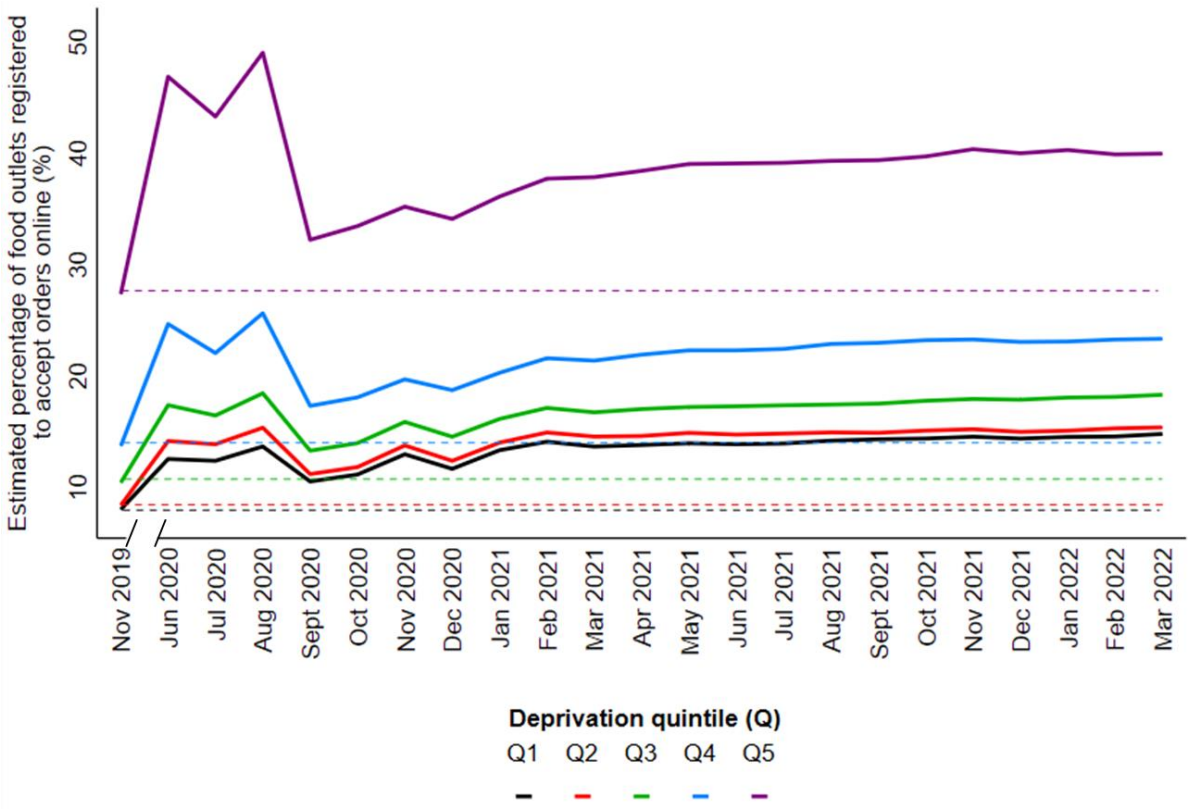

Figure 6.5: Estimated mean percentage (%) of food outlets registered to accept orders online in England between November 2019 and March 2022, stratified by derivation quintile.
Note: 2065 postcode districts included. Quintile (Q) 5 are the most deprived postcode districts. Dashed lines are the baseline (November 2019) percentages. No data were available from December 2019 to May 2020. Estimated mean percentage calculated from the coefficients of a generalised estimating equation adjusted for population density and rural urban classification.

6.6 Discussion

6.6.1 Summary of findings

As far as I am aware, my study was the first to examine changes in online access to food prepared out-of-home over time. For England as a whole, I identified an increase in the number of food outlets registered to accept orders online, with this reaching around 50,000 by March 2022. There was a parallel increase in the percentage of food outlets in the physical food environment registered to accept orders online. In contrast, the number of food outlets accessible online (i.e. those that could be ordered from by a given population in a postcode district), was on average lower in March 2022 than before the COVID-19 pandemic in November 2019. However, the magnitude of change for all measures of online access to food prepared out-of-home varied by level of deprivation. The most deprived postcode districts consistently had the highest number and percentage of food outlets registered to accept orders online. Importantly, contrary to the overall trend for England, the number of food outlets accessible

online was higher in March 2022 than at baseline in the most deprived areas. I did not observe this for less deprived areas, where the number decreased in some instances. As a result, the inequalities in the opportunity to use online food delivery services to purchase food prepared out-of-home that I reported in Chapter 5 widened over time.

6.6.2 Interpretation of findings

My finding that an increased number of food outlets had registered to accept orders online over the first two years of the COVID-19 pandemic is aligned with reports from major online food delivery services operating in England, as well as from business and news media (317, 318). Moreover, the decrease I observed in June 2020 and July 2020, accords with contemporaneous reports of food outlet closures and decreased order volume through online food delivery services (324). After July 2020, I observed a more consistent increase in the number of food outlets registered to accept orders online. As opportunities for on-premises food consumption were limited by national stay-at-home orders imposed in March 2020, followed by periods of time with restrictions that limited the number of customers consuming purchase food inside of outlets, food business owners perhaps made a strategic business decision to register to accept orders online as a way to generate revenue.

For England as a whole, I identified a decline in the number of food outlets *accessible* online between November 2019 and March 2022. This is in contrast to the increased number of food outlets *registered* to accept orders. The decline I observed was particularly pronounced in the early stages of the COVID-19 pandemic, which might have reflected a period of transition amongst food outlets that had only recently registered to accept orders online. Those that were previously unaccustomed to food delivery may have been operating with a limited delivery radius to ensure they could fulfil customer orders. Moreover, there was broader workforce instability during a time when self-isolation rules were in place, unclear restrictions on maximum travel distances legally allowed and concerns for online food delivery service courier safety (325). In combination, these factors might have contributed to the implementation of limited delivery distances and a reduced number of accessible food outlets.

The initial decline in the number of food outlets accessible online was followed by an increase at all levels of deprivation. However, as of March 2022, it was only amongst more deprived areas, and particularly the most deprived, that the number eventually surpassed levels from November 2019. As I reported in Chapter 5, the number of food outlets accessible online was highest in the most deprived areas of England in November 2019, before the COVID-19 pandemic (213). In the current study, I found evidence of an increasing divergence between the least and most

deprived areas, suggesting that inequalities in online access to food prepared out-of-home widened during the first two-years of the COVID-19 pandemic. Food sold through online food delivery services is commonly delivered by couriers on bicycles (169). As such, the distance that can be travelled whilst maintaining food quality has a natural limit. Due to the spatial distribution of food outlets in England, which is socioeconomically patterned (21, 31, 319), it is likely that the distance between food outlets and customers is shorter (and thus within any natural limit) in more deprived areas compared with less deprived areas. Regardless, given that the number of food outlets accessible online is positively associated with online food delivery service use, as I reported in Chapter 4 (214), it is possible that food purchasing practices were negatively influenced during the COVID-19 pandemic, especially amongst populations living in more deprived areas. Any changes to purchasing practices, could have implications for overall dietary patterns and diet-related health in the longer-term, however, these are unlikely to be immediately observable (326). Further research is required to help better understand how changes in online food outlet access influenced online food delivery service use, and the possible longer-term implications of this on health.

The number of food outlets registered to accept orders online as a percentage of the number of food outlets in the physical food environment had increased by March 2022. However, this increase was only apparent after a period of early instability. Food business owners with a customer-facing premises in the physical food environment reported that being registered to accept orders online was a way for customers to access their food when on-premises food consumption and travel were restricted (325). However, when restrictions ended, simultaneously managing orders placed in-person and online was difficult (325). As a result, it is possible that food business owners who only registered to accept orders online out of necessity when on-premises food consumption was restricted later de-registered when restrictions ended. This scenario would partly explain the successive increases and decreases in the percentage of food outlets registered to accept orders online, which coincided with the start and end of restrictions (see Figure 6.5).

The relative change over time for the percentage of food outlets registered to accept orders online was consistent across all levels of deprivation. However, the absolute change was highest in the most deprived areas, which led to a widening of inequalities in access to food prepared out-of-home. Food sold through online food delivery services is typically prepared inside of existing customer-facing food outlets located in the physical food environment (147). As such, my finding reflects existing urban form in the most deprived areas of England, which has a high density and concentration of food outlets (327, 328), and a concomitant increase in the number

of food outlets registered to accept orders online. Although professionals in practice recognise uncertainty due to a lack of monitoring (315), my findings provide evidence to suggest that the introduction of emergency regulations at least partly contributed to a widening of inequalities in online food access.

As of March 2022, the number of food outlets registered to accept orders online as a percentage of the number of food outlets in the physical food environment per postcode district was 24%. As such, there remains considerable scope for food outlets in the physical food environment to register to accept orders online. The scope for a further increase emphasises the coexisting nature of both the physical and digital food environment, leading to overlapping opportunities to purchase food prepared out-of-home (329). On balance, however, there are natural limits to growth since not all business owners necessarily need or want to register to accept orders online. The relative stability of each outcome from June 2021 onwards suggests a plateau might have already occurred. An apparent plateau might help to explain the decision from online food delivery services to withdraw from countries with poor revenue or growth prospects (211).

6.6.3 Possible implications for public health and future research

Over half of the Local Authorities in England have used urban planning to attempt to create healthier physical food environments by preventing new hot food takeaway outlets from opening (330). Although not yet fully clear, like the physical food environment, interventions to restrict access to food prepared out-of-home through online food delivery services might be necessary in the future (145, 212). However, using urban planning to directly target restrictions at online food delivery services might not be possible due to a lack of regulatory mechanisms (144). Accordingly, new public health interventions that account for the business model of online food delivery services may need to be developed.

The emergency regulations introduced in March 2020 ended in March 2022 (314). As a result, bars, cafés, pubs and restaurants *should* have reverted to their primary use and stopped offering an additional hot food takeaway service if they did not previously have permission. However, this does not necessarily mean that they would have had to stop accepting orders online. It is plausible that the levels of online food access I observed in March 2022 will be sustained in the future. In turn, this new baseline of online food access could influence the purchase and consumption of food prepared out-of-home. It would be interesting for future work to investigate the extent to which food outlets that operated within emergency regulations up until

March 2022 remained registered to accept orders online, even if they should have legally stopped offering an additional hot food takeaway service.

6.6.4 Strengths and limitations

I collected data over a period of two years, for a whole country. My data collection allowed me to monitor trends in online access to food prepared out-of-home on a monthly basis. An important limitation of my research, however, is that I do not have substantial pre-pandemic data that would allow any existing trends to be accounted for in analyses. Nevertheless, despite a period of missing data from before the onset of the COVID-19 pandemic in March 2020, and then between March 2020 and May 2020, I present new baseline levels of online access to food prepared out-of-home that can be used for future assessment.

I used postcode districts as the unit of analysis and acknowledge the possibility that my findings are subject to the modifiable areal unit problem (MAUP). Although the spatial unit I used for analyses has the potential to introduce bias (305), my approach reflected information published by the online food delivery service and allowed consistency with the research I presented in Chapter 5 (213).

Food outlets newly registered to accept orders online might have operated with an additional hot food takeaway service under the emergency regulations that were in place between March 2020 and March 2022. Although I have provided evidence about the total number of food outlets registered to accept orders at a given time point, I am unable to comment on whether those newly registered were operating under the emergency regulations. In turn, this limits my ability to conclude that the emergency regulations increased online access to food prepared out-of-home.

6.7 Conclusions

I investigated if and how online access to food prepared out-of-home changed over time, compared with November 2019. The number of food outlets in England that were registered to accept orders online increased. In parallel, the number of food outlets registered to accept orders online as a percentage of the number of food outlets in the physical food environment increased. Although the number of food outlets accessible online decreased for the whole of England, trends differed by level of deprivation. The number of food outlets accessible online decreased in the least deprived areas. However, the number of food outlets accessible online was maintained in more deprived areas, and increased to the largest extent in the most deprived areas.

Overall, then, I identified that online access to food prepared out-of-home changed over time, in the context of the first two-years of the COVID-19 pandemic. During this period of time, on-premises consumption of food prepared out-of-home was often restricted and it is possible that sociocultural norms about accessing this food were influenced. Data from March 2022 represent a new baseline from which future changes in access to food prepared out-of-home through online food delivery services can be assessed. Future research might attempt to understand the extent to which the changes I identified were associated with changes in online food delivery service use and in turn, longer-term implications for overall dietary patterns and diet-related health.

Chapter 7:
Discussion

I start this chapter by summarising and interpreting the principal findings of the research presented in previous chapters. After this, I discuss the overarching methodological considerations of my research and outline possible implications for public health and future research.

7.1 Summary and interpretation of principal findings

Returning to the aims of my thesis, I wanted to provide an improved understanding of the use of online food delivery services to access food prepared out-of-home, specifically with regard to the:

1. Prevalence of online food delivery service use and sociodemographic characteristics of customers.
2. Experiences of online food delivery service use from the perspective of customers.
3. Associations between measures of access to food prepared out-of-home through online food delivery services and online food delivery service use and body weight.
4. Extent to which access to food prepared out-of-home through online food delivery services is socioeconomically patterned, and how this access and any inequality changed over time.

I addressed my first aim in Chapter 2. I found that 15% of respondents living across Australia, Canada, Mexico, the United Kingdom (UK), and the United States of America (USA) reported use of an online food delivery service in the week prior to online survey completion, with the highest prevalence in Mexico. Online food delivery service customers were often male, younger, lived with children, and more highly educated. Furthermore, they often identified with an ethnic minority. Patterns were largely similar across countries. My findings for online food delivery service customers were consistent with evidence on the sociodemographic characteristics of adults reported to consume food prepared out-of-home in Australia (84), Canada (219), the UK (40, 111), and the USA (331). The consistency between my findings and this previous research suggests that population groups with certain sociodemographic characteristics purchase and consume food prepared out-of-home. To some extent, therefore, it might be possible to

transfer findings from the physical food environment to the context of the digital food environment. The similarities in sociodemographic characteristics also make the findings from my qualitative research particularly useful because they help to understand possible reasons for using one purchasing format over another.

In Chapter 3, where I addressed my second aim, frequent online food delivery service customers recognised that these services facilitate access to food prepared out-of-home. Indeed, participants reported that purchasing this food was one reason for using these services. A growing body of evidence indicates that the foods sold through online food delivery services are high in calories, total fat, saturated fat and salt (159, 162, 165, 168), which was aligned with participant expectations about `takeaway food`. This insight into sociocultural norms about food prepared out-of-home has relevance for multiple purchasing formats.

Each domain of food access was discussed in some way by the frequent online food delivery service customers in my research. For instance, participants discussed how the type and price of food (i.e. acceptability and affordability) and estimated delivery times (i.e. accommodation) influenced their online food delivery service use. Additionally, participants reported that the number of food outlets they could order from (i.e. availability and accessibility) was influential because it was higher and more varied than in the physical food environment. This perspective was supported by quantitative evidence in Chapter 4, where I addressed my third aim. In this chapter, I reported that respondents with the highest number of food outlets accessible online (between 182 and 879) had greater odds of online food delivery service use compared to those with the lowest number. Together, these findings provide confidence that the multiple domains of food access are relevant to the use of online food delivery services. Although I did not identify an association between the number of food outlets accessible online and body weight, this outcome is further along the causal pathway. The plausible relationship between online food delivery service use and body weight might be better investigated through other measures of exposure such as food purchasing data. I will discuss this further in Section 7.4.3.

I proposed that online food access precedes the use of online food delivery services and that individual-level sociodemographic characteristics might influence the decision to seek out these services. A notable finding from Chapter 4 was that the highest number of food outlets accessible online (i.e. the greatest exposure) was positively associated with online food delivery service use amongst individuals with the highest level of education, yet not those who were less well educated. A higher level of education can be protective against the influence of food outlet exposure in the physical food environment in terms of purchasing available food (109, 332), which is in contrast to my finding. Individuals of a higher socioeconomic position (for example,

those who are more highly educated) are often early-adopters of new technology (333). This might mean that they are more inclined to use online food delivery services to purchase food prepared out-of-home because it is aligned with broader digital technology use. Moreover, level of education contributes to differences in the types of food purchased out-of-home (111). Although my qualitative research in Chapter 3 indicated that online food delivery services were used to purchase energy-dense and nutrient-poor food, individuals with a higher level of education may identify and purchase relatively healthier foods due to having greater health literacy (189). This might be especially possible when a higher number of food outlets are accessible.

I addressed my fourth aim in Chapter 5, where I found that the number of food outlets accessible online was highest in the most deprived areas of England, and that levels were almost 50% greater than in the least deprived areas (106 outlets versus 70 outlets). I also addressed my fourth aim in Chapter 6, where I found that the number of food outlets accessible online significantly increased between November 2019 and March 2022 in the most deprived areas of England, but not in less deprived areas. Moreover, the number and percentage of food outlets in the physical food environment registered to accept orders online also increased over time and were consistently highest in the most deprived areas of England. Although these changes in online access to food prepared out-of-home cannot be directly attributed to the Coronavirus Disease 2019 (COVID-19) pandemic, my findings indicate that existing differences widened over this period of time. My findings are consistent with evidence that increases in the prevalence of childhood obesity were greatest in the most deprived areas of England between 2020 and 2021 (334).

7.2 Methodological considerations

I have considered the strengths and limitations of my research in each respective chapter. In this section, I discuss broader methodological considerations that are relevant to my research.

7.2.1 Confounding and reverse causality

The research in my thesis had either a cross-sectional or repeat cross-sectional study design. For many reasons, it is not generally possible to make strong causal inferences from the findings of research with these study designs (62). First, like other study designs, it is possible that the findings are subject to bias from unmeasured confounding (62). An unmeasured confounder is a variable associated with both an exposure and an outcome of interest that is not subsequently accounted for in analyses (335). In Chapter 4, I investigated the relationship between the number of food outlets accessible online (exposure) and online food delivery service use

(outcome). In this instance, the outcome was proximal and specific to the measured exposure and on a plausible pathway, which helps to minimise (although not eliminate) the risk of bias from unmeasured confounding (257). These considerations are also outlined in the Bradford Hill `criteria` commonly used to assess the causal nature of research findings (336, 337). Nevertheless, it is plausible that the positive association I reported was subject to unobserved factors. Online food delivery service customers may have selected to live in a certain area to gain access to better travel infrastructure and local amenities, which in turn might lead to a higher number of food outlets in the physical food environment and greater online food outlet access. As such, the association I observed may be attributable to lifestyle preferences that I did not account for (338, 339). Furthermore, the findings that I presented in Chapter 3 suggested that the price of food and marketing influenced online food delivery service use. However, these were not captured in my exposure measure.

Second, the findings from research with a cross-sectional or repeat cross-sectional study design, including my own, are vulnerable to bias from reverse causality. This bias refers to instances where an outcome precedes and influences the exposure rather than vice versa, which hampers the opportunity to make strong causal inferences (337, 340). It is possible that bias from reverse causality was present in the aforementioned positive association between the number of food outlets accessible online and online food delivery service use. For example, the use of online food delivery services by customers might influence the number of food outlets that register to accept orders online and become accessible in a given area, rather than exposure to food outlets through online food delivery services influencing online food delivery service use. Elsewhere, in Chapter 2, for example, it is unlikely that bias from reverse causality is a concern in associations between sociodemographic characteristics such as age and sex and online food delivery service use (62).

7.2.2 Generalisability

The research in my thesis was mostly conducted in England; a high-income, westernised country, where the consumption of food prepared out-of-home is popular (40, 341). Online food delivery services have been available in England since around 2006 (163, 316), and are used to a greater extent than in some other high-income countries (183, 211). Online food delivery services have only become available in some low- or middle-income countries and other high-income countries more recently than England (144). Access to and use of these services may be limited in these countries because it has not yet become normal to purchase food prepared out-of-home in this manner. However, online food delivery services are becoming increasingly available worldwide, which might influence sociocultural norms (147). Moreover, a global

nutrition transition has been underway for several years, with worldwide purchasing practices increasingly reflecting `western` culture (8, 206, 342). This global nutrition transition might mean that there is an increased demand for food prepared out-of-home through online food delivery services in the future. Therefore, although my findings might have limited generalisability to some countries as it stands, they provide insight into the mechanisms through which future demand would be met.

7.2.3 Investigating multiple domains of food access

Previous research in the physical food environment has tended to investigate the availability and accessibility domains of food access through measures of food outlet presence, density, or proximity (27, 77, 90). In part, the focus on these domains (rather than affordability, acceptability or accommodation) reflects the use of secondary data that are publicly available (26, 291). Moreover, to a limited extent, food outlet availability and accessibility precede the remaining domains of food access (343). Nevertheless, investigating domains of food access in isolation does not capture the multiple and complex factors that influence food purchasing practices (76, 89). Although I too investigated the availability and accessibility domains of food access in Chapters 4, 5, and 6, I also used qualitative research to investigate the remaining domains in Chapter 3. Doing so was important because it provided a comprehensive account of online food delivery service use. It also provided evidence about domains of food access that are not necessarily spatially dependent, such as the opportunity to reallocate time while waiting for meal delivery (i.e. accommodation).

7.2.4 Approach to, and scale of, data collection

I used web scraping to automate data collection from the leading online food delivery service in the UK. My use of web scraping was a considerable strength because it allowed me to conduct analyses on a national scale. In turn, in Chapters 5 and 6, I provided evidence about variation in measures of online food access across England as a whole. Doing so expanded the scope and scale of previous research that was conducted within single cities, which might have limited variability in terms of exposures and outcomes measured. Moreover, my use of web scraping allowed me to maintain a consistent data collection schedule and construct a national dataset spanning 22 months that will now be difficult to reconstruct retrospectively. While there are some concerns about the use of web scraping, including copyright infringement issues, these have not become fully established (344). Moreover, this data collection approach has been used in previous food retail research (345), and by the Office for National Statistics (the executive office of the UK Statistics Authority), who published a `web scraping policy` containing data

collection principles (346). I adhered to these principles throughout my data collection, for example, by including an appropriate delay between searches on the online food delivery service website so as not to overwhelm their servers.

Although the use of web scraping was a considerable strength of my research, there were also limitations. Collecting data from a single online food delivery service and not collecting data from small-scale services plausibly underestimated access to food prepared out-of-home through this type of service. To investigate the extent to which data collection from a single online food delivery service would lead to exposure misclassification, I compared information about food outlets identified through my data source with information collected from the next largest online food delivery service operating in England. For one region in England, over 90% of food outlets appeared in both datasets (see Appendix C: Figure S1). This comparison was useful because it provided confidence in data completeness as any undercounting was likely to have been small. Nevertheless, future research should aim to include data from multiple online food delivery services, especially since the types of food outlets registered to accept orders through certain online food delivery services might differ. Any differences might mean that the accessible food is not consistent in terms of its energy and nutrient content.

7.2.5 Purposeful exposure to online food delivery services

To become fully aware of the number of food outlets that can be ordered from (i.e. that are accessible), individuals must enter a delivery location on the platform of a given online food delivery service. It is only at this point that `exposure` to food outlets, as I conceived it in my research, truly occurs. As such, it is possible that the findings I reported in Chapter 4 are subject to bias that is comparable to selective daily mobility bias in studies investigating physical food environment exposures. This bias describes instances where exposure to food outlets, for example, is a result of individuals intentionally visiting an outlet to purchase a meal. In the context of my research, the presence of this bias would make it difficult to determine the extent to which personal preferences influence interactions with online food delivery services and subsequent exposure to food outlets that can be ordered from (347, 348). Relatedly, in Chapters 5 and 6, I provided evidence on the potential to use online food delivery services. For this potential to be realised, given populations living in the studied areas would need to be online food delivery service customers.

7.3 Possible implications for public health and policy

My empirical research has not established a definitive need for public health intervention. Nevertheless, the European region of the World Health Organization (WHO) have raised concerns about online food delivery service use because the foods available to purchase are typically high in calories, total fat, saturated fat and salt. In turn, they have indicated that public health intervention may be required in the future (212). My research also suggests, subject to further investigation, that this may be required. In the next sections, I will discuss opportunities for public health intervention from the perspective that it may be necessary in the future.

7.3.1 The interdependency of the physical and digital food environments

The business model of online food delivery services is predicated on the interdependency of the physical and digital food environments, especially the location of customer-facing food outlets. As a result, public health interventions adopted in the physical food environment are likely to influence food retail in the digital food environment. For instance, urban planning determines the spatial structures of an area (327), and public health planning documents outline how professionals in practice might prevent new outlets that would be selling food prepared out-of-home from opening (54, 55, 349, 350). As of 2018, half of Local Authorities in England (n=164, 51%) had adopted an urban planning policy to prevent new hot food takeaway outlets from opening in their boundary area (330), with a similar approach adopted in the USA (351). Implementation of this intervention would transfer to the digital food environment since a new food outlet would not have been allowed to open, thereby preventing it from registering to accept orders through online food delivery services. Given the coexisting nature of access to food prepared out-of-home in the physical and digital food environments, and despite the apparent increase in the popularity of using online food delivery services, public health interventions that include aspects of the physical food environment continue to be relevant. This seems especially the case since almost two-thirds of respondents in Chapter 2 had purchased food prepared out-of-home in the past week, but had not used an online food delivery service.

Other public health interventions might seek to address online food delivery service marketing in the physical food environment, which can include advertising inside of food outlets and on bus shelters, delivery couriers with branded clothing and transport, and food arriving in online food delivery service (rather than individual food outlet) branded packaging. Although being an online food delivery service customer may have led to greater awareness (101), the participants in my qualitative research recognised that the aforementioned marketing was present in the physical food environment (see Chapter 3). Moreover, given that the number of food outlets

registered to accept orders online was highest in the most deprived areas of England (see Chapters 5 and 6), it is reasonable to suggest that online food delivery service marketing is more prevalent in these areas. As marketing influences the purchase and consumption of food prepared out-of-home (149, 352), interventions could aim to limit exposure to this in the physical food environment. There is precedent for such approaches, with advertising restriction on the Transport for London network successfully reducing the purchase of energy, sugar and fat from foods high in fat, salt and sugar amongst populations living in the intervention area (353).

7.3.2 A public health intervention involving multiple stakeholders

In the previous section, I described interventions that seek to improve public health by restricting exposure to customer-facing food outlets and online food delivery service marketing in the physical food environment. However, frequent online food delivery service customers in my qualitative research reported no intention to discontinue their online food delivery service use (see Chapter 3). In part, this was because the food available through these services met their expectations about what takeaway food `should` be in terms of its type and energy and nutrient content. Public health interventions that attempt to guide choice towards foods that are lower in calories and nutrients of public health concern, rather than necessarily attempting to prevent online food delivery service use, are likely to be most aligned with my findings (354, 355).

An example of such an approach is the introduction of a food healthiness rating score for individual food businesses registered to accept orders online. These scores would be determined and assigned based on the composition of menus and the energy and nutrient content of foods sold, with businesses that have a healthier rating then *automatically* appearing first in customer search results (157). There is evidence that this type of intervention was acceptable to online food delivery service customers who had the opportunity to personalise how search results were displayed to them (for example, based on food healthiness) (356). Moreover, this intervention could influence purchasing practices since it is aligned with formative evidence that prioritising food businesses selling lower energy items when presenting search results on a simulated online food delivery service website led to the purchase of 12% fewer calories (166 kcal) compared with a control set of search results (357). Elsewhere, one systematic review reported that prominent placement of healthier items (according to the Eatwell Guide published by Public Health England) in supermarkets was associated with an increased purchase of displayed foods (358).

Introducing a food healthiness rating score and automatically presenting food businesses with a healthier rating first in customer search results would be multi-faceted and require the input of multiple stakeholders. Thus, it is useful to assess the mechanisms through which such an intervention might influence the purchase and consumption of food prepared out-of-home. Automatically presenting businesses selling healthier items first in customer search results might encourage retailers to reformulate their current menu items or to develop new menus according to nutritional standards required to achieve a healthier score. In the USA, mandatory calorie labelling on menus was associated with a reduction in the energy and salt content of food sold by large chain restaurants (359, 360). A food healthiness rating score could arguably operate in a similar manner. Additionally, food sold through online food delivery services is typically prepared inside of existing customer-facing premises in the physical food environment (39, 147). Public health interventions that aimed to improve the nutritional quality of food sold out-of-home by having businesses adapt their cooking practices through recipe reformulation and changing ingredients were acceptable and implementable (278, 361). If successful, these improvements would transfer to the food sold through online food delivery services. Finally, as online food delivery services already dictate the content and style of information displayed to customers (362), there is an opportunity for them to ensure that information about food healthiness rating scores of businesses (as well as information about their menu, hygiene rating, and food prices and pictures) are presented in a manner that maximises customer engagement. This might include the allocation of a colour based on food healthiness rating scores, which would be similar to the use of traffic light schemes on food packaging that can favourably influence food purchasing (363).

7.4 Future research agenda

Figure 7.1 is an amended version of the proposed causal pathway that I presented in Figure 1.6 (see Section 1.4.4). Solid lines in Figure 7.1 represent evidence generated from the research I presented in Chapters 2 to 6. Despite my contribution to knowledge, further research is required to understand the need for public health intervention and the consistency of the associations I observed. The latter is outlined in the Bradford Hill `criteria` I referred to in Section 7.2.1 (337). This further research might also investigate distal outcomes of online food delivery service use, such as those linked to the consumption of food prepared out-of-home, including cardiovascular diseases (364). In the next sections, I outline a possible agenda for future research.

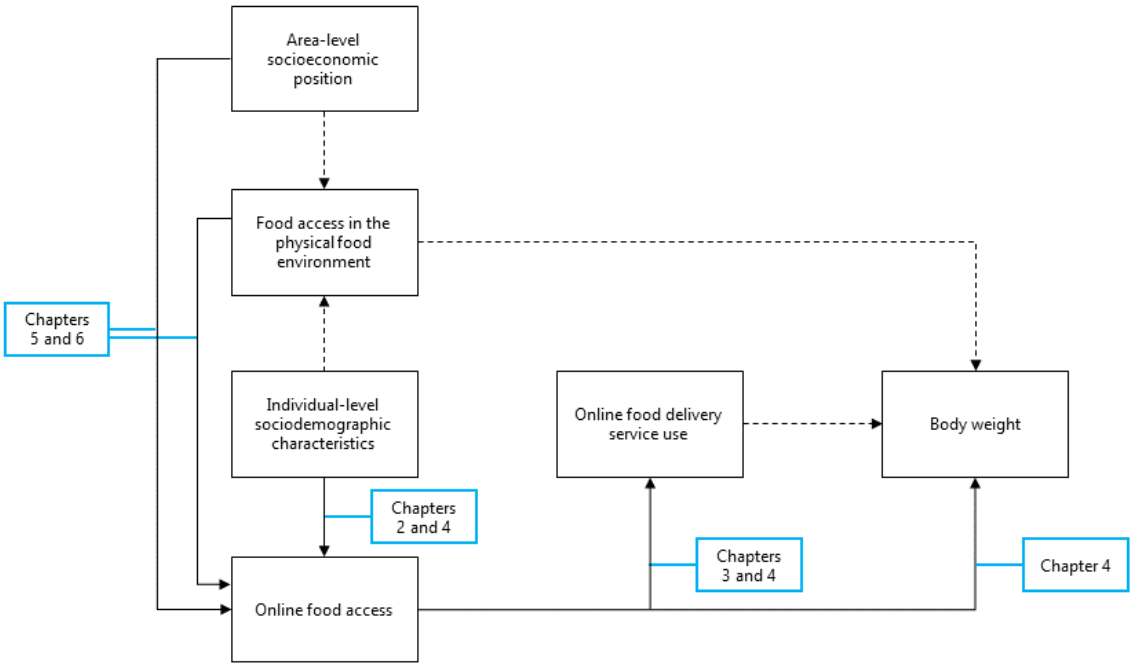

Figure 7.1: Contribution to knowledge for the proposed causal pathway between online food access (access to food prepared out-of-home through online food delivery services) and body weight.
Note: Solid lines indicate an investigated association and a contribution to knowledge.

7.4.1 Cumulative access to food prepared out-of-home

In Section 7.3.1, I referred to the interdependency of the physical and digital food environments, which is particularly important for future research. In the past, the outcome of food outlet exposure in the physical food environment was the purchase of food from customer-facing premises. However, this is no longer necessarily the case (365, 366). For instance, a given individual could pass a food outlet in the physical food environment, which might prime them for later use of an online food delivery service rather than purchasing food directly from the food outlet. As it stands, however, the physical food environment and the digital food environment are mostly viewed independently (144). Doing so might create a false dichotomy that fails to capture exposures that attenuate theoretical and plausible associations with outcomes (148). Future research should seek to consider how the physical food environment and the digital food environment provide cumulative access to food prepared out-of-home across multiple purchasing formats, and how this is associated with the purchase and consumption of food prepared out-of-home. Data that allows exposures and outcomes in both the physical and digital food environment to be considered would be required. It will be essential for this future research to consider factors that are not necessarily captured within conceptualisations of food environments. For example, social and economic factors form part of the socioecological model and operate at multiple levels (see Section 1.2.5.1: Figure 1.6). Within

these factors, and beyond the location of food outlets in the physical food environment, other socioeconomic and environmental conditions such as neighbourhood walkability and perceived safety, digital connectivity and road networks might influence food access and food purchasing practices (69, 72).

7.4.2 Supplementation or substitution of alternative purchasing formats and food sources

One aim of the online food delivery service business model is to become the preferred way that food prepared out-of-home is purchased (367). However, the potential for online food delivery service use to *supplement* the use of other purchasing formats is a public health concern (141). Although it is untested, if online food delivery services were used in addition to other purchasing formats without displacement, then overall consumption of food prepared out-of-home would increase. It is also possible that an increased frequency of online food delivery service use supplements the consumption of other types of food (i.e. not necessarily food prepared out-of-home) without displacement. In both scenarios, overall energy intake might increase, which could have health implications if sustained.

Another possibility is that the use of online food delivery services *substitutes* alternative ways of purchasing food prepared out-of-home and the consumption of other types of food (368). In this scenario, overall food consumption might be unchanged. Importantly, however, even if the use of online food delivery services does not change the overall consumption of food prepared out-of-home, the `problem` of consuming this food remains, with it now being accessed in a different manner. Awareness of this is important in the context of the possible need for public health intervention.

In line with the aforementioned scenarios, future research should seek to investigate the extent to which the use of online food delivery services contributes to overall food consumption, particularly for food prepared out-of-home. This knowledge will help provide a better understanding about the possible implications for overall dietary patterns and body weight. Longitudinal cohort studies that include data on overall food consumption and the purchasing format used to access food prepared out-of-home would be well suited for this research. In addition, cross-sectional research that measures energy intake between groups who use online food delivery services more and less frequently could provide useful insight.

7.4.3 Moving beyond the frequency of online food delivery service use

I found that the number of food outlets accessible online was associated with online food delivery service use in Chapter 4, however, I found no evidence that this exposure was

associated with body weight after controlling for potential confounders. As I discussed in Section 1.2.4.1, more frequent consumption of food prepared out-of-home is associated with poorer overall dietary patterns and living with obesity. Furthermore, the European region of the WHO have raised concerns about the increasing popularity of using online food delivery services due to the types of food sold (212). Indeed, there is evidence from Australia, New Zealand, and Canada that the food sold through online food delivery services in these countries is high in calories, total fat, saturated fat and salt (159, 165, 166). However, the food purchased through online food delivery services has not yet been established. A possible disconnect between the food *available* and the food *purchased* means that without validation, the implications of online food delivery service use on overall dietary patterns and body weight cannot be assumed (90, 148). Future research should aim to move beyond outcomes related to the frequency of online food delivery service use. This could be achieved by investigating the energy and nutrient content of food purchased. Transaction data linked with nutritional composition or menu data, offers a potential solution. Although I acknowledge that this information is not easily attainable, it may be accessible from food retailers, as demonstrated elsewhere (369, 370).

7.4.4 Online food delivery service diversification

Since the research presented in my thesis was conceived, online food delivery services in the UK have diversified in terms of the type of food accessible through their services. Although facilitating access to food prepared out-of-home remains their core function, they now also provide access to supermarkets and convenience stores selling food that would not typically be regarded as prepared out-of-home (254, 317). To some extent, this diversification reflects a digital society and sociocultural norms about receiving items rapidly and on-demand (146). Online food delivery services will plausibly be encouraged to further diversify in the future to meet customer demand for different types of food (371). Moreover, at the time of writing, despite growth in terms of revenue and the number of orders processed, many online food delivery services are not yet profitable. Operating across multiple areas of food retail may be perceived as a way to increase the potential to become profitable (39, 325, 372). As described by the Food Standards Agency, monitoring the operations of online food delivery services will be essential (373), especially in light of the COVID-19 pandemic, which is reported to have transformed food retail (374). Given that the public health implications of online food delivery service diversification are unknown, future research could seek to understand how these services contribute to overall food retail by providing access to different types of food, possibly by building on the dataset I generated for my research in Chapter 6.

7.4.5 Changes to the location of food preparation

Finally, alongside new and different types of food being available to purchase, there has been evolution in the preparation location for the food sold through online food delivery services. This is best demonstrated by the development of facilities known as `dark kitchens` (375). These facilities allow food businesses to register to accept orders through online food delivery services and prepare meals for delivery without the financial costs of having a customer-facing premises (376). In one London Borough, three dark kitchens, hosting 124 individual food businesses were identified in 2021 (376). This finding underlines the potential for the dark kitchen business model to increase access to food prepared out-of-home through online food delivery services, as the number of food businesses (i.e. 124) was greater than the number of premises approved to function (i.e. 3). Future research might seek to understand the public health implications of the dark kitchen business model, including how it uniquely contributes to the number of food outlets accessible online.

Chapter 8:
Conclusions

Previous research on access to food prepared out-of-home and the relationship between consumption of this food, and diet and body weight has typically been conducted in the context of the physical food environment. However, food prepared out-of-home can now also be accessed through online food delivery services, which are an aspect of food retail within the digital food environment. Despite these services contributing to public health concerns about the consumption of food prepared out-of-home, knowledge about the extent of their use, by whom, and the factors that might influence this, was limited. My thesis aimed to contribute to the existing evidence base by providing an improved understanding about these aspects of online food delivery service use.

First, I provided evidence that online food delivery services had been used by around one in six adults living across five upper-middle or high-income countries in the week prior to online survey completion in 2018. I found that online food delivery service customers tended to be male, younger, more highly educated, often lived with children, and identified with an ethnic minority. I also contributed to the current evidence base by providing knowledge about factors that influence online food delivery service use. Frequent online food delivery service customers living in the UK reported that these services provide streamlined purchasing processes and sell food that meets their expectations about `takeaway food`. Moreover, these frequent customers informed me that they could access a higher number of food outlets through online food delivery services compared with alternative purchasing formats. In turn, this influenced their decision to purchase food prepared out-of-home in this manner. Indeed, the number of food outlets accessible online emerged as being particularly important in the chapters that followed my qualitative research. Adults living in Great Britain with the highest number of food outlets accessible online had greater odds of online food delivery service use in the week prior to online survey completion in 2019. Taken together, this is cause for public health concern as the number of food outlets accessible online was highest in the most deprived areas of England in November 2019. Furthermore, the number increased in the most deprived areas but not elsewhere between 2020 and 2022, which suggests that inequalities in online access to food prepared out-of-home widened over time. In turn, this could lead to greater overall consumption of food prepared out-of-home amongst populations that had barriers to having healthier overall dietary patterns even before the emergence of online food delivery services.

Within an increasingly digital society, online food delivery services will likely continue to be used to purchase food prepared out-of-home. Public health interventions have been adopted to address concerns about access to and consumption of this food. However, these interventions do not necessarily address access to food prepared out-of-home through online food delivery services. Although further research is required to understand how food purchased through online food delivery services contributes to overall dietary patterns and health, there may be a need to develop new public health interventions, or to adapt and extend existing ones, to better address online access to food prepared out-of-home.

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Supplementary material

Appendix A: Supplementary material for Chapter 2

Table S1: Sociodemographic characteristics of analytic sample (n=19,378) from the 2018 International Food Policy Study.

Variable and category [a]	Australia (n=3578)		Canada (n=3698)		Mexico (n=3515)		UK (n=4694)		USA (n=3893)		Total (n=19378)	
Sex												
Male	1732	(48.4)	1835	(49.6)	1690	(48.1)	2249	(47.9)	1860	(47.8)	9367	(48.3)
Female	1847	(51.6)	1863	(50.4)	1824	(51.9)	2444	(52.1)	2032	(52.2)	10010	(51.7)
Ethnicity												
Majority	2752	(76.9)	2972	(80.4)	2828	(80.5)	4211	(89.7)	2975	(76.4)	15738	(81.2)
Minority	826	(23.1)	726	(19.6)	687	(19.5)	483	(10.3)	918	(23.6)	3640	(18.8)
Age (years): median (IQR)	48 (33-61)		51 (34-62)		38 (28-50)		50 (34-64)		49 (32-62)		47 (32-61)	
Education												
Low	1512	(42.3)	1514	(40.9)	666	(18.9)	2269	(48.3)	2261	(58.1)	8222	(42.4)
Medium	1171	(32.7)	1256	(34.0)	423	(13.2)	1091	(23.2)	390	(10.0)	4370	(22.6)
High	895	(25.0)	928	(25.1)	2387	(67.9)	1333	(28.4)	1242	(31.9)	6785	(35.0)
BMI (kg/m^2)												
Not overweight (≤ 24.9)	1422	(39.7)	1383	(37.4)	1551	(44.1)	1802	(38.4)	1364	(35.0)	7522	(38.8)
Overweight (25.0-29.9)	990	(27.7)	1107	(29.9)	1099	(31.2)	1306	(27.8)	1160	(29.8)	5661	(29.2)
Obesity (≥ 30.0)	780	(21.8)	928	(25.1)	562	(16.0)	818	(17.4)	1092	(28.1)	4180	(21.6)
Missing	386	(10.8)	280	(7.6)	304	(8.7)	767	(16.3)	277	(7.1)	2015	(10.4)
Child <18 years in home												
No	2670	(74.6)	2931	(79.2)	1723	(49.0)	3564	(75.9)	2963	(76.1)	13850	(71.5)
Yes	909	(25.4)	767	(20.8)	1792	(51.0)	1130	(24.1)	930	(23.9)	5528	(28.5)

Note: [a] data presented as n (%) unless stated, may not always equate to corresponding total due to rounding.

Table S2: Sociodemographic characteristics of non-online food delivery service customers (n=12,163) amongst the analytic sample (n=19,378), from the 2018 International Food Policy Study [a].

Variable and category	Australia (n=3578)		Canada (n=3698)		Mexico (n=3515)		UK (n=4694)		USA (n=3893)		Total (n=19378)		p value for difference [b]
Non-online food delivery service customers	2188	(61.2)	2420	(65.4)	2396	(68.2)	2439	(52.0)	2721	(69.9)	12163	(62.8)	p>0.0001
Sex													p>0.0001
Male	1011	(46.2)	1236	(51.1)	1174	(49.0)	1167	(47.9)	1278	(47.0)	5866	(48.2)	
Female	1177	(53.8)	1185	(48.9)	1222	(51.0)	1271	(52.1)	1443	(53.0)	6298	(51.8)	
Ethnicity													p>0.0001
Majority	1706	(77.9)	1930	(79.8)	1985	(82.8)	2167	(90.1)	2130	(78.3)	9947	(81.8)	
Minority	483	(22.1)	490	(20.2)	411	(17.2)	242	(9.9)	591	(21.7)	2216	(18.2)	
Age (years): median (IQR)	48 (34-61)		48 (33-61)		40 (28-52)		50 (36-64)		50 (33-61)		47 (32-60)		
Education													p>0.0001
Low	915	(41.8)	953	(39.4)	508	(21.2)	1075	(44.1)	1591	(58.5)	5042	(41.5)	
Medium	725	(33.1)	824	(34.0)	326	(13.6)	591	(24.2)	285	(10.5)	2751	(22.6)	
High	548	(25.0)	644	(26.6)	1562	(65.2)	773	(31.7)	844	(31.0)	4370	(35.9)	
BMI (kg/m^2)													p>0.0001
Not overweight (≤ 24.9)	855	(39.1)	884	(36.5)	1035	(43.2)	910	(37.3)	927	(34.1)	4611	(38.8)	
Overweight (25.0-29.9)	601	(27.5)	736	(30.4)	758	(31.6)	718	(29.4)	827	(30.4)	3460	(29.2)	
Obesity (≤ 30.0)	502	(23.0)	623	(25.7)	385	(16.1)	429	(17.6)	788	(29.0)	2727	(21.6)	
Missing	230	(10.5)	178	(7.3)	218	(9.1)	382	(15.7)	178	(6.5)	1185	(10.4)	
Child <18 years in home													
No	1646	(75.2)	1893	(78.2)	1302	(54.3)	1879	(77.0)	2108	(77.5)	8828	(72.6)	p>0.0001
Yes	542	(24.8)	528	(21.8)	1094	(45.7)	460	(23.0)	612	(22.5)	3335	(27.4)	

Notes: [a] Non-online food delivery service customers had purchased at least one meal prepared out-of-home directly from a food outlet, but not through an online food delivery service, in the past week. Unless stated data reported as n (%). May not always equate to corresponding total due to rounding.

[b] p values from Pearson's $\chi 2$ test, represents difference between categories within variable.

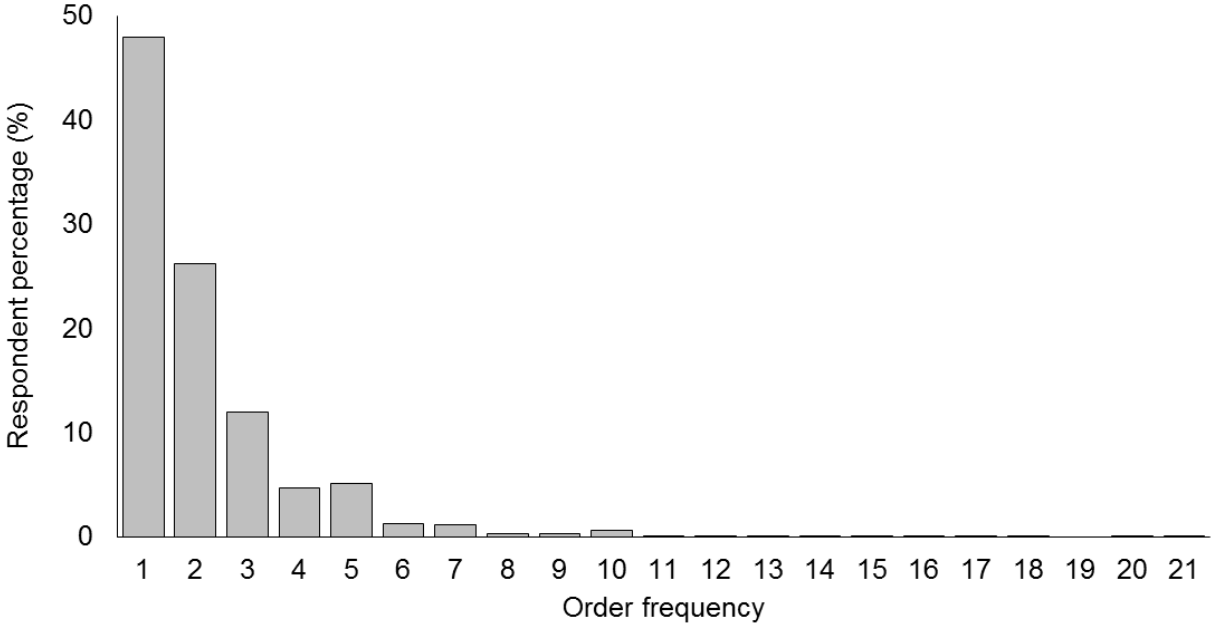


Figure S1: Frequency of online food delivery service use in the past week amongst online food delivery service customers (n=2929). Data are from the 2018 International Food Policy Study.

Table S3: Associations between prevalence of any online food delivery service use in the past week and sociodemographic characteristics amongst the analytic sample (n=19,378) from the 2018 International Food Policy Study, analysed using logistic regression.

	Model 0 [a]		Model 1 [a]	
Variable and category	OR[b]	95% CI	OR[b]	95% CI
Sex (male)	1.41	1.28, 1.55	1.54	1.38, 1.71
Age (years)	0.94	0.94, 0.95	0.95	0.94, 0.95
Education				
Low	ref	-	ref	-
Medium	1.23	1.06, 1.42	-	-
High	2.57	2.28, 2.90	-	-
Ethnicity (minority)	2.35	2.10, 2.63	1.64	1.45, 1.86
BMI (kg/m^2)				
Not overweight (≤ 24.9)	ref	-	ref	-
Overweight (25.0-29.9)	0.68	0.61, 0.76	0.90	0.79, 1.03
Obesity (≥ 30.0)	0.53	0.46, 0.61	0.87	0.75, 1.01
Missing	1.05	0.90, 1.23	1.01	0.85, 1.20
Child <18 years in home (yes)	3.84	3.48, 4.23	2.85	2.57, 3.17
Country				
Australia	0.85	0.74, 0.99	0.74	0.61, 0.85
Canada	0.51	0.44, 0.60	0.46	0.39, 0.55
Mexico	1.80	1.58, 2.06	1.01	0.87, 1.18
UK	ref	-	ref	-
USA	0.71	0.61, 0.82	0.61	0.52, 0.72

Notes: [a] Model 0 was unadjusted. Model 1 was adjusted for all independent variables except education.
[b] Odds Ratio.
[c] 95% confidence intervals.

Table S4. Odds ratio (OR) and 95% confidence intervals (CI) from two-way interaction term added to separate, maximally adjusted, logistic regression models. Data are from the 2018 International Food Policy Study.

Interaction term [a]	OR	95% CI
Sex x country (female = reference)		
Male x Australia	1.26	0.91, 1.76
Male x Canada	0.96	0.67, 1.37
Male x Mexico	0.66	0.50, 0.88
Male x USA	1.12	0.80, 1.55
Ethnicity x country (majority = reference)		
Minority x Australia	0.72	0.48, 1.08
Minority x Canada	0.90	0.60, 1.36
Minority x Mexico	0.92	0.62, 1.37
Minority x USA	1.13	0.77, 1.65
Age x country (continuous)		
Age x Australia	1.00	0.99, 1.02
Age x Canada	1.01	0.99, 1.02
Age x Mexico	1.03	1.02, 1.05
Age x USA	1.00	0.99, 1.02
Child <18 years at home x country (no = reference)		
Yes x Australia	0.82	0.59, 1.14
Yes x Canada	0.80	0.56, 1.14
Yes x Mexico	1.19	0.87, 1.61
Yes x USA	1.22	0.88, 1.69
Education x country (low = reference)		
Medium x Australia	1.47	0.94, 2.30
Medium x Canada	1.71	1.05, 2.77
Medium x Mexico	2.00	1.21, 3.31
Medium x USA	2.04	1.30, 3.20
High x Australia	2.10	1.40, 3.13
High x Canada	1.66	1.06, 2.60
High x Mexico	2.42	1.66, 3.55
High x USA	2.84	1.97, 4.08
BMI x country (not overweight = reference)		
Overweight x Australia	1.01	0.67, 1.54
Overweight x Canada	0.97	0.61, 1.53
Overweight x Mexico	1.15	0.81, 1.63
Overweight x USA	1.12	0.75, 1.66
Obesity x Australia	0.56	0.33, 0.93
Obesity x Canada	0.71	0.43, 1.16
Obesity x Mexico	0.93	0.60, 1.43
Obesity x USA	0.57	0.36, 0.91

Note: [a] Interaction term = independent variable x country, reference country throughout = UK. Interaction term added to separate maximally adjusted logistic regression models (Model 2).

Appendix B: Supplementary material for Chapter 3

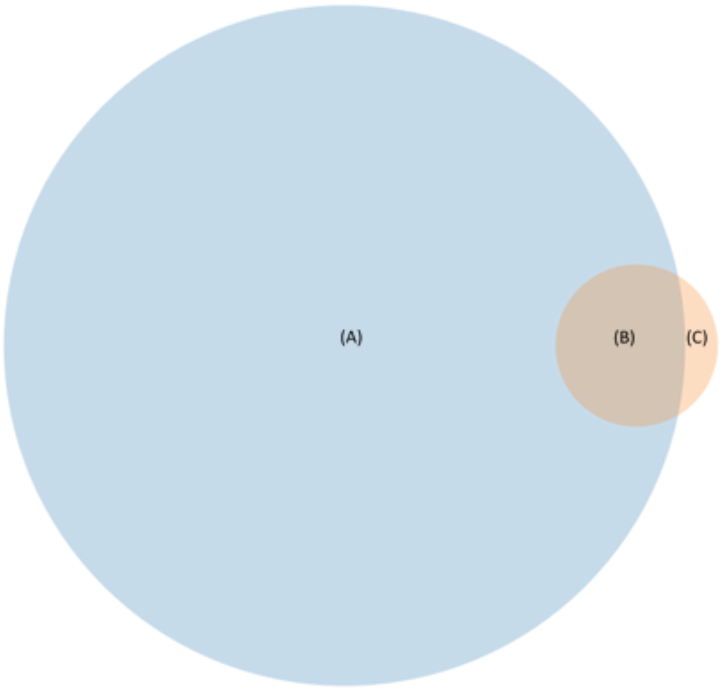
Box S1: Names of Subreddits used to post study information.

UK cities
Birmingham
Bradford
Brighton
Bristol
Cornwall
Coventry
Edinburgh
Glasgow
Leeds
Leicester
Liverpool
London
Manchester
Newcastle-upon-Tyne
Sheffield
UK or food based
AskUK
GhostKitchens
JustEatUK
Unitedkingdom

Box S2: Telephone interview topic guide with examples of questions used during data collection.

PRE-AMBLE AND INTRODUCTION
• Participant age, gender, marital status, and occupation confirmed. • Definitions for `online food delivery services` (online takeaways) and `food prepared out-of-home` (takeaway food) discussed and confirmed.
PATTERNS OF TAKEAWAY FOOD PURCHASING
• What are the different ways that you have purchased takeaway food in the past 12 months? • What do you think about when you are going to buy takeaway food? Maybe you could touch on things like how you choose the way that you are going to buy it, and the types of things you think about.
• Thinking about before March, when and why would you typically buy takeaway food? • What is it about these days or times?
ONLINE FOOD DELIVERY SERVICE ADOPTION AND USE
(*If not discussed during conversation so far*) • Which online takeaways have you used before? • When did you start using `them`? [Note: `them` from this point refers to the name of the online takeaway] • What made you first start using them? • When might you use them instead of another purchasing format? • How do you choose which food outlet you are going to buy from when you use them? • Do you think using an online takeaway changes the food outlets you buy from? Followed up with, how?
PERCEIVED BENEFITS AND DRAWBACKS OF ONLINE TAKEAWAYS
• What do you think are the most important features of online takeaways? What are you expecting when you use them? • How do you think these features might be different compared with other ways of buying takeaway food? • Still thinking about before March, in your opinion, what are the main benefits of using online takeaways? • What is not so good about using online takeaways? • You mentioned some things that might not be so good about using online takeaways, so why do you keep using them – what is it about online takeaways?
BROADER BEHAVIOURS AND PERCEPTIONS
• What do you think about when you hear the term `takeaway food`? • What do you think about the types of food you can buy through online takeaways? • Is the food you can buy online any different from the food you can buy in other ways? • Thinking about all of the different places that you can buy takeaway food from near where you live, how does that compare to online takeaways? • How do you think using an online takeaway has changed other ways of buying takeaway food? • How do you think you will you buy takeaway food in the future? • How does using online takeaways fit in with other things like cooking food at home?
SUMMARY
• Important points identified throughout interview reframed, and accuracy confirmed. • Participant asked to discuss any points in more detail or if anything had not been asked but should have been.

Appendix C: Supplementary material for Chapter 4



Comparison of food outlets registered with Just Eat and Deliveroo in one region in England (April 2020).

(A) = Food outlets registered to accept orders through Just Eat. N = **1673**
(B) = Food outlets registered to accept orders through Deliveroo. N = **334**
(C) = Food outlets exclusively registered to accept orders through Deliveroo. N = **91**

Figure S1: Comparison between food outlets registered with Just Eat and Deliveroo in one region in England. Data used in comparisons collected in April 2020.

Table S1: Sociodemographic characteristics of UK respondents from the 2019 International Food Policy Study [a].

Variable and category	Full sample (n=4139)		Included (n=3337)		Excluded (n=732)	
Sex						
Male	2022	(49.0)	1648	(49.4)	341	(46.6)
Female	2117	(51.0)	1689	(50.6)	391	(53.4)
Ethnicity						
Minority	460	(1.0)	333	(10.0)	118	(16.2)
Majority	3648	(88.0)	2988	(89.6)	599	(81.8)
Not available	31	(11.0)	15	(0.5)	15	(2.0)
Age						
Mean (SD)	48.2	(16.8)	49.4	(16.9)	43.4	(15.7)
18-29 years	803	(19.4)	570	(17.1)	208	(28.4)
30-44 years	1020	(24.6)	799	(24.0)	201	(27.4)
45-59 years	1069	(25.8)	875	(26.2)	180	(24.6)
>60 years	1247	(30.1)	1093	(32.8)	143	(19.6)
Education level						
Low	2095	(50.6)	1688	(50.6)	364	49.6)
Medium	848	(20.5)	708	(21.2)	132	(18.1)
High	1166	(28.2)	932	(27.9)	215	(29.3)
Not available	31	(0.7)	9	(0.3)	21	(2.9)
Ability to make ends meet						
Not easy	2340	(56.5)	1992	(59.7)	507	69.3
Easy	1799	(43.5)	1345	(40.3)	225	30.7
BMI (kg/m^2): mean (SD)	26.5 (3329 respondents)	(5.3)	26.6 (2863 respondents)	(5.3)	26.2 (457 respondents)	(5.5)
Weight Status						
Not overweight (BMI≤ 24.9)	1415	(34.2)	1170	(35.1)	227	(31.0)
Overweight (BMI 25-29.9)	1097	(26.5)	945	(28.3)	136	(18.6)
Obesity (BMI≥ 30)	727	(17.6)	624	(18.7)	94	(12.9)
Not available	900	(21.7)	598	(17.9)	275	(37.5)
Child at home						
No	2975	(71.9)	2433	(72.9)	490	(66.7)
Yes	1158	(27.9)	901	(27.0)	239	(32.6)
Not available	6	(0.1)	3	(0.1)	3	(0.4)
Regular smoker						
No	3206	(77.4)	2599	(77.9)	557	(76.1)
Yes	926	(22.4)	735	(22.0)	170	(23.3)
Not available	7	(0.2)	3	(0.1)	5	(0.6)

Notes: [a] Data presented as weighted number of respondents (%) unless stated. May not always equate to corresponding total due to rounding. **Full sample** = all respondents. **Included** = respondents with exposure data, but no covariate data. **Excluded** = respondents with no exposure data.

Table S2: Online food delivery service use in the past week amongst UK respondents from the 2019 International Food Policy Study [a].

Online food delivery service use	Full sample (n=4139)		Included (n=3337)		Excluded (n=732)	
Not applicable	1185	(28.6)	902	(27.0)	213	(29.1)
Refuse to Answer	17	(0.4)	7	(0.2)	10	(13.1)
Don't Know	53	(1.3)	45	(1.3)	9	(11.8)
0	2169	(52.4)	1830	(54.9)	339	(46.3)
1+	715	(17.3)	552	(16.6)	162	(22.2)

Notes: [a] Data presented as weighted number of respondents (%), unless stated. May not always equate to corresponding total due to rounding. **Not applicable** = respondents that had not purchased a meal prepared out-of-home in the past week. **Full sample** = all respondents. **Included** = respondents with exposure data, but no covariate data. **Excluded** = respondents with no exposure data.

Table S3: Odds of online food delivery service use in the past week per quarter (Q) of online food outlet access amongst the analytic sample (n=3067) from the 2019 International Food Policy Study, analysed using unadjusted binomial logistic regression.

Food outlet number [a]	OR [b]	95% CI [c]	
Q1 (0-34)	ref	-	-
Q2 (35-85)	1.35	0.91	2.03
Q3 (86-181)	1.60	1.07	2.37
Q4 (182-879)	3.11	2.17	4.45

Notes: [a] Bracketed number is the number of food outlets accessible online for each Q. [b] Odds ratio.
[c] 95% confidence intervals.

Table S4: Odds ratio (OR) and 95% confidence intervals (CI) from multiplicative interaction terms added to separate adjusted binomial logistic regression models. Data are from the 2019 International Food Policy Study.

Interaction term [a]	OR	95% CI	
Food outlet access x education (Low = reference)			
Q2 x Medium	0.75	0.26	2.14
Q2 x High	0.59	0.22	1.59
Q3 x Medium	1.19	0.42	3.35
Q3 x High	0.78	0.30	2.04
Q4 x Medium	0.58	0.21	1.60
Q4 x High	1.22	0.49	3.01
Food outlet access x age (18-29 = reference)			
Q2 x 30-44	1.05	0.38	2.90
Q2 x 45-59	0.75	0.20	2.90
Q2 x ≥60	0.77	0.12	5.07
Q3 x 30-44	0.71	0.26	1.93
Q3 x 45-59	0.70	0.19	2.60
Q3 x ≥60	0.53	0.09	2.99
Q4 x 30-44	0.68	0.27	1.70
Q4 x 45-59	0.57	0.17	1.87
Q4 x ≥60	1.86	0.40	8.65
Food outlet access x sex (Male = reference)			
Q2 x Female	3.64	1.54	8.57
Q3 x Female	4.78	2.05	11.16
Q4 x Female	3.33	1.50	7.46
Food outlet access x child at home (No = reference)			
Q2 x Yes	1.26	0.55	2.90
Q3 x Yes	1.01	0.44	2.29
Q4 x Yes	0.81	0.38	1.72

Notes: [a] Quarter (Q) 1 was the reference group throughout. Analyses adjusted for the following potential confounders: neighbourhood food outlet access, sex, age, education level, perceived income adequacy, living with children, and ethnicity. The number of food outlets accessible online for each Q were: Q1 (0-34), Q2 (35-85), Q3 (86-181), Q4 (182-879).

Table S5: Sensitivity analyses. Odds of online food delivery service use in the past week per quarter (Q) of online food outlet access amongst the analytic sample (n=3067) from the 2019 International Food Policy Study, analysed using adjusted binomial logistic regression [a].

Food outlet number	OR	95% CI	
Neighbourhood supermarket [b]			
Q1 (0-34)	ref	-	-
Q2 (35-85)	1.22	0.77	1.92
Q3 (86-181)	1.26	0.80	2.00
Q4 (182-879)	1.79	1.14	2.83
Broader food outlet type [b]			
Q1 (0-34)	ref	-	-
Q2 (35-85)	1.22	0.77	1.92
Q3 (86-181)	1.26	0.79	2.00
Q4 (182-879)	1.75	1.10	2.76

Notes: [a] Broader food outlet types = nine categories included from 2019 Ordnance Survey Points of Interest data (`Fast food and takeaway outlets`, `Fast food delivery services`, `Fish and Chip shops`, `Restaurants`, `Cafés, snack bars and tea rooms`, `Convenience stores`, `Supermarkets`, `Bakeries` and `Delicatessens`). Analyses adjusted for the following potential confounders: neighbourhood food outlet access, sex, age, education level, perceived income adequacy, presence of children at home, and ethnicity.
[b] Bracketed number = number of food outlets accessible online for each Q.

Table S6: Odds of online food delivery service use in the past week per quarter (Q) of online access to unique types of cuisine, amongst the analytic sample (n=3067) from the 2019 International Food Policy Study, analysed using unadjusted binomial logistic regression.

Unique type of cuisine number [a]	OR	95% CI	
Q1 (0-64)	ref	-	-
Q2 (65-85)	0.60	0.41	0.86
Q3 (86-108)	0.91	0.65	1.29
Q4 (109-148)	1.18	0.86	1.62

Note: [a] Bracketed number = number unique types of cuisine accessible online for each Q.

Table S7: Secondary analyses. Coefficients (coef.) and 95% confidence intervals (CI) for the association between online food outlet access and body mass index and weight status amongst the analytic sample (n=3067) from the 2019 International Food Policy Study, analysed using multinomial linear or multinomial logistic regression.

	Model 0 [a]			Model 1 [a]		
Variable and category	coef.	95% CI		coef.	95% CI	
Body mass index (kg/m^2)						
Q1 (0-34) [b]	ref	-		ref	-	-
Q2 (35-85)	-0.04	-0.74	0.67	0.03	-0.65	0.72
Q3 (86-181)	-0.17	-0.85	0.51	0.14	-0.54	0.81
Q4 (182-879)	-1.08	-1.74	-0.42	-0.11	-0.84	0.61
Weight status [c]	OR [d]	95% CI		OR	95% CI	
Overweight						
Q1 (0-34)	ref	-	-	ref	-	-
Q2 (35-85)	0.88	0.66	1.18	0.88	0.65	1.18
Q3 (86-181)	0.96	0.72	1.28	1.01	0.75	1.36
Q4 (182-879)	0.80	0.60	1.07	1.02	0.72	1.43
Obesity						
Q1 (0-34)	ref	-	-	ref	-	-
Q2 (35-85)	0.97	0.69	1.34	0.99	0.70	1.39
Q3 (86-181)	0.82	0.59	1.14	0.93	0.66	1.32
Q4 (182-879)	0.62	0.44	0.88	0.92	0.62	1.38
Not available [e]						
Q1 (0-34)	ref	-	-	ref	-	-
Q2 (35-85)	1.27	0.88	1.83	1.23	0.85	1.78
Q3 (86-181)	1.08	0.74	1.58	1.10	0.75	1.62
Q4 (182-879)	1.39	0.98	1.97	1.42	0.95	2.12

Notes: [a] Model 0 was unadjusted. Model 1 was adjusted for the following potential confounders: neighbourhood food outlet access, sex, age, education level, perceived income adequacy, living with children, ethnicity, and smoking status.

[b] Bracketed number = number of food outlets accessible online for each quarter (Q).

[c] `Not overweight` category used as reference group throughout.

[d] Odds Ratio. 95% confidence intervals.

[e] Not available category = no BMI (n=517).

Appendix D: Supplementary material for Chapter 5

Table S1: counts of food outlets registered to accept orders online and food outlets with a customer-facing premises in the physical food environment of postcode districts in England (n=2118) in November 2019.

Measure	Number
Online food delivery service	
Food outlets registered	29232
Physical food environment	
Food outlets within postcode district [a]	82455
Food outlets within neighbourhood [b]	376513

Notes: [a] Food outlet categories included: Fast food and takeaway outlets; Fast food delivery services; Fish and Chip shops; Restaurants. Data collected June 2019.
[b] `Neighbourhood` = 1600 m Euclidean radius `neighbourhood` buffer of postcode district geographic centroid.

Table S2: Coefficients (coef.) and 95% confidence intervals (CI) for the association between deprivation and the percentage of food outlets registered to accept orders online amongst postcode districts in England. Estimated using unadjusted and adjusted general linear models.

	Model 0 [a]			Model 1 [a]		
Percentage registered [b] (%)	coef.	95% CI		coef.	95% CI	
IMD score (deciles)						
1 (4.28-10.21); least deprived	ref	-	-	ref	-	-
2 (10.22-12.08)	-0.96	-4.63	2.70	-0.84	-3.86	2.18
3 (12.09-14.00)	0.49	-3.16	4.13	1.27	-1.75	4.30
4 (14.01-15.91)	4.40	0.74	8.05	2.72	-0.30	5.74
5 (15.92-18.18)	3.92	0.26	7.58	2.29	-0.73	5.31
6 (18.19-20.60)	5.39	1.74	9.04	2.93	-0.09	5.95
7 (20.61-23.54)	8.10	4.44	11.75	4.18	1.14	7.22
8 (23.55-27.06)	16.15	12.49	19.80	9.75	6.68	12.82
9 (27.07-32.89)	21.80	18.14	25.45	11.12	8.01	14.23
10 (32.90-69.51); most deprived	29.03	25.37	32.69	20.02	16.93	23.10

Notes: [a] Model 0 was unadjusted. 2113 postcode districts included. Model 1 was adjusted for population density and rural urban classification. 2084 postcode districts included.
[b] Percentage registered = percentage of food outlets in postcode district registered to accept orders online.

Table S3: Association between deprivation and online food outlet access amongst postcode districts in England. Estimated using unadjusted and adjusted negative binomial regression.

	Model 0 [a]			Model 1 [a]		
Food outlets accessible online (count)	IRR [b]	95% CI [c]		IRR [b]	95% CI [c]	
IMD score (deciles)						
1 (4.28-10.21); least deprived	ref	-	-	ref	-	-
2 (10.22-12.08)	1.02	0.81	1.29	0.97	0.81	1.17
3 (12.09-14.00)	1.32	1.04	1.67	0.97	0.81	1.18
4 (14.01-15.91)	1.57	1.24	1.99	1.01	0.84	1.23
5 (15.92-18.18)	1.51	1.19	1.90	0.94	0.78	1.13
6 (18.19-20.60)	1.68	1.33	2.12	0.87	0.72	1.06
7 (20.61-23.54)	2.16	1.71	2.72	0.99	0.81	1.20
8 (23.55-27.06)	2.64	2.09	3.33	1.12	0.92	1.36
9 (27.07-32.89)	3.08	2.44	3.89	1.19	0.97	1.45
10 (32.90-69.51); most deprived	3.51	2.78	4.44	1.51	1.24	1.83

Notes: [a] Model 0 was unadjusted. 2118 postcode districts included. Model 1 was adjusted for rural urban classification, population density, and the number of food outlets within their boundary. 2088 postcode districts included.
[b] Incidence Rate Ratios (IRR) represent expected difference of outcome at each level of deprivation, compared with the reference group.
[c] 95% confidence intervals.

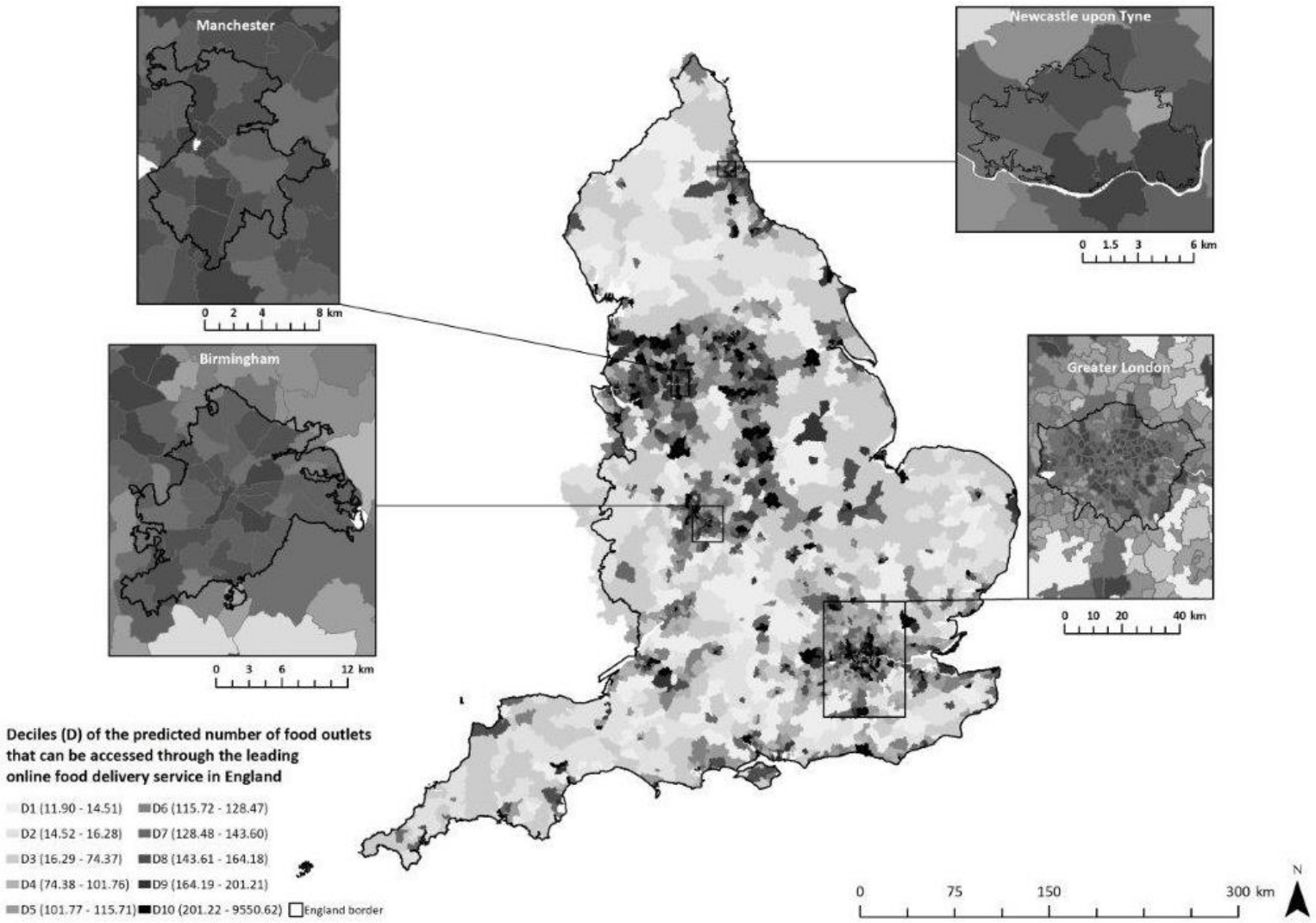


Figure S1: Deciles of the predicted number (count) of food outlets accessible online across postcode districts (n=2088) in England, in November 2019. Number estimated from a negative binomial regression model adjusted for the number of food outlets within a postcode district boundary, and rural urban classification and population density

Table S4: Association between deprivation and online unique cuisine type access amongst postcode districts in England. Estimated using unadjusted and adjusted negative binomial regression.

	Model 0 [a]			Model 1 [a]		
Unique cuisine types accessible (count)	IRR [b]	95% CI [c]		IRR [b]	95% CI [c]	
IMD score (deciles)						
1 (4.28-10.21); least deprived	ref	-	-	ref	-	-
2 (10.22-12.08)	0.96	0.80	1.14	0.90	0.82	0.99
3 (12.09-14.00)	1.05	0.88	1.25	0.86	0.78	0.95
4 (14.01-15.91)	1.18	1.00	1.41	0.81	0.73	0.89
5 (15.92-18.18)	1.12	0.94	1.33	0.76	0.69	0.84
6 (18.19-20.60)	1.21	1.02	1.44	0.75	0.68	0.83
7 (20.61-23.54)	1.39	1.17	1.66	0.67	0.61	0.74
8 (23.55-27.06)	1.62	1.37	1.93	0.73	0.66	0.81
9 (27.07-32.89)	1.87	1.58	2.23	0.80	0.72	0.88
10 (32.90-69.51); most deprived	2.08	1.75	2.48	0.83	0.75	0.92

Notes: [a] Model 0 was unadjusted. 2118 postcode districts included. Model 1 was adjusted for rural urban classification, population density, the number of food outlets within the postcode district boundary and the number of food outlets accessible online. 2088 postcode districts included.

[b] Incidence Rate Ratios (IRR) represent expected difference of outcome at each level of deprivation, compared with the reference group.

[c] 95% confidence intervals.

Table S5: Coefficients (coef.) and 95% confidence intervals (CI) for the association between deprivation and the percentage of neighbourhood food outlets accessible online amongst postcode districts in England. Estimated using unadjusted and adjusted general linear models.

	Model 0 [a]			Model 1 [a]		
Percentage accessible online [b] (%)	coef.	95% CI [c]		coef.	95% CI [c]	
IMD score (deciles)						
1 (4.28-10.21); least deprived	ref	-	-	ref	-	-
2 (10.22-12.08)	-9.72	-20.63	1.20	-8.17	-18.80	2.46
3 (12.09-14.00)	-16.41	-27.28	-5.55	-12.19	-22.85	-1.53
4 (14.01-15.91)	-14.35	-25.21	-3.48	-14.28	-24.90	-3.65
5 (15.92-18.18)	-20.05	-30.92	-9.17	-19.32	-29.95	-8.69
6 (18.19-20.60)	-21.84	-32.67	-11.00	-21.11	-31.72	-10.51
7 (20.61-23.54)	-30.34	-41.21	-19.48	-29.40	-40.10	-18.69
8 (23.55-27.06)	-16.54	-27.41	-5.68	-14.79	-25.58	-3.99
9 (27.07-32.89)	-10.59	-21.43	0.25	-11.06	-21.97	-0.16
10 (32.90-69.51); most deprived	0.05	-10.80	10.90	-3.38	-14.22	7.45

Notes: [a] Model 0 was unadjusted. 2104 postcode districts included. Model 1 was adjusted for population density and rural urban classification. 2076 postcode districts included.

[b] Percentage accessible online = the number of food outlets accessible online as a percentage of the number physically accessible in the neighbourhood, based on Ordnance Survey Points of Interest data. `Neighbourhood` = 1600 m Euclidean radius `neighbourhood` buffer of postcode district geographic centroid.

[c] 95% confidence intervals.

Table S6: Sensitivity analyses: Coefficients (coef.) and 95% confidence intervals (CI) for the association between deprivation and the percentage of food outlets registered to accept orders online amongst postcode districts in England. Estimated using unadjusted and adjusted general linear models and nine categories of food outlets from Ordnance Survey Points of Interest data [a].

	Model 0 [b]			Model 1 [b]		
Percentage registered [c] (%)	coef.	95% CI		coef.	95% CI	
IMD score (deciles)						
1 (4.28-10.21); least deprived	ref	-	-	ref	-	-
2 (10.22-12.08)	-0.05	-1.83	1.72	0.03	-1.44	1.50
3 (12.09-14.00)	0.37	-1.40	2.15	0.77	-0.70	2.24
4 (14.01-15.91)	2.17	0.40	3.95	1.37	-0.10	2.84
5 (15.92-18.18)	2.59	0.82	4.37	1.83	0.36	3.30
6 (18.19-20.60)	2.51	0.74	4.29	1.35	-0.12	2.82
7 (20.61-23.54)	4.24	2.47	6.01	2.36	0.88	3.84
8 (23.55-27.06)	7.73	5.95	9.50	4.58	3.09	6.07
9 (27.07-32.89)	11.35	9.58	13.12	6.18	4.67	7.69
10 (32.90-69.51); most deprived	14.45	12.67	16.22	9.99	8.49	11.49

Notes: [a] Food outlet categories included: Fast food and takeaway outlets, Fast food delivery services, Fish and Chip shops, Restaurants, Cafés, snack bars and tea rooms, Convenience stores, Supermarkets, Bakeries, Delicatessens.
[b] Model 0 was unadjusted. 2118 postcode districts included. Model 1 was adjusted for population density and rural urban classification. 2088 postcode districts included.
[c] Percentage registered = the number of food outlets registered to accept orders online as a percentage of the number of food outlets with a customer-facing premises, based on Ordnance Survey Points of Interest data percentage of food outlets in postcode district registered to accept orders online based on Ordnance Survey Points of Interest data.

Table S7: Sensitivity analyses: Association between deprivation and online food outlet access amongst postcode districts in England. Estimated using unadjusted and adjusted negative binomial regression and nine categories of food outlets from Ordnance Survey Points of Interest data [a].

	Model 0 [b]			Model 1 [b]		
Food outlets accessible online	IRR [c]	95% CI [d]		IRR [c]	95% CI [d]	
IMD score (deciles)						
1 (4.28-10.21); least deprived	ref	-	-	ref	-	-
2 (10.22-12.08)	1.02	0.81	1.29	0.98	0.81	1.18
3 (12.09-14.00)	1.32	1.04	1.67	0.98	0.81	1.18
4 (14.01-15.91)	1.57	1.24	1.99	1.01	0.84	1.22
5 (15.92-18.18)	1.51	1.19	1.90	0.94	0.78	1.14
6 (18.19-20.60)	1.68	1.33	2.12	0.87	0.72	1.05
7 (20.61-23.54)	2.16	1.71	2.72	0.99	0.81	1.20
8 (23.55-27.06)	2.64	2.09	3.33	1.12	0.92	1.36
9 (27.07-32.89)	3.08	2.44	3.89	1.19	0.97	1.45
10 (32.90-69.51); most deprived	3.51	2.78	4.44	1.51	1.24	1.83

Notes: [a] Food outlet categories included: Fast food and takeaway outlets, Fast food delivery services, Fish and Chip shops, Restaurants, Cafés, snack bars and tea rooms, Convenience stores, Supermarkets, Bakeries, Delicatessens.
[b] Model 0 was unadjusted. 2118 postcode districts included. Model 1 was adjusted for population density and rural urban classification. 2087 postcode districts included.
[c] Incidence Rate Ratios represent expected difference of outcome at each level of deprivation, compared with the reference group.
[d] 95% confidence intervals.

Table S8: Sensitivity analyses: Association between deprivation and online unique cuisine type access amongst postcode districts in England. Estimated using unadjusted and adjusted negative binomial regression and nine categories of food outlets from Ordnance Survey Points of Interest data [a].

	Model 0 [b]			Model 1 [b]		
Unique cuisine types accessible count)	IRR [c]	95% CI [d]		IRR [c]	95% CI [d]	
IMD score (deciles)						
1 (4.28-10.21); least deprived	ref	-	-	ref	-	-
2 (10.22-12.08)	0.96	0.80	1.14	0.90	0.82	0.99
3 (12.09-14.00)	1.05	0.88	1.25	0.86	0.78	0.95
4 (14.01-15.91)	1.18	1.00	1.41	0.81	0.73	0.89
5 (15.92-18.18)	1.12	0.94	1.33	0.77	0.69	0.84
6 (18.19-20.60)	1.21	1.02	1.44	0.75	0.68	0.83
7 (20.61-23.54)	1.39	1.17	1.66	0.67	0.61	0.75
8 (23.55-27.06)	1.62	1.37	1.93	0.73	0.66	0.81
9 (27.07-32.89)	1.87	1.58	2.23	0.80	0.73	0.89
10 (32.90-69.51); most deprived	2.08	1.75	2.48	0.83	0.75	0.92

Notes: [a] Food outlet categories included: Fast food and takeaway outlets, Fast food delivery services, Fish and Chip shops, Restaurants, Cafés, snack bars and tea rooms, Convenience stores, Supermarkets, Bakeries, Delicatessens.
[b] Model 0 was unadjusted. 2118 postcode districts included. Model 1 was adjusted for rural urban classification, population density, the number of food outlets in the postcode district boundary, based on Ordnance Survey Points of Interest data and the number of food outlets accessible online. 2088 postcode districts included.
[c] Incidence Rate Ratios represent expected difference of outcome at each level of deprivation, compared with the reference group.
[d] 95% confidence intervals

Table S9: Sensitivity analyses: Coefficients (coef.) and 95% confidence intervals (CI) for the association between deprivation and the percentage of neighbourhood food outlets accessible online amongst postcode districts in England. Estimated using unadjusted and adjusted general linear models and nine categories of food outlets from Ordnance Survey Points of Interest data [a].

	Model 0 [b]			Model 1 [b]		
Percentage accessible online [c] (%)	coef.	95% CI		coef.	95% CI	
IMD score (deciles)						
1 (4.28-10.21); least deprived	ref	-	-	ref	-	-
2 (10.22-12.08)	-0.44	-7.09	6.22	0.59	-6.00	7.19
3 (12.09-14.00)	-2.08	-8.71	4.55	-0.09	-6.70	6.53
4 (14.01-15.91)	-6.66	-13.31	-0.01	-6.69	-13.30	-0.08
5 (15.92-18.18)	-7.07	-13.72	-0.42	-6.62	-13.22	-0.02
6 (18.19-20.60)	-9.49	-16.13	-2.85	-9.13	-15.73	-2.53
7 (20.61-23.54)	-12.40	-19.04	-5.75	-12.07	-18.72	-5.41
8 (23.55-27.06)	-6.08	-12.73	0.57	-5.38	-12.09	1.33
9 (27.07-32.89)	-1.99	-8.63	4.65	-2.31	-9.10	4.48
10 (32.90-69.51); most deprived	3.08	-3.57	9.73	1.18	-5.57	7.92

Notes: [a] Food outlet categories included: Fast food and takeaway outlets, Fast food delivery services, Fish and Chip shops, Restaurants, Cafés, snack bars and tea rooms, Convenience stores, Supermarkets, Bakeries, Delicatessens.
[b] Model 0 was unadjusted. 2104 postcode districts included. Model 1 was adjusted for population density and rural urban classification. 2087 postcode districts included.
[c] Percentage accessible online = the number of food outlets accessible online as a percentage of the number physically accessible in the neighbourhood, based on Ordnance Survey Points of Interest data. `Neighbourhood` = 1600 m Euclidean radius `neighbourhood` buffer of postcode district geographic centroid.

Appendix E: Supplementary material for Chapter 6

Table S1: Operationalisation of matching monthly and quarterly data [a].

Month	Quarter [b]
November 2019	Q4 2019
June 2020	Q3 2020
July 2020	Q3 2020
August 2020	Q3 2020
September 2020	Q4 2020
October 2020	Q4 2020
November 2020	Q4 2020
December 2020	Q1 2021
January 2021	Q1 2021
February 2021	Q1 2021
March 2021	Q2 2021
April 2021	Q2 2021
May 2021	Q2 2021
June 2021	Q3 2021
July 2021	Q3 2021
August 2021	Q3 2021
September 2021	Q4 2021
October 2021	Q4 2021
November 2021	Q4 2021
December 2021	Q1 2022
January 2022	Q1 2022
February 2022	Q1 2022
March 2022	Q1 2022

Notes: [a] Monthly data from the online food delivery service.
[b] Quarterly data from Ordnance Survey Points of Interest.

Table S2: number (count) of food outlets registered to accept orders online in postcode districts in England, stratified by deprivation [a b].

	Deprivation quintile					
	1 (least deprived)	2	3	4	5 (most deprived)	England
Month						
Nov 2019	3.0 (1.0-8.0)	4.0 (1.0-12.0)	6.0 (1.0-18.0)	13.0 (3.0-25.0)	24.0 (12.0-39.0)	7.0 (1.0-21.0)
Jun 2020	4.0 (1.0-9.0)	5.0 (1.0-15.0)	7.0 (1.0-19.5)	15.0 (3.0-28.0)	25.0 (14.0-42.0)	8.0 (2.0-24.0)
Jul 2020	3.0 (1.0-9.0)	5.0 (0.0-15.0)	6.0 (1.0-17.0)	12.0 (2.0-26.0)	24.0 (10.0-39.0)	7.0 (1.0-22.0)
Aug 2020	4.0 (1.0-10.0)	5.0 (1.0-16.0)	7.0 (1.0-20.0)	14.0 (3.0-29.0)	27.0 (13.0-44.0)	8.0 (2.0-25.0)
Sept 2020	4.0 (1.0-11.0)	5.0 (1.0-16.0)	7.0 (1.0-21.0)	15.0 (4.0-30.0)	28.0 (15.0-46.0)	9.0 (2.0-26.0)
Oct 2020	4.0 (1.0-11.0)	6.0 (1.0-16.0)	7.0 (1.0-22.0)	16.0 (4.0-32.0)	29.0 (16.0-48.0)	10.0 (2.0-27.0)
Nov 2020	5.0 (1.0-13.0)	7.0 (1.0-19.0)	9.0 (2.0-24.5)	17.0 (4.0-34.0)	30.0 (17.0-50.0)	11.0 (3.0-29.0)
Dec 2020	4.0 (1.0-11.5)	6.0 (1.0-17.0)	8.0 (1.0-23.0)	16.0 (4.0-33.0)	30.0 (16.0-48.0)	10.0 (2.0-28.0)
Jan 2021	5.0 (1.0-13.0)	7.0 (1.0-20.0)	10.0 (2.0-24.0)	18.0 (4.0-35.0)	31.0 (18.0-51.0)	11.0 (3.0-30.0)
Feb 2021	5.0 (2.0-14.0)	7.0 (1.0-20.0)	10.0 (2.0-25.0)	18.5 (5.0-38.0)	33.0 (18.0-54.0)	12.0 (3.0-31.0)
Mar 2021	5.0 (1.5-13.0)	7.0 (1.0-21.0)	9.0 (2.0-25.0)	18.0 (4.0-38.0)	33.0 (18.0-54.0)	12.0 (3.0-32.0)
Apr 2021	5.0 (1.0-14.0)	7.0 (1.0-20.0)	9.5 (2.0-25.0)	18.5 (4.0-38.0)	33.0 (18.0-55.0)	12.0 (3.0-32.0)
May 2021	5.0 (1.0-14.0)	7.0 (1.0-20.0)	9.5 (2.0-25.5)	19.0 (5.0-39.0)	34.0 (18.0-56.0)	12.0 (3.0-32.0)
Jun 2021	5.0 (1.0-14.0)	7.0 (1.0-19.0)	10.0 (2.0-25.5)	20.0 (5.0-39.0)	35.0 (19.0-56.0)	12.0 (3.0-32.0)
Jul 2021	5.0 (1.0-14.0)	8.0 (1.0-19.0)	10.0 (2.0-26.0)	19.5 (5.0-39.0)	35.0 (19.0-56.0)	12.0 (3.0-33.0)
Aug 2021	5.0 (1.0-13.5)	8.0 (1.0-20.0)	10.0 (2.0-27.0)	19.0 (4.0-41.0)	34.0 (19.0-56.0)	12.0 (3.0-33.0)
Sept 2021	5.0 (1.0-14.0)	8.0 (1.0-20.0)	10.0 (2.0-27.0)	20.0 (4.0-41.0)	35.0 (19.0-58.0)	13.0 (3.0-33.0)
Oct 2021	5.0 (1.0-14.0)	8.0 (1.0-21.0)	10.0 (2.0-28.0)	20.0 (5.0-41.0)	35.0 (20.0-60.0)	13.0 (3.0-33.0)
Nov 2021	5.0 (1.0-14.0)	8.0 (1.0-21.0)	10.0 (2.0-28.0)	20.0 (5.0-41.0)	36.0 (20.0-59.0)	13.0 (3.0-34.0)
Dec 2021	5.0 (1.0-14.0)	8.0 (1.0-20.0)	10.0 (2.0-27.5)	20.0 (5.0-41.0)	35.0 (20.0-59.0)	13.0 (3.0-34.0)
Jan 2022	5.0 (1.0-14.5)	8.0 (1.0-21.0)	10.0 (2.0-27.5)	20.0 (4.0-41.0)	36.0 (20.0-59.0)	13.0 (3.0-34.0)
Feb 2022	5.0 (1.0-15.0)	8.0 (1.0-21.0)	10.0 (1.5-28.0)	21.0 (5.0-41.0)	36.0 (19.0-59.0)	13.0 (3.0-34.0)
Mar 2022	5.0 (1.0-15.0)	8.0 (1.0-21.0)	10.0 (2.0-29.0)	21.0 (4.0-41.0)	35.0 (20.0-59.0)	13.0 (3.0-34.0)

Notes: [a] data are reported as Median (IQR).

[b] food outlets with a customer-facing premises in a postcode district, based on Ordnance Survey Points of Interest data, registered to accept orders through the online food delivery service.

Table S3: change (%) for the number of food outlets registered to accept orders online in postcode districts in England, stratified by deprivation [a] [b].

	Deprivation quintile					
	1 (least deprived)	2	3	4	5 (most deprived)	England
Month						
Nov 2019 (baseline)	-	-	-	-	-	-
Jun 2020	14.3 (0.0-36.7)	14.0 (0.0-35.4)	11.1 (0.0-30.8)	12.0 (0.0-25.0)	11.1 (0.0-23.1)	12.0 (0.0-29.5)
Jul 2020	13.3 (0.0-39.4)	15.4 (0.0-40.0)	13.2 (0.0-33.3)	8.3 (-5.6-26.3)	10.7 (0.0-23.8)	11.8 (0.0-33.3)
Aug 2020	20.0 (0.0-50.0)	23.7 (0.0-50.0)	19.3 (0.0-46.2)	20.0 (0.0-40.9)	17.0 (3.7-33.3)	20.0 (0.0-42.9)
Sept 2020	25.0 (0.0-54.9)	25.0 (0.0-50.0)	22.2 (0.0-50.0)	24.8 (3.8-41.7)	22.2 (8.0-36.7)	23.1 (0.0-46.8)
Oct 2020	33.3 (0.0-66.7)	28.6 (0.0-60.0)	26.7 (4.9-55.6)	28.6 (8.3-50.0)	26.7 (12.0-41.7)	28.1 (6.3-50.0)
Nov 2020	50.0 (9.1-100.0)	50.0 (20.0-85.7)	43.7 (18.2-83.3)	35.9 (16.7-66.7)	32.1 (16.9-50.0)	41.5 (16.7-75.0)
Dec 2020	36.8 (0.0-75.0)	37.7 (0.0-68.6)	34.9 (0.0-66.7)	30.8 (9.1-56.3)	28.6 (14.3-47.5)	33.3 (7.1-61.5)
Jan 2021	58.3 (14.3-100.0)	50.0 (25.0-100.0)	50.0 (20.0-87.5)	41.3 (17.6-74.2)	36.1 (21.4-56.3)	45.1 (20.0-83.3)
Feb 2021	66.7 (25.0-100.0)	59.7 (30.3-100.0)	50.0 (23.1-100.0)	45.2 (26.2-77.8)	41.3 (26.7-63.6)	50.0 (25.2-91.8)
Mar 2021	60.0 (20.0-100.0)	56.8 (28.6-100.0)	50.0 (19.4-87.5)	45.6 (21.4-80.0)	42.9 (27.3-65.5)	50.0 (24.0-87.5)
Apr 2021	63.2 (20.0-100.0)	55.8 (27.3-100.0)	50.0 (20.0-91.7)	49.2 (24.0-83.3)	44.4 (28.6-67.5)	50.0 (25.0-91.7)
May 2021	66.7 (25.0-100.0)	60.0 (30.0-100.0)	50.0 (22.2-95.7)	51.8 (24.0-87.5)	47.5 (30.2-72.4)	52.0 (26.7-95.2)
Jun 2021	66.7 (20.0-100.0)	57.1 (28.6-100.0)	50.0 (23.1-100.0)	51.8 (23.1-89.5)	50.0 (33.3-72.4)	54.5 (27.3-100.0)
Jul 2021	66.7 (20.0-100.0)	59.0 (30.8-100.0)	50.0 (23.1-100.0)	51.9 (25.0-89.5)	50.0 (32.7-74.5)	54.5 (28.0-100.0)
Aug 2021	68.8 (20.0-100.0)	60.0 (31.6-100.0)	52.8 (20.0-100.0)	52.8 (27.3-96.0)	50.0 (33.3-80.8)	54.5 (28.0-100.0)
Sept 2021	68.4 (22.2-109.1)	62.5 (33.3-100.0)	56.3 (25.0-100.0)	56.3 (31.3-97.1)	51.6 (33.3-83.3)	57.9 (30.8-100.0)
Oct 2021	71.4 (21.4-110.0)	63.2 (33.3-100.0)	56.9 (28.0-100.0)	60.0 (32.1-96.8)	52.8 (34.5-83.3)	60.0 (30.7-100.0)
Nov 2021	75.0 (25.0-114.3)	63.8 (33.3-104.3)	56.5 (26.2-100.0)	61.3 (33.3-100.0)	55.6 (36.6-87.5)	61.1 (33.3-100.0)
Dec 2021	66.7 (20.0-116.7)	63.8 (33.3-106.3)	58.6 (27.3-100.0)	59.2 (33.3-100.0)	55.6 (35.7-84.4)	60.0 (33.0-100.0)
Jan 2022	71.4 (20.0-120.0)	66.1 (34.5-107.1)	60.0 (28.1-106.3)	62.5 (32.1-100.0)	57.1 (35.0-87.5)	62.5 (33.3-100.0)
Feb 2022	71.4 (22.2-116.7)	66.7 (33.3-114.3)	61.6 (28.6-109.7)	62.0 (31.8-100.0)	55.6 (36.2-85.7)	62.5 (33.3-100.0)
Mar 2022	80.0 (22.2-120.0)	69.0 (33.3-120.0)	66.7 (30.0-106.3)	62.8 (33.3-100.0)	57.9 (34.0-87.5)	65.4 (33.3-100.0)

Notes: [a] data are reported as Median (IQR).

[b] food outlets with a customer-facing premises in a postcode district, based on Ordnance Survey Points of Interest data, registered to accept orders through the online food delivery service.

Table S4: number (count) of food outlets accessible online in postcode districts in England, stratified by deprivation [a] [b].

	Deprivation quintile					
	1 (least deprived)	2	3	4	5 (most deprived)	England
Month						
Nov 2019	37.0 (14.0-70.5)	38.0 (10.0-96.0)	62.0 (8.5-134.5)	86.0 (12.0-190.0)	164.0 (87.0-273.0)	63.5 (16.0-156.0)
Jun 2020	19.0 (6.0-43.0)	18.0 (5.0-68.0)	36.5 (4.0-95.0)	64.5 (9.0-152.0)	134.0 (72.0-223.0)	41.0 (9.0-120.0)
Jul 2020	17.0 (4.0-42.5)	16.0 (3.0-63.0)	30.0 (2.0-85.0)	38.5 (1.0-122.0)	115.0 (45.0-207.0)	32.0 (4.0-104.0)
Aug 2020	20.0 (6.0-47.0)	17.0 (3.0-68.0)	33.0 (3.0-97.0)	58.5 (3.0-156.0)	137.0 (67.0-235.0)	38.0 (6.0-122.0)
Sept 2020	20.0 (6.0-48.0)	19.0 (5.0-74.0)	40.0 (4.0-103.5)	70.0 (11.0-166.0)	145.0 (76.0-242.0)	45.0 (9.0-131.0)
Oct 2020	21.0 (6.0-49.0)	20.0 (5.0-80.0)	41.0 (5.0-106.5)	71.5 (11.0-171.0)	149.0 (79.0-254.0)	45.5 (9.0-135.0)
Nov 2020	24.5 (20.0-51.0)	23.0 (11.0-86.0)	42.5 (10.0-110.0)	76.0 (20.0-177.0)	157.0 (84.0-261.0)	48.0 (20.0-141.0)
Dec 2020	22.0 (7.0-52.5)	21.0 (5.0-83.0)	42.5 (5.0-111.5)	74.5 (12.0-179.0)	156.0 (81.0-260.0)	47.0 (10.0-141.0)
Jan 2021	24.0 (19.0-53.5)	23.0 (10.0-84.0)	43.5 (10.0-114.5)	77.0 (17.0-185.0)	164.0 (84.0-273.0)	49.0 (18.0-146.0)
Feb 2021	26.0 (17.0-58.0)	23.0 (11.0-92.0)	48.0 (10.0-127.0)	83.5 (19.0-193.0)	171.0 (89.0-286.0)	53.0 (18.0-155.0)
Mar 2021	27.0 (9.0-59.0)	24.0 (6.0-95.0)	49.0 (5.5-131.0)	86.5 (14.0-204.0)	175.0 (93.0-298.0)	55.0 (11.0-161.0)
Apr 2021	26.5 (9.0-59.0)	25.0 (6.0-97.0)	50.5 (6.0-132.0)	89.5 (14.0-204.0)	178.0 (94.0-300.0)	54.5 (11.0-164.0)
May 2021	27.0 (9.0-59.0)	24.0 (6.0-97.0)	49.5 (6.0-133.0)	88.5 (15.0-205.0)	178.0 (97.0-299.0)	55.0 (11.0-165.0)
Jun 2021	26.0 (9.0-59.0)	25.0 (7.0-99.0)	49.5 (6.0-133.5)	89.5 (14.0-212.0)	181.0 (97.0-301.0)	54.0 (11.0-167.0)
Jul 2021	27.0 (9.0-58.5)	25.0 (7.0-99.0)	48.0 (6.0-133.0)	89.5 (13.0-207.0)	180.0 (100.0-299.0)	55.0 (11.0-166.0)
Aug 2021	27.0 (8.0-59.5)	26.0 (6.0-100.0)	48.5 (5.5-133.0)	89.5 (13.0-208.0)	176.0 (98.0-294.0)	56.0 (11.0-164.0)
Sept 2021	27.0 (9.0-58.5)	26.0 (7.0-98.0)	48.5 (6.0-136.0)	91.0 (13.0-214.0)	180.0 (102.0-299.0)	56.0 (12.0-167.0)
Oct 2021	26.0 (9.0-59.5)	27.0 (6.0-100.0)	49.0 (6.0-136.5)	90.0 (14.0-213.0)	181.0 (100.0-301.0)	56.0 (12.0-166.0)
Nov 2021	26.0 (8.5-59.5)	27.0 (7.0-102.0)	49.0 (6.0-136.0)	93.0 (14.0-211.0)	185.0 (103.0-305.0)	57.0 (12.0-168.0)
Dec 2021	26.0 (8.0-58.5)	26.0 (7.0-98.0)	50.0 (6.5-132.0)	93.5 (13.0-211.0)	180.0 (104.0-303.0)	57.0 (11.0-164.0)
Jan 2022	26.5 (8.0-60.0)	26.0 (6.0-100.0)	50.0 (6.0-133.5)	95.5 (15.0-210.0)	178.0 (106.0-303.0)	57.0 (11.0-165.0)
Feb 2022	26.5 (8.0-60.0)	25.0 (6.0-100.0)	50.0 (7.0-134.5)	97.0 (13.0-214.0)	174.0 (104.0-297.0)	57.0 (12.0-164.0)
Mar 2022	27.0 (8.5-60.5)	27.0 (6.0-103.0)	50.0 (6.5-133.5)	95.0 (13.0-217.0)	175.0 (104.0-292.0)	57.0 (11.0-163.0)

Notes: [a] data are reported as Median (IQR).

[b] food outlets registered to accept orders online that would deliver to a given postcode district.

Table S5: change (%) for the number of food outlets accessible online in postcode districts in England, stratified by deprivation [a] [b].

	Deprivation quintile					
	1 (least deprived)	2	3	4	5 (most deprived)	England
Month						
Nov 2019 (baseline)	-	-	-	-	-	-
Jun 2020	-37.7 (-62.8--13.0)	-33.3 (-57.1--12.4)	-28.6 (-53.2--4.1)	-19.0 (-36.2-0.0)	-17.3 (-27.6--4.2)	-25.5 (-50.0--6.7)
Jul 2020	-40.5 (-71.4--14.3)	-33.3 (-64.3--10.7)	-31.3 (-66.7--3.1)	-21.4 (-60.0-0.0)	-17.0 (-32.0--2.7)	-27.6 (-60.5--5.9)
Aug 2020	-34.1 (-64.3--10.0)	-33.3 (-62.5--7.7)	-27.7 (-56.1-0.0)	-15.6 (-38.7-10.0)	-12.6 (-27.1-2.2)	-23.5 (-50.0-0.0)
Sept 2020	-33.3 (-62.5--8.3)	-29.9 (-55.6--2.3)	-22.3 (-49.1-0.0)	-11.5 (-31.9-12.2)	-8.8 (-23.1-6.2)	-19.6 (-46.0-0.0)
Oct 2020	-30.9 (-60.0--5.7)	-28.6 (-53.8-0.0)	-20.1 (-47.6-2.6)	-8.3 (-30.2-16.7)	-5.8 (-20.6-10.0)	-16.9 (-43.7-5.3)
Nov 2020	-11.1 (-37.3-21.1)	-10.1 (-40.0-24.8)	-10.9 (-36.5-20.8)	0.6 (-22.2-25.8)	-0.8 (-16.2-14.4)	-5.5 (-30.9-20.8)
Dec 2020	-28.6 (-55.6-0.0)	-24.2 (-55.0-3.6)	-17.3 (-44.2-6.6)	0.0 (-23.9-22.4)	-1.8 (-17.6-12.9)	-13.0 (-41.9-11.1)
Jan 2021	-7.1 (-36.5-24.8)	-8.3 (-38.9-30.8)	-6.0 (-33.3-27.2)	5.6 (-19.6-33.6)	2.2 (-14.6-17.5)	-1.5 (-29.1-25.0)
Feb 2021	-4.8 (-33.3-29.0)	0.0 (-32.0-33.3)	0.0 (-30.2-30.7)	11.0 (-13.8-41.1)	8.0 (-9.0-24.0)	2.4 (-23.8-30.0)
Mar 2021	-14.8 (-47.5-14.7)	-10.1 (-48.1-21.6)	-5.9 (-36.8-24.3)	11.8 (-14.4-40.4)	10.5 (-7.5-28.4)	0.0 (-31.6-27.4)
Apr 2021	-14.5 (-48.4-14.8)	-8.3 (-49.2-25.0)	-3.7 (-37.0-26.5)	12.1 (-12.5-43.6)	12.6 (-5.5-30.8)	0.0 (-31.5-28.6)
May 2021	-14.0 (-47.1-17.4)	-8.3 (-46.0-24.3)	-3.7 (-37.0-26.6)	13.9 (-12.9-43.4)	12.8 (-4.3-31.5)	0.0 (-31.3-29.3)
Jun 2021	-12.5 (-48.4-20.0)	-8.2 (-45.5-24.1)	-2.4 (-35.3-25.5)	13.1 (-14.6-43.3)	12.7 (-5.5-32.2)	0.0 (-30.8-28.7)
Jul 2021	-15.2 (-50.0-18.2)	-8.3 (-44.7-25.0)	-4.6 (-37.5-25.2)	14.0 (-14.2-41.4)	12.9 (-6.4-32.6)	0.0 (-31.6-28.4)
Aug 2021	-16.3 (-50.0-15.4)	-11.3 (-50.0-20.4)	-4.0 (-39.2-25.0)	10.6 (-13.9-43.5)	11.8 (-7.2-31.7)	0.0 (-32.7-28.3)
Sept 2021	-15.2 (-50.0-18.4)	-8.3 (-49.2-25.0)	-1.8 (-36.8-28.9)	12.8 (-14.7-45.5)	13.9 (-4.5-34.1)	0.0 (-31.0-30.6)
Oct 2021	-14.5 (-50.0-18.5)	-8.7 (-47.4-25.9)	-2.3 (-38.4-31.4)	12.3 (-14.3-49.2)	14.3 (-4.6-33.6)	0.0 (-31.8-31.7)
Nov 2021	-14.5 (-49.4-14.3)	-8.8 (-50.0-27.7)	0.0 (-37.0-31.0)	14.6 (-14.8-51.7)	14.7 (-5.8-35.2)	0.0 (-32.3-32.3)
Dec 2021	-16.1 (-50.0-15.0)	-9.5 (-50.0-26.5)	-4.0 (-36.1-30.9)	13.6 (-15.6-50.0)	14.0 (-6.3-33.4)	0.0 (-32.7-31.7)
Jan 2022	-13.5 (-48.6-16.7)	-9.3 (-50.0-25.0)	-1.4 (-37.3-31.4)	15.3 (-13.8-52.7)	13.3 (-5.7-34.6)	0.0 (-31.8-31.6)
Feb 2022	-14.5 (-50.0-19.0)	-9.4 (-50.0-27.3)	-1.8 (-36.0-32.3)	11.8 (-16.7-50.0)	13.2 (-7.9-33.1)	0.0 (-33.3-32.0)
Mar 2022	-12.7 (-48.6-20.0)	-7.5 (-48.8-28.6)	-1.1 (-35.0-33.2)	13.8 (-18.2-52.5)	13.1 (-7.9-33.8)	0.0 (-32.0-33.3)

Notes: [a] data are reported as Median (IQR).

[b] food outlets registered to accept orders online that would deliver to a given postcode district.

Table S6: percentage of food outlets registered to accept orders online in postcode districts in England, stratified by deprivation [a] [b].

	Deprivation quintile					
	1 (least deprived)	2	3	4	5 (most deprived)	England
Month						
Nov 2019	7.9 (2.2-14.9)	8.7 (1.5-19.0)	12.5 (1.9-23.5)	20.4 (6.5-30.8)	27.8 (19.7-37.4)	14.3 (3.8-26.0)
Jun 2020	11.8 (3.3-21.5)	13.6 (3.0-30.4)	19.0 (3.7-36.2)	31.9 (8.8-50.0)	48.6 (34.5-63.5)	22.2 (6.2-43.5)
Jul 2020	10.5 (2.8-21.1)	13.0 (0.0-31.0)	17.5 (2.4-35.0)	26.7 (5.3-47.6)	47.1 (29.8-61.3)	20.0 (4.3-41.2)
Aug 2020	12.5 (3.9-23.3)	13.6 (2.6-32.8)	19.2 (4.0-39.2)	31.6 (7.7-53.7)	50.9 (36.0-66.7)	22.7 (6.0-46.0)
Sept 2020	9.7 (2.9-18.8)	11.1 (2.5-25.0)	15.5 (3.4-28.6)	23.7 (7.7-37.8)	33.3 (23.6-43.7)	17.4 (5.2-32.7)
Oct 2020	10.5 (3.5-19.6)	11.8 (2.9-26.0)	15.9 (3.8-29.8)	24.0 (7.7-38.5)	34.2 (24.7-45.5)	18.2 (5.6-33.8)
Nov 2020	12.5 (4.2-22.9)	14.3 (3.2-29.7)	18.1 (4.9-33.8)	25.8 (9.1-41.5)	36.0 (26.6-46.7)	20.8 (6.8-36.6)
Dec 2020	10.8 (3.7-20.5)	12.1 (2.6-27.0)	16.4 (3.8-31.4)	24.2 (7.7-39.3)	35.1 (25.7-45.5)	18.6 (5.7-34.8)
Jan 2021	12.5 (4.8-23.5)	14.9 (3.0-29.8)	18.3 (4.7-33.8)	26.3 (8.5-42.2)	37.4 (27.2-48.1)	21.1 (6.9-37.5)
Feb 2021	13.5 (5.5-25.0)	14.9 (3.4-32.3)	19.0 (5.0-36.0)	27.9 (9.4-43.6)	39.2 (28.6-50.0)	22.0 (7.4-39.1)
Mar 2021	12.5 (5.2-23.8)	14.8 (3.4-31.3)	18.8 (4.3-34.3)	27.0 (9.2-44.6)	39.5 (28.4-50.0)	21.6 (7.1-38.6)
Apr 2021	12.5 (4.9-23.9)	14.8 (3.0-31.3)	18.8 (4.6-34.0)	27.7 (8.8-45.5)	40.2 (28.7-50.0)	21.6 (7.1-39.2)
May 2021	12.4 (5.0-23.7)	14.3 (3.4-32.6)	19.3 (4.9-34.4)	28.4 (9.3-46.2)	40.9 (29.3-50.9)	22.1 (7.2-40.0)
Jun 2021	12.5 (4.8-23.7)	14.3 (3.9-32.4)	19.5 (4.9-34.6)	27.9 (9.6-45.6)	40.7 (29.3-51.8)	22.2 (7.1-40.0)
Jul 2021	12.5 (4.5-24.8)	14.3 (4.0-32.6)	20.0 (4.9-34.6)	28.1 (9.6-46.2)	40.7 (29.1-51.3)	22.2 (7.1-40.0)
Aug 2021	12.5 (4.5-23.8)	14.0 (3.9-33.3)	19.8 (4.9-35.3)	29.8 (9.5-45.7)	41.0 (29.3-52.8)	22.6 (7.1-40.3)
Sept 2021	13.0 (4.8-24.8)	14.3 (3.9-32.9)	20.0 (4.9-35.0)	29.4 (9.7-46.1)	40.9 (29.5-51.5)	22.9 (7.2-40.3)
Oct 2021	13.0 (4.9-24.5)	14.8 (3.9-33.3)	20.2 (5.3-35.8)	29.5 (9.7-46.1)	41.2 (29.8-52.0)	23.0 (7.5-40.8)
Nov 2021	13.1 (5.1-24.9)	14.9 (4.0-33.3)	20.0 (5.3-35.9)	30.1 (9.7-46.2)	41.5 (30.8-53.1)	23.2 (7.4-40.9)
Dec 2021	12.5 (4.8-25.2)	14.8 (4.0-33.3)	20.1 (5.3-35.6)	30.0 (9.4-46.2)	40.9 (30.2-53.1)	23.1 (7.2-40.8)
Jan 2022	12.7 (4.8-25.5)	14.8 (4.0-33.0)	20.4 (5.0-36.2)	30.1 (10.6-46.4)	41.5 (30.8-53.2)	23.4 (7.4-40.9)
Feb 2022	12.8 (4.8-25.0)	14.8 (4.2-33.3)	20.7 (5.3-36.6)	31.0 (11.0-46.2)	41.5 (30.2-53.1)	23.3 (7.7-40.8)
Mar 2022	13.2 (4.7-25.9)	14.9 (4.1-33.3)	20.5 (5.3-36.6)	30.8 (11.3-46.6)	41.9 (30.7-52.4)	24.0 (7.7-41.0)

Notes: [a] data are reported as Median (IQR).

[b] percentage calculated as the number of food outlets registered to accept orders online compared with the number of food outlets with a customer-facing premises in a postcode district, based on Ordnance Survey Points of Interest data.

Table S7: change (%) for the percentage of food outlets registered to accept orders online in postcode districts in England, stratified by deprivation [a] [b].

	Deprivation quintile					
	1 (least deprived)	2	3	4	5 (most deprived)	England
Month						
Nov 2019 (baseline)	-	-	-	-	-	-
Jun 2020	44.7 (17.4-81.0)	54.1 (28.3-79.2)	53.5 (30.0-82.9)	62.9 (33.3-92.4)	75.3 (49.2-99.5)	58.1 (31.1-88.8)
Jul 2020	45.0 (14.8-83.9)	56.6 (26.3-84.1)	55.3 (22.2-84.6)	55.5 (20.9-88.5)	69.6 (40.6-99.7)	57.2 (24.0-90.5)
Aug 2020	56.5 (20.8-95.7)	63.6 (31.7-101.6)	66.1 (37.5-101.3)	74.1 (34.0-111.1)	85.1 (52.8-115.3)	69.2 (35.0-107.2)
Sept 2020	22.1 (0.0-54.6)	21.3 (2.3-52.3)	19.9 (2.3-44.0)	22.1 (3.6-40.0)	19.4 (3.4-36.6)	20.5 (2.2-44.0)
Oct 2020	28.7 (0.0-62.5)	26.8 (5.7-59.1)	25.6 (5.2-55.2)	25.4 (6.4-46.3)	23.1 (7.7-39.4)	25.2 (5.2-51.0)
Nov 2020	50.0 (9.0-100.0)	46.9 (16.7-79.3)	40.0 (13.9-76.5)	34.3 (13.6-59.2)	29.5 (14.1-50.7)	38.3 (13.8-69.7)
Dec 2020	33.8 (1.8-71.4)	33.5 (6.2-64.5)	31.9 (5.9-60.9)	27.3 (7.5-52.3)	24.7 (8.0-43.8)	29.2 (6.2-57.5)
Jan 2021	52.9 (10.2-105.7)	50.9 (20.9-89.7)	44.6 (17.1-82.9)	38.2 (13.1-66.7)	33.3 (15.2-53.8)	41.3 (15.5-77.3)
Feb 2021	63.1 (23.3-113.5)	57.1 (26.5-99.0)	46.8 (20.0-88.6)	41.2 (20.8-71.6)	37.9 (20.6-59.5)	46.3 (21.9-85.8)
Mar 2021	55.6 (19.3-102.3)	51.6 (21.7-94.0)	45.1 (14.5-79.8)	43.5 (17.8-70.9)	37.6 (20.2-61.3)	44.6 (18.7-79.2)
Apr 2021	58.7 (20.3-100.0)	50.3 (23.0-94.9)	45.6 (17.9-83.8)	44.4 (19.0-76.3)	39.5 (20.6-63.0)	45.6 (20.0-82.8)
May 2021	61.4 (19.3-103.9)	53.0 (23.1-100.0)	45.2 (19.1-86.6)	47.5 (19.9-81.4)	41.6 (22.8-66.1)	48.4 (20.8-85.7)
Jun 2021	62.5 (15.4-105.6)	51.8 (22.5-100.0)	46.8 (18.6-88.7)	45.0 (20.0-79.7)	43.8 (23.8-65.0)	48.6 (20.4-86.7)
Jul 2021	62.7 (12.8-103.0)	53.0 (22.8-100.0)	46.8 (18.6-89.7)	46.5 (19.7-81.5)	43.1 (23.8-66.7)	49.2 (20.4-87.4)
Aug 2021	63.9 (13.3-105.8)	54.0 (23.0-100.0)	46.7 (14.3-89.6)	47.0 (22.2-84.7)	43.9 (24.2-67.3)	50.0 (20.8-89.6)
Sept 2021	64.8 (16.7-109.8)	54.2 (25.0-105.3)	49.5 (17.2-89.3)	46.7 (22.6-83.0)	43.4 (24.3-70.2)	50.5 (21.8-90.0)
Oct 2021	66.7 (15.3-109.1)	55.9 (25.6-105.3)	50.0 (21.0-90.9)	50.0 (23.4-86.2)	44.0 (25.4-73.0)	51.9 (22.9-91.4)
Nov 2021	67.6 (18.4-112.3)	56.9 (28.0-106.5)	50.0 (19.1-90.9)	51.8 (26.2-86.7)	46.2 (24.4-76.3)	53.0 (23.3-93.8)
Dec 2021	62.3 (14.5-111.9)	58.2 (23.5-102.2)	51.4 (22.6-92.0)	49.1 (26.2-86.8)	44.8 (23.4-74.5)	51.9 (22.5-92.2)
Jan 2022	63.0 (15.3-112.3)	58.9 (26.1-102.2)	53.1 (23.0-100.0)	53.6 (22.0-87.9)	46.3 (24.0-76.3)	53.8 (22.7-93.8)
Feb 2022	66.6 (16.7-113.5)	58.6 (25.0-104.5)	54.3 (21.9-100.0)	54.2 (22.7-84.2)	44.8 (25.0-74.8)	54.2 (23.1-93.9)
Mar 2022	70.7 (16.7-116.0)	62.0 (25.0-106.2)	55.1 (24.0-98.9)	53.0 (24.8-88.9)	44.8 (22.4-75.8)	55.3 (23.0-96.1)

Notes: [a] data are reported as Median (IQR).

[b] percentage calculated as the number of food outlets registered to accept orders online compared with the number of food outlets with a customer-facing premises in a postcode district, based on Ordnance Survey Points of Interest data.

Table S8: number (count) of food outlets in the physical food environment in postcode districts in England, stratified by deprivation [a b].

	Deprivation quintile					
	1 (least deprived)	2	3	4	5 (most deprived)	England
Month						
Nov 2019	52.3 (42.0)	59.5 (42.7)	69.3 (65.4)	83.3 (77.1)	100.5 (82.1)	71.9 (65.3)
Jun 2020	40.6 (29.9)	44.6 (29.3)	50.1 (42.9)	56.7 (47.9)	63.0 (48.5)	50.5 (40.8)
Jul 2020	40.6 (29.9)	44.6 (29.3)	50.1 (42.9)	56.7 (47.9)	63.0 (48.5)	50.5 (40.8)
Aug 2020	40.6 (29.9)	44.6 (29.3)	50.1 (42.9)	56.7 (47.9)	63.0 (48.5)	50.5 (40.8)
Sept 2020	52.8 (42.5)	60.2 (43.2)	70.4 (66.4)	84.9 (77.7)	102.6 (82.1)	73.1 (65.9)
Oct 2020	52.8 (42.5)	60.2 (43.2)	70.4 (66.4)	84.9 (77.7)	102.6 (82.1)	73.1 (65.9)
Nov 2020	52.8 (42.5)	60.2 (43.2)	70.4 (66.4)	84.9 (77.7)	102.6 (82.1)	73.1 (65.9)
Dec 2020	53.0 (42.9)	60.6 (43.5)	70.9 (66.9)	85.2 (78.1)	103.1 (82.2)	73.5 (66.2)
Jan 2021	53.0 (42.9)	60.6 (43.5)	70.9 (66.9)	85.2 (78.1)	103.1 (82.2)	73.5 (66.2)
Feb 2021	53.0 (42.9)	60.6 (43.5)	70.9 (66.9)	85.2 (78.1)	103.1 (82.2)	73.5 (66.2)
Mar 2021	53.5 (43.2)	61.2 (43.7)	71.4 (67.0)	86.1 (78.5)	104.3 (83.0)	74.2 (66.7)
Apr 2021	53.5 (43.2)	61.2 (43.7)	71.4 (67.0)	86.1 (78.5)	104.3 (83.0)	74.2 (66.7)
May 2021	53.5 (43.2)	61.2 (43.7)	71.4 (67.0)	86.1 (78.5)	104.3 (83.0)	74.2 (66.7)
Jun 2021	53.8 (43.5)	61.4 (43.9)	71.6 (67.3)	86.6 (78.3)	105.3 (83.2)	74.6 (66.9)
Jul 2021	53.8 (43.5)	61.4 (43.9)	71.6 (67.3)	86.6 (78.3)	105.3 (83.2)	74.6 (66.9)
Aug 2021	53.8 (43.5)	61.4 (43.9)	71.6 (67.3)	86.6 (78.3)	105.3 (83.2)	74.6 (66.9)
Sept 2021	53.8 (43.7)	61.8 (44.4)	72.1 (68.1)	87.7 (80.0)	106.5 (84.1)	75.3 (67.8)
Oct 2021	53.8 (43.7)	61.8 (44.4)	72.1 (68.1)	87.7 (80.0)	106.5 (84.1)	75.3 (67.8)
Nov 2021	53.8 (43.7)	61.8 (44.4)	72.1 (68.1)	87.7 (80.0)	106.5 (84.1)	75.3 (67.8)
Dec 2021	54.1 (43.9)	62.1 (44.6)	72.4 (68.3)	88.1 (80.3)	106.9 (84.3)	75.6 (68.0)
Jan 2022	54.1 (43.9)	62.1 (44.6)	72.4 (68.3)	88.1 (80.3)	106.9 (84.3)	75.6 (68.0)
Feb 2022	54.1 (43.9)	62.1 (44.6)	72.4 (68.3)	88.1 (80.3)	106.9 (84.3)	75.6 (68.0)
Mar 2022	54.1 (43.9)	62.1 (44.6)	72.4 (68.3)	88.1 (80.3)	106.9 (84.3)	75.6 (68.0)

Notes: [a] data are reported as Mean (standard deviation).

[b] the number of food outlets with a customer-facing premises in a postcode district, based on Ordnance Survey Points of Interest data, published quarterly.

Table S9: change (%) for the number of food outlets in the physical food environment in postcode districts in England, stratified by deprivation [a] [b].

	Deprivation quintile					
	1 (least deprived)	2	3	4	5 (most deprived)	England
Month						
Nov 2019 (baseline)	-	-	-	-	-	-
Jun 2020	-18.4 (10.5)	-20.9 (11.0)	-22.8 (11.4)	-26.8 (13.1)	-33.4 (11.6)	-24.2 (12.6)
Jul 2020	-18.4 (10.5)	-20.9 (11.0)	-22.8 (11.4)	-26.8 (13.1)	-33.4 (11.6)	-24.2 (12.6)
Aug 2020	-18.4 (10.5)	-20.9 (11.0)	-22.8 (11.4)	-26.8 (13.1)	-33.4 (11.6)	-24.2 (12.6)
Sept 2020	1.0 (9.0)	1.1 (8.0)	1.7 (9.6)	2.5 (10.1)	4.0 (11.7)	2.0 (9.7)
Oct 2020	1.0 (9.0)	1.1 (8.0)	1.7 (9.6)	2.5 (10.1)	4.0 (11.7)	2.0 (9.7)
Nov 2020	1.0 (9.0)	1.1 (8.0)	1.7 (9.6)	2.5 (10.1)	4.0 (11.7)	2.0 (9.7)
Dec 2020	1.4 (9.5)	1.7 (8.2)	2.6 (9.6)	2.9 (11.3)	4.7 (11.7)	2.6 (10.1)
Jan 2021	1.4 (9.5)	1.7 (8.2)	2.6 (9.6)	2.9 (11.3)	4.7 (11.7)	2.6 (10.1)
Feb 2021	1.4 (9.5)	1.7 (8.2)	2.6 (9.6)	2.9 (11.3)	4.7 (11.7)	2.6 (10.1)
Mar 2021	2.2 (10.3)	2.8 (9.0)	3.3 (9.9)	4.4 (12.7)	6.0 (12.4)	3.7 (10.9)
Apr 2021	2.2 (10.3)	2.8 (9.0)	3.3 (9.9)	4.4 (12.7)	6.0 (12.4)	3.7 (10.9)
May 2021	2.2 (10.3)	2.8 (9.0)	3.3 (9.9)	4.4 (12.7)	6.0 (12.4)	3.7 (10.9)
Jun 2021	2.6 (10.6)	3.1 (9.1)	3.6 (10.0)	5.1 (12.9)	7.3 (13.2)	4.3 (11.3)
Jul 2021	2.6 (10.6)	3.1 (9.1)	3.6 (10.0)	5.1 (12.9)	7.3 (13.2)	4.3 (11.3)
Aug 2021	2.6 (10.6)	3.1 (9.1)	3.6 (10.0)	5.1 (12.9)	7.3 (13.2)	4.3 (11.3)
Sept 2021	2.5 (11.2)	3.6 (10.2)	4.1 (10.6)	6.1 (13.3)	8.5 (13.9)	4.9 (12.0)
Oct 2021	2.5 (11.2)	3.6 (10.2)	4.1 (10.6)	6.1 (13.3)	8.5 (13.9)	4.9 (12.0)
Nov 2021	2.5 (11.2)	3.6 (10.2)	4.1 (10.6)	6.1 (13.3)	8.5 (13.9)	4.9 (12.0)
Dec 2021	3.1 (11.6)	4.1 (10.3)	4.5 (10.7)	6.6 (13.5)	9.0 (14.1)	5.3 (12.2)
Jan 2022	3.1 (11.6)	4.1 (10.3)	4.5 (10.7)	6.6 (13.5)	9.0 (14.1)	5.3 (12.2)
Feb 2022	3.1 (11.6)	4.1 (10.3)	4.5 (10.7)	6.6 (13.5)	9.0 (14.1)	5.3 (12.2)
Mar 2022	3.1 (11.6)	4.1 (10.3)	4.5 (10.7)	6.6 (13.5)	9.0 (14.1)	5.3 (12.2)

Notes: [a] data are reported as Mean (standard deviation).

[b] the number of food outlets with a customer-facing premises in a postcode district, based on Ordnance Survey Points of Interest data, published quarterly.

Table S10: Incidence Rate Ratios (IRR) and 95% confidence intervals (CI) for the number (count) of food outlets registered to accept orders online in postcode districts in England, stratified by deprivation, estimated using an unadjusted negative binomial generalised estimating equation.

	Deprivation quintile																	
	1 (least deprived)			2			3			4			5 (most deprived)			England		
	IRR	95% CI		IRR	95% CI		IRR	95% CI		IRR	95% CI		IRR	95% CI		IRR	95% CI	
Month																		
Nov 2019	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref
Jun 2020	1.18	1.16	1.20	1.18	1.16	1.20	1.17	1.15	1.19	1.16	1.13	1.18	1.13	1.11	1.16	1.15	1.14	1.16
Jul 2020	1.18	1.16	1.20	1.17	1.15	1.19	1.10	1.08	1.12	1.03	1.01	1.06	1.06	1.04	1.08	1.09	1.08	1.10
Aug 2020	1.29	1.27	1.32	1.27	1.25	1.30	1.23	1.21	1.25	1.22	1.19	1.25	1.19	1.17	1.22	1.23	1.22	1.24
Sept 2020	1.32	1.30	1.35	1.31	1.29	1.34	1.29	1.27	1.32	1.29	1.26	1.32	1.25	1.22	1.27	1.28	1.27	1.29
Oct 2020	1.38	1.36	1.41	1.38	1.35	1.40	1.36	1.33	1.38	1.35	1.32	1.38	1.29	1.27	1.32	1.34	1.32	1.35
Nov 2020	1.57	1.54	1.60	1.55	1.52	1.58	1.50	1.47	1.52	1.44	1.41	1.48	1.36	1.33	1.39	1.45	1.43	1.46
Dec 2020	1.45	1.42	1.47	1.45	1.42	1.48	1.43	1.40	1.46	1.40	1.37	1.43	1.33	1.31	1.36	1.39	1.38	1.40
Jan 2021	1.61	1.58	1.64	1.59	1.56	1.62	1.53	1.50	1.55	1.49	1.45	1.52	1.41	1.38	1.44	1.49	1.48	1.50
Feb 2021	1.69	1.66	1.72	1.66	1.63	1.69	1.62	1.59	1.65	1.55	1.52	1.59	1.46	1.43	1.50	1.56	1.54	1.57
Mar 2021	1.68	1.65	1.71	1.67	1.64	1.70	1.61	1.58	1.64	1.56	1.53	1.60	1.49	1.46	1.52	1.57	1.56	1.58
Apr 2021	1.69	1.66	1.72	1.67	1.64	1.70	1.63	1.60	1.66	1.59	1.56	1.63	1.52	1.48	1.55	1.59	1.58	1.60
May 2021	1.71	1.68	1.74	1.69	1.66	1.73	1.65	1.62	1.68	1.62	1.58	1.66	1.53	1.50	1.57	1.61	1.60	1.62
Jun 2021	1.72	1.69	1.75	1.70	1.67	1.73	1.65	1.62	1.68	1.63	1.60	1.67	1.55	1.52	1.59	1.62	1.61	1.64
Jul 2021	1.73	1.70	1.76	1.71	1.67	1.74	1.66	1.63	1.69	1.64	1.60	1.68	1.56	1.52	1.59	1.63	1.62	1.64
Aug 2021	1.75	1.72	1.78	1.72	1.69	1.75	1.67	1.63	1.70	1.66	1.62	1.70	1.56	1.53	1.60	1.64	1.63	1.65
Sept 2021	1.77	1.74	1.80	1.74	1.71	1.77	1.68	1.65	1.71	1.68	1.65	1.72	1.58	1.55	1.62	1.66	1.65	1.68
Oct 2021	1.78	1.75	1.81	1.75	1.72	1.78	1.70	1.66	1.73	1.70	1.66	1.74	1.59	1.56	1.63	1.67	1.66	1.69
Nov 2021	1.80	1.77	1.83	1.76	1.73	1.80	1.71	1.68	1.74	1.71	1.67	1.75	1.61	1.58	1.65	1.69	1.67	1.70
Dec 2021	1.79	1.76	1.82	1.75	1.72	1.78	1.71	1.68	1.74	1.70	1.66	1.74	1.61	1.57	1.64	1.68	1.67	1.70
Jan 2022	1.81	1.78	1.84	1.76	1.73	1.80	1.73	1.69	1.76	1.71	1.67	1.75	1.62	1.58	1.65	1.70	1.68	1.71
Feb 2022	1.82	1.79	1.85	1.76	1.73	1.80	1.73	1.70	1.76	1.71	1.68	1.76	1.61	1.57	1.64	1.69	1.68	1.71
Mar 2022	1.84	1.81	1.88	1.78	1.75	1.81	1.75	1.71	1.78	1.72	1.68	1.76	1.61	1.57	1.64	1.70	1.69	1.72

Table S11: Incidence Rate Ratios (IRR) and 95% confidence intervals (CI) for the number (count) of food outlets registered to accept orders online in postcode districts in England, stratified by deprivation, estimated using an adjusted negative binomial generalised estimating equation [a].

	Deprivation quintile																	
	1 (least deprived)			2			3			4			5 (most deprived)			England		
	IRR	95% CI		IRR	95% CI		IRR	95% CI		IRR	95% CI		IRR	95% CI		IRR	95% CI	
Month																		
Nov 2019	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref
Jun 2020	1.22	1.17	1.28	1.24	1.19	1.28	1.21	1.16	1.26	1.19	1.14	1.23	1.14	1.11	1.17	1.18	1.16	1.19
Jul 2020	1.19	1.14	1.24	1.22	1.18	1.27	1.16	1.11	1.21	1.08	1.04	1.12	1.07	1.05	1.10	1.11	1.10	1.13
Aug 2020	1.32	1.26	1.38	1.31	1.27	1.36	1.28	1.23	1.34	1.25	1.20	1.30	1.20	1.16	1.23	1.24	1.22	1.26
Sept 2020	1.30	1.24	1.35	1.30	1.25	1.34	1.27	1.22	1.33	1.27	1.22	1.31	1.24	1.21	1.27	1.26	1.25	1.28
Oct 2020	1.38	1.32	1.44	1.36	1.32	1.41	1.34	1.29	1.40	1.32	1.27	1.37	1.28	1.25	1.31	1.32	1.31	1.34
Nov 2020	1.61	1.55	1.68	1.58	1.53	1.64	1.55	1.48	1.61	1.41	1.36	1.47	1.35	1.31	1.38	1.47	1.45	1.50
Dec 2020	1.43	1.38	1.50	1.40	1.35	1.45	1.40	1.34	1.46	1.34	1.30	1.39	1.31	1.28	1.35	1.36	1.34	1.38
Jan 2021	1.66	1.59	1.73	1.60	1.54	1.65	1.59	1.53	1.66	1.45	1.40	1.51	1.39	1.35	1.42	1.51	1.49	1.53
Feb 2021	1.74	1.67	1.82	1.68	1.62	1.74	1.64	1.58	1.71	1.52	1.47	1.57	1.44	1.41	1.48	1.57	1.55	1.60
Mar 2021	1.70	1.63	1.77	1.65	1.59	1.71	1.59	1.53	1.66	1.52	1.46	1.57	1.47	1.43	1.50	1.56	1.54	1.58
Apr 2021	1.70	1.63	1.77	1.64	1.58	1.69	1.60	1.54	1.67	1.55	1.49	1.60	1.49	1.45	1.53	1.57	1.55	1.60
May 2021	1.71	1.64	1.79	1.67	1.61	1.73	1.62	1.55	1.68	1.57	1.51	1.62	1.51	1.47	1.55	1.59	1.57	1.62
Jun 2021	1.71	1.64	1.78	1.67	1.61	1.73	1.62	1.56	1.69	1.58	1.52	1.63	1.53	1.49	1.57	1.60	1.58	1.63
Jul 2021	1.71	1.64	1.78	1.67	1.61	1.73	1.64	1.58	1.71	1.59	1.53	1.65	1.53	1.49	1.57	1.61	1.59	1.63
Aug 2021	1.72	1.65	1.80	1.67	1.62	1.73	1.64	1.58	1.71	1.61	1.56	1.67	1.54	1.50	1.57	1.62	1.60	1.64
Sept 2021	1.74	1.67	1.81	1.69	1.63	1.75	1.66	1.60	1.73	1.64	1.58	1.70	1.56	1.52	1.60	1.64	1.62	1.66
Oct 2021	1.74	1.67	1.81	1.71	1.65	1.77	1.68	1.62	1.75	1.66	1.60	1.72	1.57	1.53	1.61	1.65	1.63	1.68
Nov 2021	1.76	1.69	1.84	1.72	1.66	1.78	1.70	1.63	1.77	1.67	1.61	1.73	1.59	1.55	1.63	1.67	1.65	1.69
Dec 2021	1.75	1.68	1.82	1.69	1.63	1.76	1.70	1.63	1.77	1.66	1.60	1.72	1.59	1.55	1.62	1.66	1.64	1.69
Jan 2022	1.77	1.69	1.84	1.71	1.65	1.77	1.72	1.65	1.79	1.66	1.60	1.72	1.59	1.56	1.63	1.67	1.65	1.70
Feb 2022	1.77	1.70	1.85	1.73	1.67	1.79	1.72	1.65	1.79	1.68	1.62	1.74	1.59	1.55	1.63	1.68	1.66	1.70
Mar 2022	1.80	1.73	1.88	1.73	1.67	1.80	1.73	1.66	1.80	1.68	1.62	1.74	1.59	1.55	1.63	1.69	1.66	1.71

Note: [a] adjusted for population density, rural urban classification and the number of food outlets with a customer-facing premises in a postcode district, based on Ordnance Survey Points of Interest data. 2067 postcode districts included.

Table S12: Incidence Rate Ratios (IRR) and 95% confidence intervals (CI) for the number (count) of food outlets accessible online in postcode districts in England, stratified by deprivation, estimated using an unadjusted negative binomial generalised estimating equation.

	Deprivation quintile																	
	1 (least deprived)			2			3			4			5 (most deprived)			England		
	IRR	95% CI		IRR	95% CI		IRR	95% CI		IRR	95% CI		IRR	95% CI		IRR	95% CI	
Month																		
Nov 2019	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref
Jun 2020	0.71	0.70	0.73	0.82	0.80	0.84	0.77	0.76	0.79	0.84	0.82	0.86	0.82	0.80	0.85	0.80	0.80	0.81
Jul 2020	0.68	0.67	0.69	0.75	0.74	0.77	0.72	0.70	0.73	0.68	0.66	0.70	0.71	0.69	0.73	0.71	0.70	0.71
Aug 2020	0.78	0.76	0.79	0.87	0.85	0.89	0.82	0.80	0.83	0.89	0.86	0.91	0.86	0.83	0.88	0.85	0.84	0.86
Sept 2020	0.81	0.79	0.82	0.96	0.94	0.98	0.89	0.87	0.91	0.97	0.94	1.00	0.91	0.89	0.94	0.92	0.91	0.92
Oct 2020	0.84	0.82	0.85	1.01	0.99	1.03	0.94	0.92	0.96	1.02	0.99	1.05	0.95	0.92	0.97	0.96	0.95	0.97
Nov 2020	0.95	0.93	0.96	1.09	1.07	1.11	1.00	0.98	1.02	1.08	1.05	1.11	0.98	0.95	1.01	1.02	1.01	1.03
Dec 2020	0.89	0.88	0.91	1.07	1.05	1.10	1.00	0.98	1.02	1.08	1.05	1.11	0.98	0.95	1.01	1.01	1.00	1.02
Jan 2021	0.96	0.94	0.98	1.12	1.09	1.14	1.04	1.01	1.06	1.12	1.09	1.15	1.02	0.99	1.05	1.05	1.04	1.06
Feb 2021	1.01	0.99	1.03	1.18	1.15	1.20	1.09	1.07	1.11	1.17	1.14	1.20	1.08	1.04	1.11	1.11	1.10	1.12
Mar 2021	1.00	0.98	1.02	1.19	1.16	1.21	1.11	1.09	1.13	1.20	1.17	1.23	1.11	1.08	1.14	1.13	1.12	1.14
Apr 2021	1.02	1.00	1.04	1.21	1.18	1.23	1.13	1.11	1.15	1.22	1.19	1.26	1.13	1.10	1.17	1.15	1.14	1.16
May 2021	1.02	1.01	1.04	1.22	1.20	1.25	1.14	1.12	1.17	1.24	1.21	1.27	1.13	1.10	1.17	1.16	1.15	1.17
Jun 2021	1.01	0.99	1.03	1.19	1.16	1.21	1.12	1.10	1.14	1.21	1.18	1.25	1.13	1.09	1.16	1.14	1.13	1.15
Jul 2021	1.02	1.00	1.04	1.19	1.17	1.22	1.12	1.10	1.15	1.22	1.19	1.25	1.13	1.10	1.16	1.14	1.13	1.15
Aug 2021	1.01	1.00	1.03	1.19	1.16	1.21	1.11	1.09	1.13	1.21	1.18	1.25	1.12	1.09	1.15	1.14	1.12	1.15
Sept 2021	1.03	1.01	1.05	1.21	1.19	1.24	1.14	1.12	1.17	1.24	1.21	1.28	1.14	1.10	1.17	1.16	1.15	1.17
Oct 2021	1.03	1.01	1.05	1.20	1.18	1.23	1.14	1.11	1.16	1.24	1.20	1.27	1.14	1.11	1.17	1.16	1.14	1.17
Nov 2021	1.03	1.01	1.05	1.21	1.18	1.24	1.14	1.12	1.16	1.24	1.21	1.27	1.14	1.11	1.18	1.16	1.15	1.17
Dec 2021	1.02	1.00	1.04	1.20	1.17	1.22	1.13	1.10	1.15	1.22	1.19	1.26	1.13	1.10	1.16	1.15	1.13	1.16
Jan 2022	1.02	1.00	1.04	1.20	1.18	1.23	1.13	1.11	1.16	1.23	1.20	1.26	1.13	1.10	1.17	1.15	1.14	1.16
Feb 2022	1.01	0.99	1.03	1.18	1.15	1.21	1.11	1.09	1.13	1.21	1.18	1.24	1.11	1.08	1.14	1.13	1.12	1.14
Mar 2022	1.02	1.00	1.04	1.18	1.16	1.21	1.11	1.09	1.14	1.21	1.18	1.24	1.11	1.08	1.15	1.13	1.12	1.15

Table S13: Incidence Rate Ratios (IRR) and 95% confidence intervals (CI) for the number (count) of food outlets accessible online in postcode districts in England, stratified by deprivation, estimated using an adjusted negative binomial generalised estimating equation [a].

	Deprivation quintile																
	1 (least deprived)			2			3			4			5 (most deprived)			England		
	IRR	95% CI		IRR	95% CI		IRR	95% CI		IRR	95% CI		IRR	95% CI		IRR	95% CI	
Month																		
Nov 2019	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref
Jun 2020	0.57	0.55	0.59	0.58	0.56	0.60	0.66	0.64	0.68	0.74	0.71	0.77	0.84	0.81	0.87	0.67	0.66	0.68
Jul 2020	0.55	0.54	0.57	0.55	0.53	0.57	0.62	0.60	0.64	0.61	0.58	0.63	0.73	0.70	0.75	0.60	0.59	0.61
Aug 2020	0.61	0.59	0.63	0.61	0.59	0.63	0.69	0.67	0.71	0.77	0.74	0.80	0.87	0.84	0.90	0.70	0.69	0.71
Sept 2020	0.63	0.61	0.65	0.64	0.62	0.66	0.75	0.73	0.77	0.82	0.79	0.85	0.90	0.87	0.93	0.73	0.72	0.75
Oct 2020	0.65	0.64	0.67	0.67	0.65	0.69	0.78	0.76	0.81	0.86	0.83	0.89	0.93	0.91	0.96	0.77	0.75	0.78
Nov 2020	0.86	0.83	0.88	0.82	0.80	0.85	0.93	0.90	0.96	0.97	0.93	1.01	0.97	0.94	1.00	0.91	0.90	0.92
Dec 2020	0.69	0.68	0.71	0.70	0.68	0.73	0.83	0.80	0.85	0.91	0.87	0.94	0.97	0.94	1.00	0.81	0.79	0.82
Jan 2021	0.85	0.83	0.87	0.83	0.81	0.86	0.97	0.95	1.00	0.99	0.96	1.03	1.01	0.98	1.04	0.93	0.91	0.94
Feb 2021	0.88	0.85	0.90	0.86	0.84	0.89	1.01	0.98	1.04	1.04	1.00	1.08	1.06	1.03	1.10	0.96	0.95	0.98
Mar 2021	0.79	0.77	0.81	0.79	0.76	0.82	0.93	0.90	0.95	1.02	0.98	1.06	1.10	1.06	1.13	0.91	0.90	0.92
Apr 2021	0.80	0.78	0.82	0.81	0.78	0.83	0.95	0.92	0.97	1.03	1.00	1.07	1.12	1.08	1.15	0.92	0.91	0.94
May 2021	0.81	0.79	0.83	0.81	0.79	0.84	0.95	0.92	0.98	1.05	1.01	1.09	1.12	1.09	1.16	0.93	0.92	0.95
Jun 2021	0.80	0.78	0.83	0.80	0.78	0.83	0.94	0.91	0.97	1.02	0.99	1.06	1.11	1.08	1.15	0.92	0.91	0.93
Jul 2021	0.80	0.78	0.82	0.80	0.78	0.83	0.94	0.91	0.96	1.03	0.99	1.06	1.11	1.08	1.15	0.92	0.91	0.93
Aug 2021	0.80	0.78	0.82	0.79	0.77	0.82	0.92	0.90	0.95	1.02	0.98	1.06	1.10	1.07	1.14	0.91	0.90	0.93
Sept 2021	0.81	0.79	0.83	0.81	0.78	0.84	0.96	0.93	0.98	1.04	1.00	1.08	1.12	1.09	1.16	0.93	0.92	0.95
Oct 2021	0.81	0.79	0.83	0.81	0.78	0.83	0.95	0.93	0.98	1.04	1.00	1.08	1.12	1.09	1.16	0.93	0.92	0.94
Nov 2021	0.81	0.79	0.83	0.81	0.78	0.84	0.96	0.93	0.99	1.04	1.00	1.08	1.13	1.09	1.16	0.93	0.92	0.95
Dec 2021	0.80	0.78	0.82	0.80	0.77	0.83	0.95	0.92	0.98	1.03	0.99	1.07	1.11	1.08	1.15	0.92	0.91	0.94
Jan 2022	0.80	0.78	0.82	0.80	0.78	0.83	0.95	0.93	0.98	1.03	1.00	1.07	1.12	1.08	1.15	0.93	0.91	0.94
Feb 2022	0.80	0.78	0.82	0.80	0.77	0.82	0.95	0.92	0.98	1.02	0.98	1.06	1.10	1.06	1.13	0.92	0.90	0.93
Mar 2022	0.81	0.79	0.83	0.80	0.78	0.83	0.95	0.92	0.98	1.03	0.99	1.07	1.10	1.07	1.13	0.92	0.91	0.93

Note: [a] adjusted for population density, rural urban classification and the number of food outlets with a customer-facing premises in a postcode district, based on Ordnance Survey Points of Interest data. 2067 postcode districts included.

Table S14: Coefficients (coef.) and 95% confidence intervals (CI) for the percentage of food outlets registered to accept orders online in postcode districts in England, stratified by deprivation, calculated using an unadjusted generalised estimating equation [a].

	Deprivation quintile																	
	1 (least deprived)			2			3			4			5 (most deprived)			England		
	coef.	95% CI		coef.	95% CI		coef.	95% CI		coef.	95% CI		coef.	95% CI		coef.	95% CI	
Month																		
Nov 2019	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref
Jun 2020	0.47	0.43	0.51	0.54	0.50	0.58	0.54	0.51	0.58	0.64	0.60	0.69	0.83	0.79	0.88	0.60	0.58	0.62
Jul 2020	0.45	0.41	0.50	0.52	0.47	0.57	0.48	0.43	0.53	0.52	0.45	0.58	0.69	0.62	0.76	0.53	0.50	0.55
Aug 2020	0.56	0.52	0.60	0.63	0.57	0.68	0.61	0.56	0.66	0.69	0.63	0.75	0.92	0.86	0.97	0.67	0.65	0.69
Sept 2020	0.28	0.24	0.32	0.30	0.26	0.33	0.26	0.22	0.29	0.25	0.22	0.29	0.23	0.20	0.26	0.25	0.23	0.26
Oct 2020	0.34	0.31	0.38	0.35	0.31	0.39	0.31	0.27	0.35	0.30	0.26	0.33	0.28	0.25	0.32	0.30	0.29	0.32
Nov 2020	0.51	0.46	0.55	0.51	0.46	0.56	0.45	0.41	0.49	0.39	0.35	0.43	0.36	0.33	0.40	0.42	0.40	0.44
Dec 2020	0.39	0.35	0.44	0.40	0.35	0.44	0.35	0.32	0.39	0.33	0.29	0.38	0.31	0.28	0.35	0.34	0.32	0.36
Jan 2021	0.54	0.48	0.59	0.53	0.48	0.58	0.47	0.42	0.51	0.42	0.38	0.47	0.40	0.36	0.44	0.44	0.42	0.46
Feb 2021	0.60	0.55	0.65	0.59	0.54	0.64	0.53	0.49	0.57	0.49	0.45	0.54	0.47	0.43	0.50	0.51	0.49	0.53
Mar 2021	0.56	0.52	0.61	0.57	0.52	0.61	0.50	0.46	0.55	0.48	0.43	0.53	0.47	0.43	0.51	0.49	0.47	0.51
Apr 2021	0.58	0.53	0.62	0.57	0.52	0.62	0.52	0.48	0.57	0.51	0.46	0.56	0.50	0.46	0.54	0.51	0.49	0.53
May 2021	0.59	0.54	0.63	0.59	0.54	0.64	0.54	0.49	0.58	0.53	0.48	0.58	0.52	0.48	0.56	0.53	0.51	0.55
Jun 2021	0.58	0.54	0.63	0.58	0.54	0.63	0.54	0.50	0.58	0.53	0.48	0.58	0.52	0.48	0.56	0.53	0.51	0.55
Jul 2021	0.59	0.54	0.63	0.59	0.54	0.63	0.54	0.50	0.59	0.54	0.49	0.58	0.53	0.49	0.57	0.53	0.51	0.55
Aug 2021	0.61	0.56	0.66	0.60	0.55	0.64	0.55	0.50	0.59	0.56	0.51	0.61	0.53	0.49	0.58	0.54	0.52	0.56
Sept 2021	0.62	0.57	0.66	0.59	0.55	0.64	0.55	0.51	0.60	0.56	0.51	0.62	0.54	0.49	0.58	0.55	0.53	0.57
Oct 2021	0.62	0.57	0.67	0.61	0.56	0.65	0.57	0.52	0.62	0.58	0.53	0.63	0.55	0.51	0.59	0.56	0.54	0.58
Nov 2021	0.63	0.59	0.68	0.62	0.57	0.66	0.58	0.53	0.63	0.58	0.53	0.63	0.58	0.53	0.62	0.57	0.55	0.59
Dec 2021	0.62	0.57	0.67	0.60	0.55	0.65	0.58	0.53	0.62	0.57	0.52	0.62	0.56	0.52	0.61	0.56	0.54	0.58
Jan 2022	0.63	0.58	0.68	0.61	0.57	0.66	0.59	0.54	0.63	0.57	0.52	0.62	0.57	0.53	0.62	0.57	0.55	0.59
Feb 2022	0.63	0.59	0.68	0.62	0.58	0.67	0.59	0.54	0.64	0.58	0.53	0.63	0.56	0.51	0.60	0.57	0.55	0.59
Mar 2022	0.65	0.60	0.70	0.63	0.58	0.68	0.60	0.55	0.65	0.58	0.53	0.63	0.56	0.52	0.61	0.58	0.56	0.60

Note: [a] percentage calculated as the number of food outlets registered to accept orders online compared with the number of food outlets with a customer-facing premises in a postcode district, based on Ordnance Survey Points of Interest data. 2115 postcode districts included.

Table S15: Coefficients (coef.) and 95% confidence intervals (CI) for the percentage of food outlets registered to accept orders online in postcode districts in England, stratified by deprivation, calculated using an adjusted generalised estimating equation [a].

	Deprivation quintile																	
	1 (least deprived)			2			3			4			5 (most deprived)			England		
	coef.	95% CI		coef.	95% CI		coef.	95% CI		coef.	95% CI		coef.	95% CI		coef.	95% CI	
Month																		
Nov 2019	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref
Jun 2020	0.50	0.46	0.54	0.59	0.54	0.63	0.59	0.55	0.64	0.72	0.67	0.78	0.85	0.81	0.90	0.67	0.64	0.69
Jul 2020	0.48	0.44	0.53	0.57	0.51	0.62	0.53	0.47	0.59	0.58	0.50	0.66	0.71	0.64	0.78	0.58	0.55	0.61
Aug 2020	0.60	0.55	0.64	0.68	0.62	0.74	0.67	0.61	0.72	0.77	0.70	0.85	0.94	0.88	1.00	0.74	0.72	0.77
Sept 2020	0.30	0.26	0.34	0.32	0.28	0.36	0.28	0.24	0.31	0.28	0.24	0.32	0.23	0.20	0.27	0.27	0.26	0.29
Oct 2020	0.37	0.33	0.41	0.38	0.34	0.43	0.33	0.29	0.37	0.33	0.29	0.37	0.29	0.26	0.32	0.33	0.31	0.35
Nov 2020	0.54	0.49	0.59	0.56	0.50	0.61	0.48	0.44	0.53	0.43	0.39	0.48	0.37	0.33	0.40	0.46	0.44	0.48
Dec 2020	0.42	0.37	0.46	0.43	0.38	0.49	0.38	0.34	0.43	0.37	0.32	0.42	0.32	0.28	0.36	0.37	0.35	0.39
Jan 2021	0.57	0.52	0.62	0.58	0.52	0.63	0.50	0.45	0.55	0.47	0.42	0.53	0.41	0.37	0.44	0.49	0.47	0.51
Feb 2021	0.63	0.58	0.69	0.65	0.60	0.71	0.58	0.53	0.62	0.55	0.50	0.60	0.48	0.44	0.51	0.56	0.54	0.58
Mar 2021	0.60	0.55	0.65	0.62	0.57	0.67	0.55	0.50	0.59	0.54	0.48	0.59	0.48	0.44	0.52	0.54	0.52	0.57
Apr 2021	0.61	0.56	0.66	0.63	0.57	0.68	0.57	0.52	0.62	0.57	0.51	0.63	0.51	0.46	0.55	0.56	0.54	0.58
May 2021	0.62	0.57	0.67	0.65	0.60	0.70	0.58	0.53	0.63	0.59	0.53	0.65	0.53	0.49	0.57	0.58	0.56	0.60
Jun 2021	0.62	0.57	0.66	0.64	0.59	0.69	0.59	0.54	0.63	0.59	0.54	0.65	0.53	0.49	0.58	0.58	0.56	0.60
Jul 2021	0.62	0.57	0.67	0.64	0.59	0.70	0.59	0.54	0.64	0.60	0.54	0.66	0.54	0.49	0.58	0.59	0.56	0.61
Aug 2021	0.64	0.59	0.69	0.65	0.60	0.70	0.60	0.54	0.65	0.62	0.57	0.68	0.54	0.50	0.59	0.60	0.58	0.62
Sept 2021	0.65	0.60	0.70	0.65	0.60	0.70	0.60	0.55	0.65	0.63	0.57	0.69	0.55	0.50	0.59	0.60	0.58	0.63
Oct 2021	0.66	0.61	0.71	0.66	0.61	0.72	0.62	0.57	0.67	0.64	0.59	0.70	0.56	0.52	0.60	0.62	0.59	0.64
Nov 2021	0.67	0.62	0.72	0.67	0.62	0.73	0.63	0.58	0.68	0.65	0.59	0.71	0.59	0.54	0.63	0.63	0.61	0.65
Dec 2021	0.66	0.61	0.71	0.66	0.60	0.71	0.63	0.57	0.68	0.63	0.57	0.70	0.57	0.53	0.62	0.62	0.59	0.64
Jan 2022	0.67	0.62	0.72	0.66	0.61	0.71	0.64	0.59	0.69	0.64	0.58	0.70	0.58	0.54	0.63	0.63	0.60	0.65
Feb 2022	0.67	0.62	0.72	0.68	0.63	0.73	0.64	0.59	0.70	0.65	0.59	0.71	0.57	0.52	0.61	0.63	0.60	0.65
Mar 2022	0.69	0.64	0.74	0.69	0.63	0.74	0.66	0.60	0.71	0.65	0.59	0.71	0.57	0.52	0.62	0.64	0.61	0.66

Note: [a] percentage calculated as the number of food outlets registered to accept orders online compared with the number of food outlets with a customer-facing premises in a postcode district, based on Ordnance Survey Points of Interest data. Adjusted for population density and rural urban classification. 2065 postcode districts included.

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