



# Understanding the socio-spatial distribution of “dark retail” in England: Development of a unique retail location dataset

Yuru Huang<sup>a</sup>, Tom RP. Bishop<sup>a</sup>, Jean Adams<sup>a</sup>, Steven Cummins<sup>b</sup>, Matthew Keeble<sup>a,c</sup>, Chiara Rinaldi<sup>d</sup>, Annie Schiff<sup>a</sup>, Thomas Burgoine<sup>a,\*</sup> 

<sup>a</sup> MRC Epidemiology Unit, University of Cambridge School of Clinical Medicine, Cambridge, UK

<sup>b</sup> Population Health Innovation Lab, Department of Public Health, Environments & Society, Faculty of Public Health & Policy, London School of Hygiene & Tropical Medicine, London, UK

<sup>c</sup> Department of Marketing, Faculty of Business and Economics, University of Antwerp, Antwerp, Belgium

<sup>d</sup> Department of Public Health, Environments & Society, Faculty of Public Health & Policy, London School of Hygiene & Tropical Medicine, London, UK

## ABSTRACT

Online food delivery services (OFDS) are an increasingly popular way of accessing both ready-to-consume foods and groceries. Such foods are sometimes delivered from facilities not open to the public - so called ‘dark retail’. However, there is a lack of data on ‘dark retail’, which limits understanding of their location, prevalence and growth. We identified different types of dark kitchens (i.e., “virtual brands”, “ghost kitchens”) and dark grocery stores (i.e., “large dark grocers”, “small/independent dark grocers”). Using data on 113,370 unique online food outlets from three major food delivery platforms (*Uber Eats*, *JustEat*, and *Deliveroo*) in England, we created a database of dark retail locations and analysed their socio-spatial distribution. Dark retail accounted for 14 % of all online food outlets, with the majority being virtual brands. Overall, dark retail is more likely to be located in more deprived areas. The extent of dark retail observed highlights the importance of incorporating them into existing regulatory frameworks. Our database and findings provide insights into the socio-spatial distribution of dark retail, which could inform future research and policy development in this area.

## 1. Background

The use and availability of online food delivery services has expanded rapidly over recent decades. The global online food delivery market is estimated to generate \$1.23 trillion in revenue in 2024; quadruple the size of this market in 2019 (Statista., 2024). This growth has been driven by substantially increased use of these services among adults. For example, in Australia, 17 % of adults reporting using these services in the past 7 days in 2018, growing to 25 % in 2021; in Canada, this proportion rose from 12 % to 19 %, and in the UK, from 19 % to 28 % (Gupta et al., 2024). This increase in use is also reflected in the total number of food outlets registering to sell their products on online platforms. In the UK, the number of outlets available through meal delivery apps nearly doubled from 2019 to 2022 (Keeble et al., 2023).

By placing orders using online food delivery services (OFDS e.g. *Uber Eats*, *JustEat*, *Deliveroo*), customers no longer need to visit food outlets in person. This has facilitated the expansion of a “dark retail” business model. Specifically, “dark kitchens” operate to fulfil online orders for delivery of food that is ready for immediate consumption, and “dark grocers” facilitate rapid grocery delivery. We identified two types of

dark kitchens, as defined in Table 1. The first are ghost kitchens, which are non-customer-facing commercial kitchens (Rinaldi et al., 2022; *Uber Eats*., 2024). Food is prepared in these kitchens and then delivered directly to consumers. FoodStars, Karma Kitchens, and Deliveroo Editions are leading ghost kitchen providers in England. Each offers co-working kitchen spaces, typically within industrial, warehouse-type premises (Rinaldi et al., 2022). Each food tenant operating within these locations has its own staff and equipment but typically share storage and other facilities (BBC, 2019). As well as providing kitchen infrastructure, Deliveroo Editions collaborates with established restaurant brands and offers additional logistical support. (Delivery Editions., 2024) Exploratory research in the London Borough of Haringey in 2021 identified three ghost kitchen locations that collectively rented space to 116 tenants, with one housing 72 (Rinaldi et al., 2022). Alongside these multi-brand commercial kitchens, single retailer-owned ghost kitchens, such as McDonald’s McDelivery kitchens, are also used to expand delivery capacity (Barakat et al., 2022).

The second type of dark kitchens are *virtual brands* operating out of existing high street kitchens, specifically to fulfil online orders (*Uber Eats*., 2024). Customers are not able to interact with these virtual brands

\* Corresponding author.

E-mail address: [tb464@medschl.cam.ac.uk](mailto:tb464@medschl.cam.ac.uk) (T. Burgoine).

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**Table 1**  
Definitions of dark kitchens, dark grocery stores and sub types.

Dark Retail Type	Subtype	Definition	Example(s)
<b>Dark Kitchens</b> ( <u>delivery-</u> <u>focused, non-</u> <u>customer-facing</u> retailers that serve ready-to- consume food and drinks)	Ghost Kitchens	Non-customer- facing commercial kitchens <b>without a high street storefront</b> or in- person ordering.	<i>Deliveroo</i> Editions, McDelivery Kitchens
	Virtual Brands	Retailers that <b>operate within existing high street food outlets</b> but serve a separate delivery-focused brand. Customers can visit the physical store location but won't see or order from the virtual brand's menu.	Bella Italia's virtual brands: <i>Super Nonna</i> <i>Pasta, Mac Shake,</i> <i>Bird Box</i>
<b>Dark Grocery Stores</b> ( <u>delivery-</u> <u>focused, non-</u> <u>customer-facing</u> retailers that sell groceries)	Large dark grocers	Large chains that operate warehouses designed specifically for grocery delivery without a storefront.	Getir, GoPuff
	Small/ independent dark grocers	Small or independent grocers that operate retail spaces without a storefront. May include small convenience stores operating online under different brand names or operating from storage spaces.	365 Alcohol Delivery

in-store. For example, Bella Italia (a high street food outlet) offers virtual brands such as Super Nonna Pasta, Mac Shake, and Bird Box. Foods for these virtual brands are cooked in Bella Italia kitchens on the high street, but are only available through online food delivery services.

Another recent development in digital food retail are rapid grocery delivery services (RGDS). Online grocery orders can now be delivered to customers within 20 mins. Whereas online grocery orders are typically fulfilled from the aisles of a high street retailer, RGDS orders are more commonly fulfilled from “dark grocery stores”, which are dedicated warehouses or storage spaces customers cannot typically access. An example of a larger, chain dark grocer is GoPuff (Rinaldi et al., 2022), but independent dark grocers also exist. These smaller, non-chain dark grocers tend to specialise in alcohol and tobacco, as opposed to the wider array of groceries offered by chains (Rinaldi et al., 2022). In this study, we do not include online fulfilment centres for next-day grocery delivery—we focus on premises facilitating rapid grocery delivery services.

The popularity of dark retail among food businesses is premised on drastically reduced operational costs (Giousmpasoglou et al., 2024). In the out-of-home sector, high delivery commissions from meal delivery platforms (typically 15 %–30 %) can make it unsustainable for many restaurants to operate online (Ahuja et al., 2021). The dark kitchen business model provides an option for restaurants that want to focus on delivery to reduce their overheads, or to increase their reach by experimenting with multiple virtual brands that can target distinct consumer segments (Giousmpasoglou et al., 2024). For example, a sushi restaurant might introduce a vegan menu under a separate virtual brand to attract vegan customers and maximise the use of its existing kitchen. For online grocery delivery services, their profit are typically only 0.5–1.5 % of sales due to high delivery costs, compared to 5–7 % for offline grocery shopping (Kuijpers et al., 2018). A dark grocery store can reduce operational costs and improve efficiency.

Another significant advantage for businesses operating under the

dark retail model is that planning permission is already secured for the premises and its use. This may be particularly beneficial for businesses operating in local authorities (LAs) that are seeking to curb the proliferation of hot food takeaway outlets through planning regulations. For example, 35 LAs in England restrict new takeaways in management zones around schools (Rahilly et al., 2024a). These are areas (e.g., within 400 m of a school centre, access point or boundary) where planning permission can be denied to new takeaways, but existing takeaways and industrial premises are unaffected. Dark retail may therefore help food retailers circumvent these policies, effectively undermining them, by incentivising their operation from industrial premises or within existing outlets that are not subject to these regulations.

While potentially beneficial to business, dark retail poses challenges to existing regulatory frameworks and has the potential to impact consumer safety and health. As reported by the Food Standards Agency (FSA), monitoring of food hygiene practices within dark kitchens is perceived as challenging (Barakat et al., 2022). Additionally, research has demonstrated that an increased number of food outlets accessible online is associated with more frequent use of these services (Keeble et al., 2021a). Dark retail further raises the possibility for proliferation of online options, and as such may contribute to increased online delivery use. UK evidence has also consistently shown that there are more food outlets accessible online in more deprived areas, which may therefore be contributing to observed dietary inequalities (Bennett et al., 2024; Keeble et al., 2021a). It is possible that dark retail may exacerbate this inequality by promoting more online food outlets in deprived areas.

Although some research has investigated the business models and practices of dark retail (da Cunha et al., 2024; Rai, 2023), little is known about their locations, their distribution by level of deprivation, or their relative prevalence in LAs that have attempted to curb the proliferation of new takeaway food outlets on the high street using urban planning policy. This knowledge gap is likely because these retail operations are not included in, or easily identifiable from, databases typically used in academic studies or local authority monitoring. Virtual brands (as businesses), for example, are not required to register with LAs who only mandate a register of food retail premises. Without these data it is impossible to assess the current dark retail landscape, monitor its future evolution, or evaluate potential impacts on population health. Consequently, policymakers cannot make evidence-informed decisions about the necessity for regulation of dark retail, nor what any intervention might look like.

In this study we aimed to quantify and understand the current landscape of dark retail across England. The objectives were to develop and describe a dataset of dark retail locations in England, and to assess whether locations of dark retail vary by deprivation at the lower super output area level (LSOA), and the adoption of takeaway management zones at the local authority level.

2. Methods

2.1. Overview

We used multiple data sources, including information from online food delivery platforms, physical food outlet listings, food hygiene rating schemes, and the official websites of commercial kitchens, to identify dark retail locations in England. These locations were verified using Google Street View images, Google Places reviews, and data from local authority (LA) planning application portals. After identifying dark retail locations, we investigated whether their distribution varied by area-level deprivation and, for dark kitchens only, whether their distributions varied by adoption of takeaway management zones.

## 2.2. Data sources

### 2.2.1. Online food delivery platforms

Cross-sectional data from the three leading online food delivery platforms (i.e. *JustEat*, *Deliveroo*, and *Uber Eats*) in the UK were collected from March to April 2024 using the Python Scrapy framework [Scrapy at a Glance \(2020\)](#). We gathered data on all food outlets delivering to each postcode district in England, including their businesses names and physical addresses. As a food outlet may appear on multiple online food delivery platforms, we deduplicated the data to create a unique, comprehensive online food outlet dataset. After deduplication, our dataset was reduced from 188,655 online food outlets to 113,370 unique records. The accuracy of this deduplication process was 100 % based on a randomly selected sample of online food outlets in 20 postcodes. Details of the deduplication process can be found in Supplementary appendix File 1. This dataset was the sampling frame for our dark retail identification.

### 2.2.2. Physical food outlets

Data on physical food outlets (i.e., bricks-and-mortar stores) and online food delivery platforms in England were used to identify virtual brands and reference dark kitchens and dark grocery stores. Detailed methodologies and rationales are explained in the next section.

We used two different sources of physical food outlet data: the Food Standards Agency's (FSA) Food Hygiene Rating Scheme (FHRS) data and Ordnance Survey Points of Interest (OS POI) data. The FHRS data, collected in May 2024 using the FSA's public-facing Application Programming Interface (API) included all food businesses (e.g. restaurants, pubs, cafes, takeaways, supermarkets) inspected by LAs for the purposes of food hygiene certification ([Food Standards Agency, 2022](#)). We also obtained OS POI data in December 2023. OS POI is a comprehensive location-based dataset of over four million business listings. We deleted POIs where names and postcodes were identical, as these were duplicate entries.

It is important to note that neither data source is considered a “gold standard” for physical food outlet locations. Our initial exploration

indicated that some dark retail spaces were inspected by the FHRS and/or included in POI data. Therefore, a hybrid approach was necessary to improve the identification of dark retail locations with different data sources, as described below.

## 2.3. Identifying dark retail locations

### 2.3.1. Dark kitchens

Different approaches were needed for the identification of “ghost kitchens” and “virtual brands”.

### 2.3.2. Ghost kitchens

Ghost kitchens were identified using two different data sources: online food delivery platform data and the publicly available locations of major commercial kitchen providers ([Fig. 1](#)). Building on previous work, we included locations of ghost kitchens from *FoodStars*, *Karma Kitchen*, *Dephna*, *Jacuna*, *CloudX Kitchen*, *Ready Kitchen*, and *Deliveroo Editions* ([Rinaldi et al., 2022](#)). For each provider, we searched for their kitchen locations in England using a combination of their official websites, Google Maps, and FHRS data.

To supplement this list of ghost kitchen locations, we also used our deduplicated national dataset for food outlets present on major online food delivery platforms to identify additional ghost kitchens. Using *Deliveroo Editions* data, we manually reviewed and identified keywords for potential ghost kitchen addresses ([Fig. 1](#)). We also determined locations where more than five food outlets were present, based on their address. We tested thresholds from two to eight retailers, and determined that five was optimal, effectively capturing all potential ghost kitchen locations while maintaining a manageable workload for manual review. We then reviewed all food outlets in these locations using data sources listed in [Fig. 1](#). For example, if a Google Places review indicated that a retailer offered a dine-in option, it would be excluded as a ghost kitchen. Elsewhere, a local authority planning application might confirm that a location is intended to be used as a commercial kitchen. YH reviewed all of the resulting 5943 food outlets from 1005 locations, and TBu double-checked 10 % of these locations for accuracy. Of only

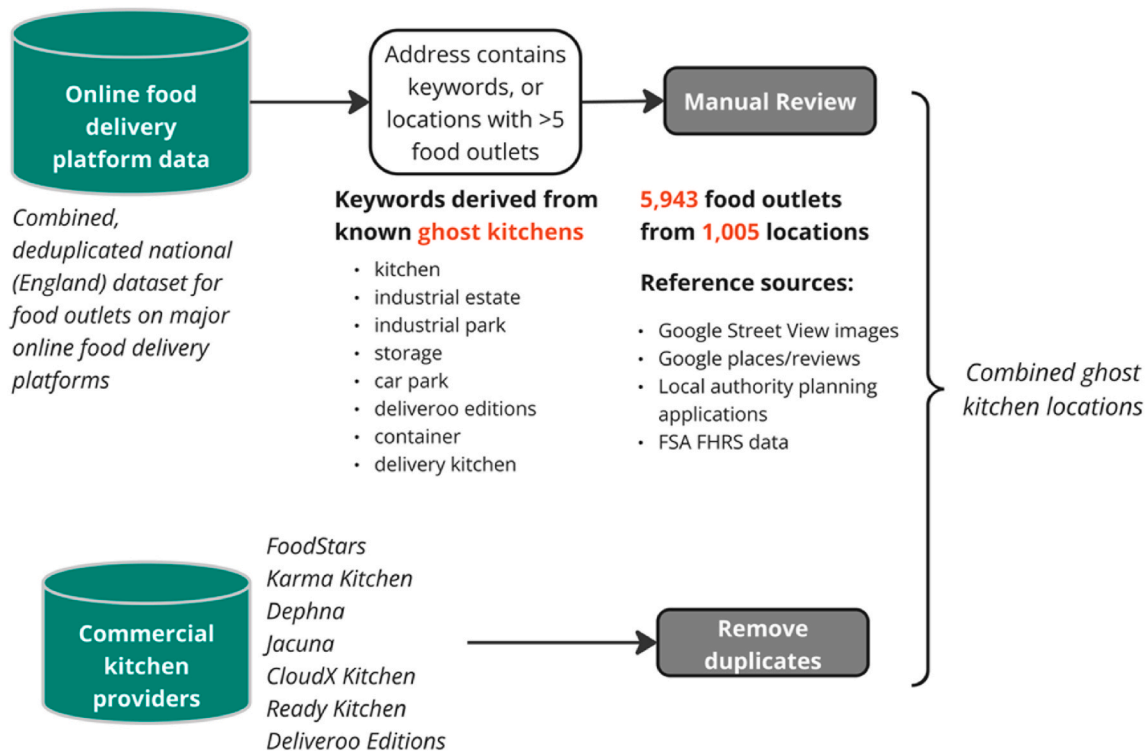


Fig. 1. The process of identifying ghost kitchens.

eight disagreements, all were resolved.

### 2.3.3. Virtual brands

Virtual brands operate out of existing high street food outlets and therefore they do not require additional food hygiene inspections. This means they would not typically be listed in FHRS data. For food outlets present on an online food delivery platform but not located in a ghost kitchen, we matched the data to both FHRS and OS POI data (Fig. 2). Food outlets that could not be found in the FHRS or OS POI datasets, and that were not grocery stores or supermarkets, were deemed virtual brands. The matching process was similar to the deduplication process originally used when combining data from all OFDS: food outlets were matched on postcode sectors, food outlet names were standardised before calculating a string similarity score, and pairs with a similarity score greater than 0.85 were deemed a match. We additionally identified known virtual brands operating nationally (google searches), such as SoBe Burger, Ugly Chicken, and Dirty Vegan Burgers. The full list of these known virtual brands can be found in Supplementary appendix File 2.

### 2.4. Dark grocery stores

We used a similar hybrid approach to identify all dark grocery stores. We first identified the locations of major dark grocer operators (Rinaldi et al., 2022), which were Getir, Sip Up, Go Puff, Gorillas, Londel, and Zapp, within FHRS and our online food delivery platform data. We identified additional dark grocery stores not previously known to the research team from online food delivery platform data. We first filtered for online food outlets identifying as grocery stores (see details in Supplementary appendix File 3). We included alcohol shops in our grocery definition for two reasons: (1) most of these shops also have grocery items (e.g. ramen, crisps), and (2) rapid alcohol delivery may have public health implications and could be subject to future research.

After identifying all grocery stores, we removed major high street grocery chains as they do not offer rapid grocery delivery from dark stores (e.g. Morrisons, Tesco, Sainsbury's - see full list in Supplementary appendix File 4). We then manually reviewed food outlets that contained keywords listed in Fig. 3. This list of key words was developed through data exploration, which involved a manual review of a 10 % subset of all online grocery store names and addresses. In addition to the words "unit" and "storage", which were common in addresses, this review also revealed that names of dark grocers frequently included the words "tobacco", "alcohol" and related terms. After filtering by keywords, a manual review process, akin to the ghost kitchen review

process, involved examination of Google Street View images and Google Places reviews. For example, if Google Places showed an image of the food outlet as a location accessible to customers, it would not be considered a dark grocery store.

### 2.5. Analysis

We mapped the geographic distribution of dark kitchens and dark grocery stores, reporting *total number of locations* and *total number of businesses* (i.e. brands or tenants) by the nine English regions. Geolocations were obtained by matching postcodes to the National Statistics Postcode Lookup in February 2024 (Office for National Statistics., 2021). We examined nine dark retail location variables. For dark kitchens, these were (1) the number of unique dark kitchen *locations*, calculated as the sum of (2) the number of high street kitchens hosting at least one virtual brand and (3) the number of ghost kitchens. We also calculated (4) the number of dark kitchen *businesses*, which was the sum of (5) the number of virtual brands hosted within high street kitchens and (6) the number of ghost kitchen tenants. For dark grocery stores, we examined (7) their total number only, which was the sum of (8) the number of large dark grocers and (9) the number of small dark grocers, as they tend not to operate out of shared spaces.

The analysis of dark retail and area-level deprivation was conducted at the lower super output area level. This is the smallest geographic unit available in England that includes data on deprivation. A sensitivity analysis at the local authority level was also performed (see Supplementary appendix File 5). We used quintiles of 2019 index of multiple deprivation (IMD) scores. IMD is a composite measure used to classify relative deprivation in small areas in England, considering seven domains: income, employment, education, skills and training, health and disability, crime, barriers to housing and services, and living environment (Ministry of Housing, Communities & Local Government, 2019). We used zero-inflated negative binomial (ZINB) models due to having over dispersed count data with excess zeros across all nine location variables at the LSOA level. The count and logit components of the ZINB model included standardised population density (mid-year 2022 estimates from ONS) (Office for National Statistics, 2024). We also fitted a standard negative binomial (NB) model for each variable with the same covariates. The final model was selected (ZINB or NB) based on which had the lower AIC (Office for National Statistics, 2024). We did not adjust for urban/rural status as most of the dark retail locations were in urban areas. For all analyses, unless otherwise specified, we reported both the crude values and the adjusted marginal effects at the mean (MEM).

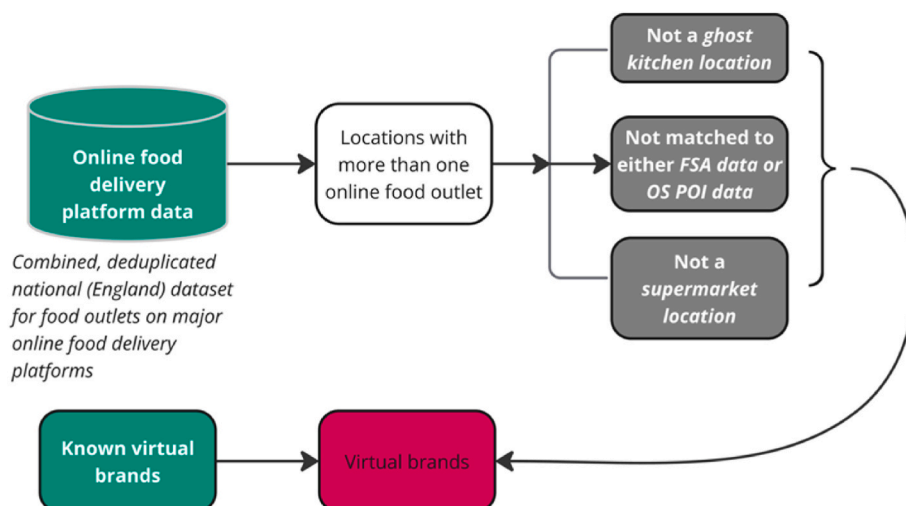


Fig. 2. The process of identifying virtual brands.



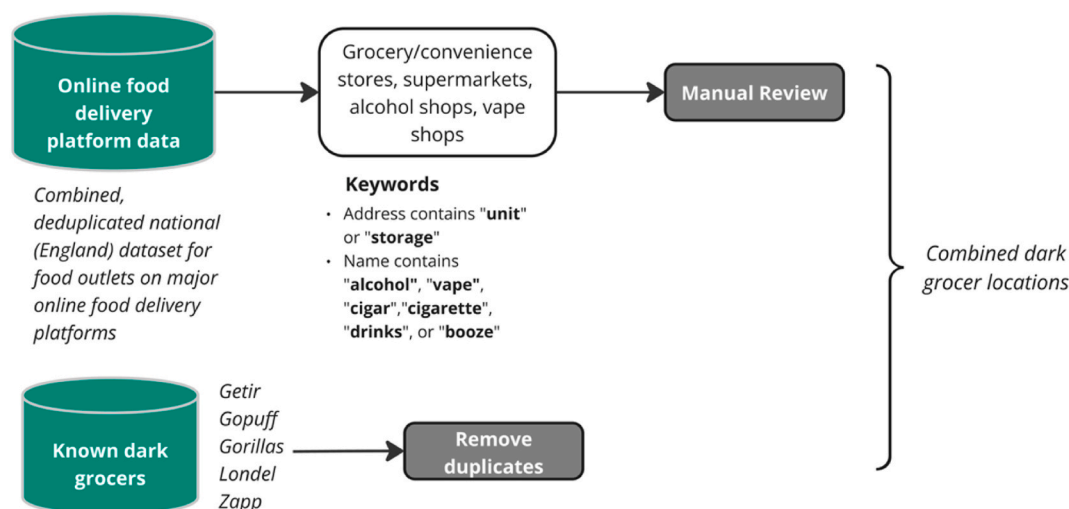


Fig. 3. The process of identifying dark grocers.

We tested the relationship between dark kitchen number and the adoption of takeaway management zones at the LA level. We chose this as the unit of analysis because LAs are responsible for adopting planning regulations. Adoption status (yes/no) was obtained in 2021 through Freedom of Information (FOI) requests sent to all 325 LAs (Rahilly et al., 2024b). We used ZINB models to examine the relationship between LA adoption of these regulations and number of dark kitchens, adjusting for LA IMD ranking and population density. Deprivation is a strong correlate of takeaway management zones adoption (Keeble et al., 2019).

### 3. Results

#### 3.1. Descriptive statistics

We identified 15,809 businesses operating from 7054 dark kitchens. Of these, 14,083 (89.1 %) were virtual brands operating from high street kitchens, and 1726 (10.9 %) were tenants operating from ghost kitchens. The median number of tenants operating out of each ghost kitchen was seven (IQR: 2–15, min-max:1–59), while each high street location had a

median of one virtual brand (IQR: 1–2, min-max:1–40). Table 2 shows that the regions with the highest percentage of dark kitchens were London (20.5 %), the South East (15.8 %), and the East of England (15.5 %). Overall, businesses operating from dark kitchens accounted for 15.9 % of all food outlets operating on online food delivery platforms (excluding groceries). This percentage comprised 14.2 % virtual brands and 1.7 % ghost kitchens.

We also identified 470 dark grocery stores in 362 locations. Of these, 236 (50.2 %) were small/independent dark grocers. Like dark kitchens, London was the region with the highest percentage of dark grocery stores (56.6 %). Overall, dark grocery stores accounted for 3.4 % of rapid grocery services on online food delivery platforms.

Fig. 4 shows that Tower Hamlets ( $n = 531$ ), Birmingham ( $n = 399$ ), and Manchester ( $n = 341$ ) LAs had the highest numbers of businesses operating from dark kitchens. The London Borough of Tower Hamlets also had the highest number of businesses operating from dark grocery stores ( $n = 30$  stores), followed by Ealing ( $n = 25$ ) and Wandsworth ( $n = 24$ ) LAs.

Regarding dark kitchen locations, Birmingham had the highest

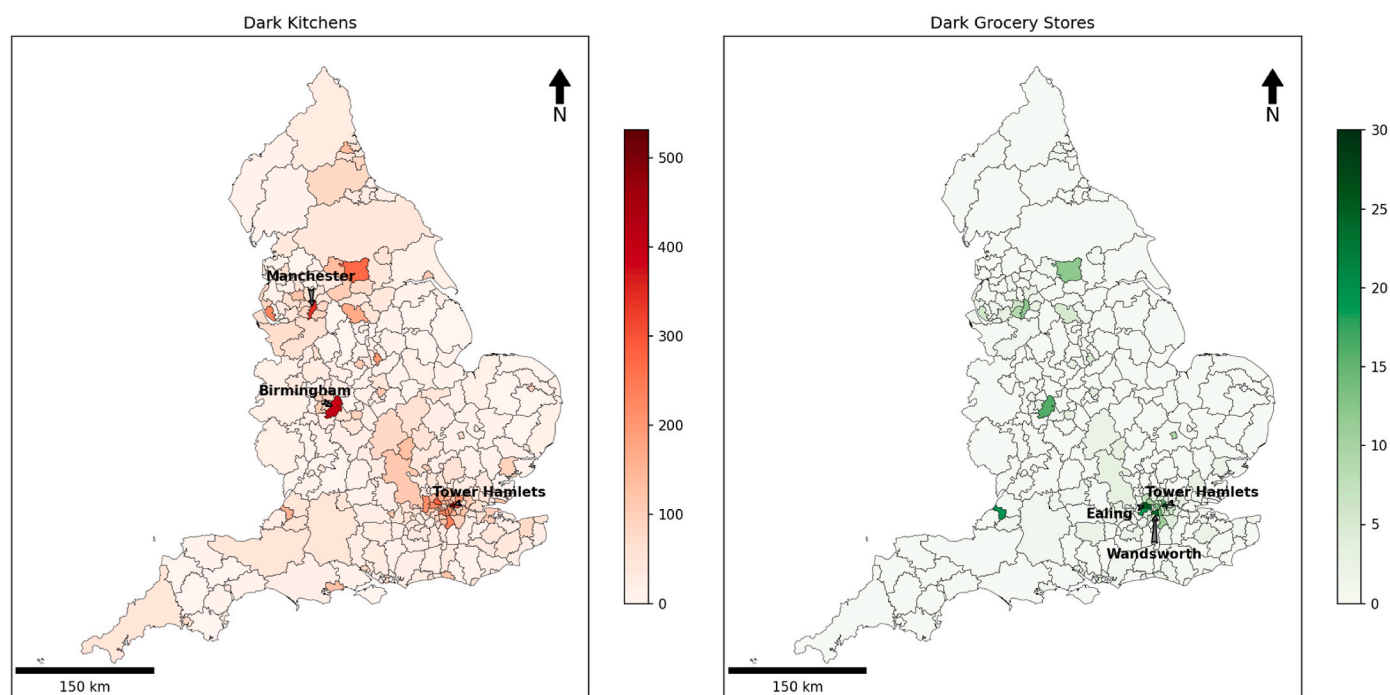
Table 2

Number of dark retail locations, and businesses operating from dark retail locations, by geographic region in England.

Region	Dark kitchens (ghost kitchens + kitchens hosting virtual brands)				Dark grocery stores			
	Ghost kitchen tenants/ Ghost kitchens	Virtual brands/ Kitchens hosting virtual brands	Dark kitchen businesses/ Dark kitchens	Percentage of all dark kitchens by region <sup>a</sup>	Small/independent dark grocer tenants/small/independent dark grocer locations	Large dark grocers/large dark grocer locations	Dark grocery stores (small + large)/dark grocer locations	Percentage of all dark grocery stores by region <sup>b</sup>
London	1206/96	4033/1604	5239/1700	20.5/16.9	110/61	156/129	266/190	8.00/6.65
South East	72/11	2268/1147	2340/1158	15.8/16.3	34/32	11/11	45/43	1.80/1.87
North West	176/14	1751/946	1927/960	14.6/14.8	32/23	19/16	51/39	2.87/2.37
East of England	67/11	1348/655	1415/666	15.5/14.9	15/10	4/4	19/14	1.48/1.20
West Midlands	93/8	1263/684	1356/692	13.5/13.6	5/3	19/16	24/19	1.90/1.64
Yorkshire and the Humber	49/7	1106/623	1155/630	12.7/13.2	15/12	5/5	20/17	1.83/1.72
East Midlands	27/4	907/482	934/486	14.0/14.6	8/8	9/9	17/17	1.79/1.92
South West	30/7	822/450	852/457	13.0/12.9	16/11	10/10	26/21	2.52/2.20
North East	6/4	585/300	591/304	13.4/12.9	1/1	1/1	2/2	0.30/0.34

<sup>a</sup> The percentage of all dark kitchen businesses among all non-grocery takeaways on online food delivery platforms in each region/percentage of all dark kitchens among all non-grocery locations on online delivery platforms in each region.

<sup>b</sup> The percentage of all dark grocery businesses among all rapid grocery delivery on online food delivery platforms in each region/percentage of all dark grocery locations among all rapid grocery delivery locations on online delivery platforms in each region.



**Fig. 4.** Number of businesses operating from dark kitchens, and number of dark grocery stores by local authority in England. The top three LAs are highlighted on the map.

number ( $n = 167$ ), followed by Leeds ( $n = 133$ ) and Manchester ( $n = 123$ ). For dark grocery store locations, Wandsworth topped the list with 17, followed by the City of Bristol ( $n = 15$ ) and Hounslow ( $n = 13$ ).

### 3.2. Associations between locations of dark retail and deprivation

Across all nine dark retail location variables, there were more dark retail locations and businesses operating in more deprived areas in both crude and adjusted models (Fig. 5, model details can be found in Supplementary appendix File 6). In more deprived LSOAs, there were generally more dark kitchens and businesses operating out of dark kitchens, as well as more dark grocers. For example, the most deprived quintile of LSOAs (0.73 dark kitchens, 95 % CI = 0.66, 0.79) had on average 3.60 times more food outlets operating out of dark kitchens compared to the least deprived LSOAs (0.20 dark kitchens, 95 % CI = 0.18, 0.22). Although this difference was attenuated after adjusting for population density (2.34 times greater), it remained substantial.

Although the overall increasing trend in numbers of dark retailers with increasing deprivation persisted, exceptions to the linearity of these relationships were observed for ghost kitchens and all dark grocery store variables, wherein the *second most deprived* LSOAs had the highest number compared to other quintiles. For example, the second most deprived LSOAs had more dark grocers (0.021 dark grocers, 95 % CI: 0.015–0.026) than the most deprived LSOAs (0.016 dark grocers, 95 % CI: 0.013–0.020) in adjusted models.

### 3.3. Associations between locations of dark retail and adoption of takeaway management zones around schools

LAs that had adopted takeaway management zones around schools had consistently more dark kitchens, as well as more businesses operating from dark kitchens, relative to non-adopters (Fig. 6). In adjusted models, the differences were not statistically significant but the pattern persisted. For example, adjusted figures show an average of 50.06 (95 % CI: 35.86, 64.25) businesses operating out of dark kitchens in LAs with management zones, compared to 41.63 (95 % CI: 37.47, 45.78) in LAs without. The crude values were 102.71 (95 % CI: 77.21, 128.22) for

those with management zones and 46.80 (95 % CI: 39.23, 54.37) for those without. Details of the model output can be found in Supplementary appendix File 7.

## 4. Discussion

### 4.1. Summary of findings

We identified a total of 15,809 businesses operating out of 7054 dark kitchens, in addition to 470 dark grocery stores across England. Together, they accounted for 14 % of all food outlets on online food delivery platforms as of April 2024. Among all non-grocery stores on online food delivery platforms, 15.9 % were operating from dark kitchens. The majority of dark kitchens were virtual brands (89.1 %). In terms of location, we found that most dark retail clustered in London and other major urban centres. Overall, there were also more dark retail locations and businesses operating out of dark retail locations in more deprived areas. Additionally, we observed that local authorities with takeaway management zones around schools had higher numbers of dark kitchens. However, this difference was not statistically significant after adjusting for population density and area deprivation.

### 4.2. Interpretation of findings

#### 4.2.1. Prevalence of dark retail

In this study, we estimated that dark retail made up 14 % of all online food outlets, with dark kitchens accounting for 15.9 % of non-grocery outlets. A previous exploratory study conducted across two postcodes in Liverpool identified 9 % of retailers operating from dark kitchens among 180 food outlets (Bradshaw, 2024). Elsewhere, a study in Brazil found that 27 % of online food outlets were based in dark kitchens (Hakim et al., 2023). This difference in prevalence suggests that the degree of retailing from dark locations may vary by geographic region. In this study, the majority of dark retailers we identified were virtual brands operating out of high street kitchens. Presently, ghost kitchens and dark grocery stores, whether independent or part of a chain, remain relatively less common.

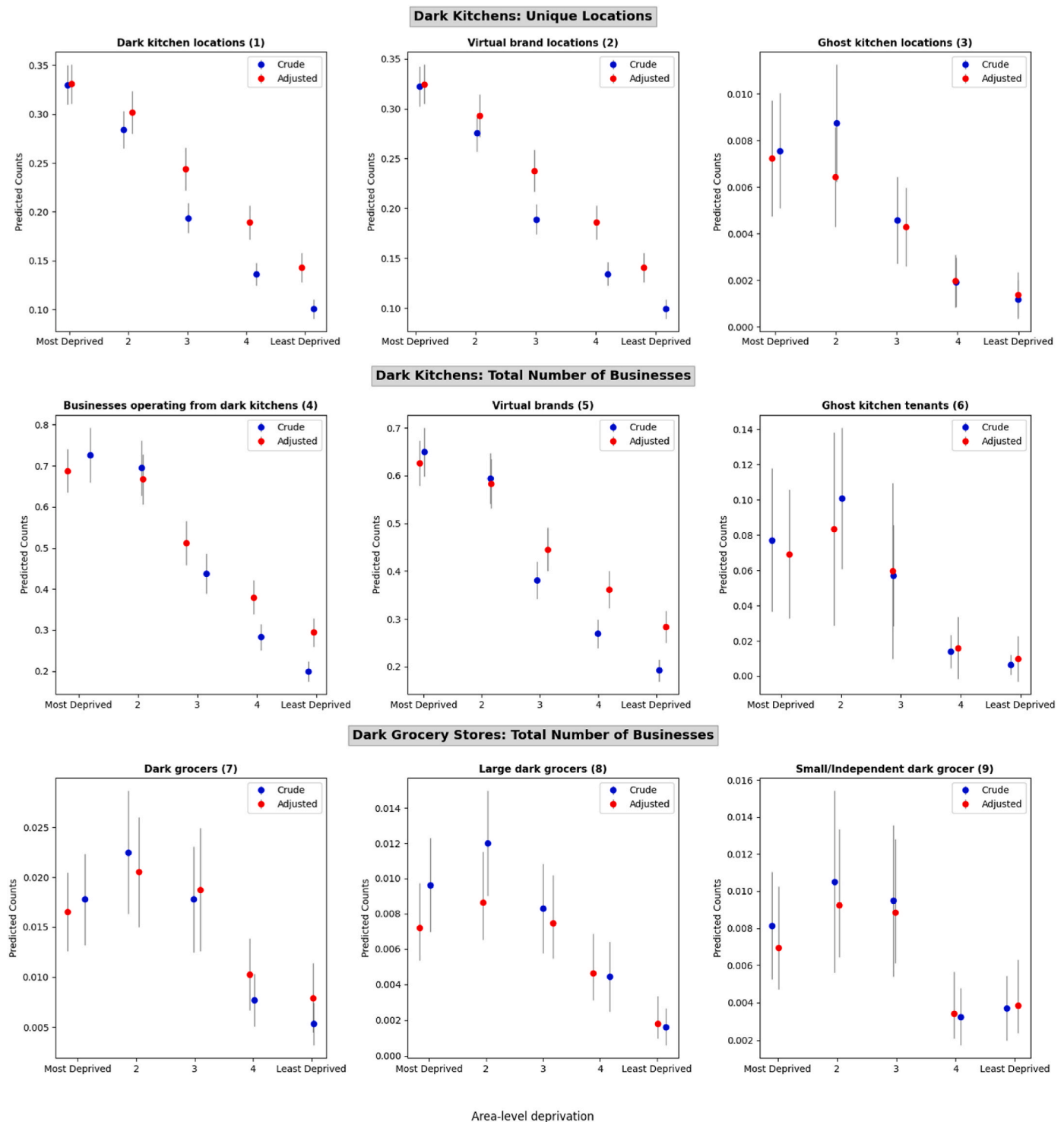
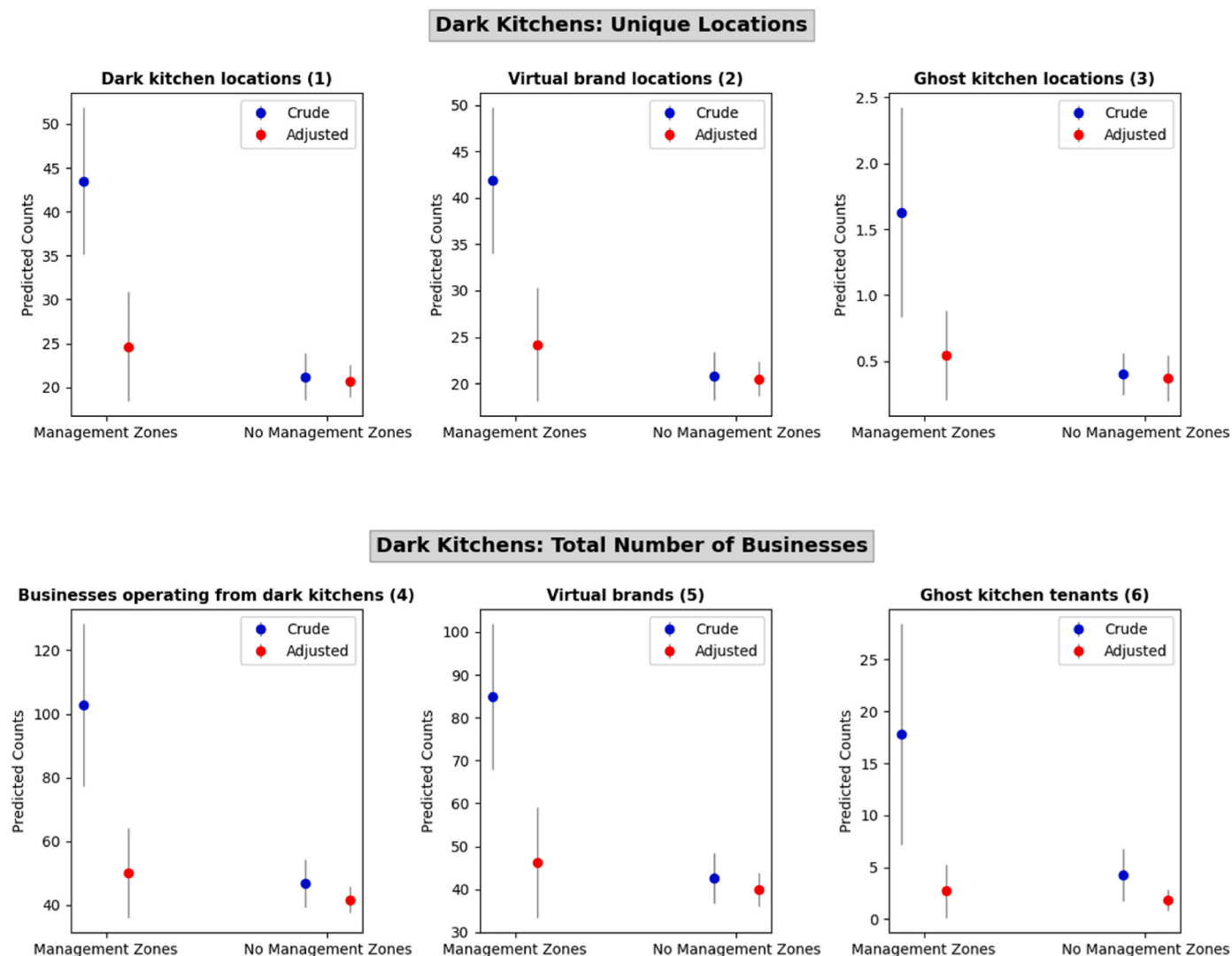


Fig. 5. Associations between area level deprivation and dark retail locations at the LSOA level. Adjusted models account for population density.

The lower prevalence of ghost kitchens and dark grocery stores can be attributed to several factors. Unlike virtual brands that operate from existing high street kitchens, ghost kitchens and dark grocery stores need additional investment into their own facilities. With the post-pandemic return to brick-and-mortar shopping and dining out, their growth may have also slowed (National Restaurant Association, 2023; BBC, 2019; BBC, 2024). Competition from major retailers that can offer a wider range of products at competitive prices, may be squeezing out smaller operators. New regulations in countries like France and the Netherlands have further restricted the expansion of dark grocery stores,

mandating closures or preventing new openings in response to residents' complaints about noise from supply trucks, and delivery e-bikes overwhelming their streets. (Che, 2023) As a result, Getir and Gorillas, key players in this space, have decided to exit markets in the UK, Europe, and the US. (Dodds, 2024) In a similar vein, many large restaurant chains are now reconsidering the delivery-only strategy for some of their ghost kitchens (National Restaurant Association, 2023).

This does not mean dark retail will “go dark”. Food delivery sales continue to grow at a faster rate than dine-in sales, even post-pandemic (27.3 % vs 13.9 % growth, 2022–2024) (Euromonitor Passport, 2023).



**Fig. 6.** Associations between the adoption of takeaway management zones around schools and dark kitchen locations at the local authority level. Adjusted models account for population density and area-level deprivation.

Virtual brands, which we observed to be highly prevalent among dark kitchens and dark retail as a whole, allow businesses to easily add or terminate additional brands as needed while still maintaining sales from their physical outlets. This model reduces costs, expands customer reach, and may lead to higher profitability (Schaefer and Guzmán, 2021). Likely to be located on high streets in commercial areas, virtual brands operating from these kitchens may generate fewer complaints from residents, who may be unaware of their presence. By leveraging existing spaces instead of investing in dedicated delivery facilities (i.e. ghost kitchens), virtual brands offer a flexible and adaptable business model. However, both ghost kitchens and virtual brands may contribute to the proliferation of online food outlets, potentially leading to greater exposure to unhealthy food and promoting its purchase and consumption (Keeble et al., 2021a).

While grocery stores are traditionally seen as sources of healthier food options, rapid deliveries from dark grocery stores may be contributing easier access to unhealthy products. With the focus on convenience, these services differ from mainstream online grocery platforms (e.g., Tesco home delivery), which typically offer a broader range of products, including healthier choices. We found that many dark grocery stores primarily offered alcohol and tobacco products for sale. This is supported by previous findings, where over 90 % of dark grocery stores in the London Borough of Haringey sold alcohol online, and more

than half offered tobacco or e-cigarettes (Rinaldi et al., 2022; Sharpe et al., 2024). Moreover, a scoping review found that on-demand alcohol delivery services often poorly enforce age verification, which combined with a lack of accountability from third-party delivery services and widespread geographical and temporal availability, may have resulted in increased underage drinking (Duthie et al., 2023). Additionally, many alcohol deliveries come from storage units, raising questions about whether they are properly licensed (Sharpe et al., 2024). The lack of regulatory control over these services requires a rethinking of our current regulatory frameworks. This could involve stricter licensing requirements for dark grocery retailers to ensure they meet the same standards as traditional brick-and-mortar stores. For example, age verification policies could be reinforced through mandatory identity checks before purchase and ID verification at delivery. Additionally, clearer legal responsibilities for third-party delivery platforms could strengthen compliance with public health and consumer protection regulations.

#### 4.2.2. Unequally distributed dark retail

With respect to deprivation, the distributions we observed in dark retail closely mirror those of physical and wider online food outlet availability in the UK. That is to say, more dark retail locations and businesses were found in deprived neighborhoods (Keeble et al., 2021b;



Maguire et al., 2015). This is likely driven by land and premises availability, operational efficiency through proximity to markets, perceived consumer demand, and lower rents (Keeble et al., 2021b; Shapiro, 2023). This commercial placement, however, may exacerbate existing inequalities by increasing access to unhealthy foods and other harmful commodities in deprived communities, while doing little to improve access to affordable, fresh, healthy produce. Further, traditional grocery stores in deprived neighborhoods may close due to competition from dark retail, leaving residents without internet or the means to pay delivery fees at risk of losing essential grocery access. Further research is needed to assess the impact of dark retail on physical stores and food access.

In this study, we also found that local authorities who had adopted takeaway management zones around schools had higher numbers of dark kitchens compared to those who had not, although this difference was not significant after adjusting for area deprivation and population density. This could be an indication that dark kitchens are preferred by businesses in these LAs, and as such are being used to undermine planning regulations, which are intended to improve public health through reducing future exposure to takeaways by denial of planning permission to new outlets. However, further investigation is needed to establish causation. Additionally, virtual brands operating within existing kitchens do not require additional planning permission. Overall, this regulatory gap allows online food outlets to operate with less scrutiny than traditional hot food takeaway outlets. Globally, regulations surrounding dark retail are still evolving, as cities and governments strive to address the challenges that these emerging business models are perceived to pose. São Paulo has been a pioneer in regulating dark kitchens (Machado Meyer, 2023). The city's legislation differentiates dark kitchens based on their size, restricting larger operations to industrial zones and establishing guidelines for smaller ones within residential areas. This type of regulatory model may also have value elsewhere.

As well as the challenges posed to the planning system, dark retail may also challenge existing hygiene inspection frameworks. While some platforms mandate a minimum hygiene rating to be achieved by new businesses (e.g., JustEat requires new businesses to have a hygiene rating of at least 3), a greater number of businesses operating online may result in inspection delays (Bradshaw, 2024). Moreover, virtual brands, which share kitchens with existing businesses, are currently not required to undergo separate inspections by the FSA. This raises health and safety concerns, for example related to the cross-contamination of foods, and allergens, attributable to the preparation of multiple different cuisines in one kitchen space. Policymakers must also consider the implications of dark retail when developing regulations, ensuring that these businesses do not exploit regulatory gaps in ways that could harm public health.

#### 4.3. Strengths and limitations

A major strength of this study is the use of online food delivery platform data for all of England. We collected, standardised, and de-duplicated data from three major UK online food delivery platforms, encompassing over 100,000 unique online food outlets. Given the limited prior research in public health on this emerging topic, we defined various types of dark retail and streamlined processes for updating this list. Our work will enable researchers to continue their research agenda in this space with the most up-to-date data available.

This study, however, remains exploratory and has several limitations. While we made efforts to automate and streamline this process, a significant amount of manual checking was still involved, which would make future replication time-consuming. This challenge could be overcome using machine and/or deep learning methods, which should be the subject of further research. Data from this analysis could be used to develop and train such a model. Another important limitation is that the gold standard for identifying dark retail locations would involve on-the-ground verification, but this was not possible. Instead, we relied on

multiple online data sources to inform our judgments, with cross-validation by multiple researchers. While the locations identified in this study are therefore likely to be dark retail sites based on the information available to us, there remains the possibility that some may not be included, or inaccurately classified. For example, the keyword list we developed may not fully capture all dark retail sites, despite being supplemented by other data sources. However, in opportunistically comparing our results with those from a survey of local authority colleagues in North East England, wherein they were asked to report locations of known dark kitchens, only one of the 29 ghost kitchens they identified was missing from our final dataset.

Additionally, while we captured all online food outlets listed on three online food delivery platforms, we did not include other platforms where dark retail may be present, such as Facebook Marketplace, or smaller aggregator apps like Foodstuff. The complexity of identifying food outlets on these platforms made it challenging to systematically include them. Also, according to Euromonitor, the three meal delivery apps in our study accounted for 66.6 % of all online food delivery sales, with the remainder primarily coming from chains' own delivery services (Euromonitor Passport, 2023). However, many chains, such as Domino's, are also listed on these three platforms. Therefore, we consider these platforms to be a comprehensive source to use to identify dark retail locations.

To identify virtual brands, we assumed that these businesses were not registered with the FSA. While this assumption holds true in the majority of instances, we did find examples where virtual brands *were* registered with the FSA. For example, while The Hideout is a physical food outlet, their FSA record (i.e., "The Hideout/ChikBox/KTown/Locked Loaded") also clearly lists the virtual brands they operate. This could potentially lead to an underestimation of virtual brands. To address this, we flagged popular delivery-only virtual brands (e.g., ChikBox, KTown, Locked Loaded, full list see Supplementary appendix File 2), as these are key players in this space. Additionally, we matched our data with OS POI data to reduce the virtual brands' false positive rate.

Another major limitation of this study is that we only focused on the physical locations of these outlets. While the geographical placement of dark retailers is crucial for local authority regulation, a more pertinent question concerning population exposure is where these dark retailers *deliver*. However, the delivery areas of dark retail are dynamic, often shifting based on factors such as the time of day and availability of delivery drivers. This dynamism complicates efforts to assess the true extent of population exposure and also presents regulatory challenges.

In this study, we also excluded home kitchens, catering services, messaging app-based ordering and delivery (e.g. WhatsApp), and retailers offering next-day delivery from our analysis. However, their scale and impact in England may require further investigation. Furthermore, this study used OS POI data from December 2023, which created a slight temporal discrepancy with the meal delivery app data, which was collected between April and May 2024. However, we assumed that POI data remained relatively stable over such a short period. Lastly, this analysis was limited to England and did not include Northern Ireland, Wales, or Scotland. The proposed approach, however, can be applied to these other countries in the UK, in which the datasets we used are also available.

#### 4.4. Future directions for dark retail research

Further research is necessary to understand the potential health and other impacts posed by dark retail, about which we can presently only speculate. Dark retail certainly seems to be rapidly emergent, but our data will serve as a valuable baseline for benchmarking future dark retail growth. We hope our evidence will also inform a broader conversation on whether and what regulatory actions are needed in response.

One important area for future investigation is the delivery *range* of dark retail compared to other online food delivery services. Dark

retailers may potentially deliver to areas farther away, and with lower fees than other online outlets, perhaps due to lower operating costs and the need to reach neighbourhoods with higher demand. Understanding delivery areas would allow for a more accurate assessment of population exposure to dark retail and therefore help to establish potential links to health and other outcomes.

While it is established that foods available on online food delivery platforms are typically unhealthy (Duthie et al., 2023; Partridge et al., 2020), it remains unclear whether items offered and purchased *through dark retail* are similarly so. For example, in dark grocery stores, we observed a significant number of outlets offering alcohol and tobacco products for sale. Systematically comparing these offerings to high street retail offerings, and assessing whether subpopulations, such as young adults, are more likely to order these items from dark retail could reveal important implications for population health.

Overall, the most critical public health question still remains whether dark retail is harmful to public health. Potential gaps in food hygiene inspections associated with dark retail, about which little is known, may pose a danger to food safety. This business model may also contribute to the proliferation of unhealthy food online, potentially leading to more frequent consumption, poorer diets and diet-related health. More research is therefore needed to guide effective policy action.

## 5. Conclusions

Dark retail, which is made up of dark kitchens and dark grocery stores, accounts for approximately 14 % of all online food outlets. The vast majority (89 %) of all dark kitchens are virtual brands located within existing high street kitchens. Dark retail in all its forms is significantly concentrated in more deprived areas and major cities like London. This strategic placement has the potential to exacerbate existing systematic differences in food access by deprivation, thereby contributing to known health inequalities. Businesses may also be leveraging dark retail opportunities to bypass planning regulations that target traditional take-aways on the high street, which could further undermine public health objectives. It is critical that policymakers be aware of the presence of dark retail and its potential impact. However, further research is needed to fully understand the impacts of dark retail, particularly in relation to food access, dietary patterns, and population health.

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## CRedit authorship contribution statement

**Yuru Huang:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Formal analysis, Data curation. **Tom RP. Bishop:** Writing – review & editing, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Jean Adams:** Writing – review & editing, Supervision, Methodology, Investigation, Funding acquisition, Conceptualization. **Steven Cummins:** Writing – review & editing, Supervision, Methodology, Investigation, Funding acquisition, Conceptualization. **Matthew Keeble:** Writing – review & editing, Supervision, Methodology, Investigation, Funding acquisition, Conceptualization. **Chiara Rinaldi:** Writing – review & editing, Supervision, Methodology,

Investigation, Funding acquisition, Conceptualization. **Annie Schiff:** Writing – review & editing, Supervision, Project administration, Data curation. **Thomas Burgoine:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization.

## Declaration of competing interest

None to declare.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.healthplace.2025.103462>.

## Data availability

The authors do not have permission to share data.

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