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# Irish exceptionalism? local food environments and dietary quality

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## ABSTRACT

**Objective** To explore whether distance to and density of food outlets within the local area have an impact on individual dietary quality, controlling for the socioeconomic characteristics of individuals and their households.

**Methods** An analysis of the Survey of Lifestyle, Attitudes and Nutrition in Ireland (SLÁN), a two-stage clustered sample of 10 364 individuals aged 18+ from the Republic of Ireland. Socioeconomic status was measured using net household income and highest level of education. Diet was assessed via a food frequency questionnaire and the results scored in terms of cardiovascular risk. Food availability was measured in terms of distance to (Euclidean and network) and density of different types of food outlets. Dietary quality was decomposed using fixed effects regression models.

**Results** There is a pronounced gradient in distances to nearest food store and quality of diet by socioeconomic status. Controlling for individual and household socioeconomic status and demographic characteristics, individuals who live closer to a larger food outlet or who live in an area with a higher density of larger food outlets have a significantly better diet in terms of cardiovascular risk.

**Conclusions** Studies outside of North America have failed to find that the physical availability of food plays a significant role in socioeconomic gradients in diet and nutrition. This study suggests that food availability in the Republic of Ireland plays a small but statistically significant role in influencing the diets of individuals and communities and, as such, may also influence socioeconomic inequalities in health.

## INTRODUCTION

Dietary quality is an important predictor of health outcomes and plays a prominent role in premature death from a number of chronic health conditions including cardiovascular disease and some cancers. There is now a substantial literature showing that the unequal distribution of material, social and cultural resources in society contributes to social gradients in food and nutrient intake among some population groups.[1–6]

Inadequate nutritional intake and poor dietary habits are also associated with food poverty. Many definitions of food poverty have appeared in the literature, the majority of which include, to a greater or lesser extent, the issues of food affordability and access to a healthy and nutritious diet to be consumed in a socially and acceptable way.[3 7–12] Food poverty is a complex and multi-faceted problem,[3 7 10–14] with widespread consequences for dietary intake, lifestyle behaviour and, ultimately, health outcomes.[3 14 15]

Food poverty can occur as a direct result of a lack of resources at the individual and household level. Low income impacts on the affordability of food and influences the quantity and quantity of food consumed. Low income may also impact indirectly on diet via the local area although studies of this subject have found varying results depending on national context. Studies from the USA and Canada have consistently shown that poorer communities have fewer larger supermarkets and more convenience stores and take-away food outlets. Shops in poorer areas are more likely to stock a higher proportion of processed foods which tend to be higher in saturated fats, salt and sugars, and a smaller range of fruit and vegetables than larger stores. The smaller convenience stores also tend to charge higher prices than larger supermarkets.[16–18] Proximity to a supermarket and number of local supermarkets is positively associated with higher fruit and vegetable intake and better dietary quality among low income households.[19]

Evidence from the UK, Australia and the Netherlands, on the other hand, has not shown an association between socioeconomic status of the area, food availability and diet. Although some UK studies in the late 1980s did show an association between food availability and poorer areas,[20] later studies did not find differences in the availability or price of food between better and worse off communities.[21 22] Moreover, studies have also failed to find an independent association between neighbourhood and community food availability and individual diet and fruit and vegetable intake once adequate control is taken of household income.[23 24]

It is unclear why the findings from North American studies are so different from those elsewhere but it has been suggested that the different regulatory environment in the USA compared to European countries and Australia in combination with the higher levels of socioeconomic segregation in North America due to ethnic and racial divisions, may contribute.[25] Low levels of inward migration until comparatively recently mean that Ireland has nothing like the racial or ethnic segregation of the USA, but there has been a tendency since the 1960s for lower income and local authority housing in Ireland to be built in large estates on the periphery of the larger cities, with little or no infrastructure, including retail opportunities.[26] This may well mean that Ireland has higher levels of socioeconomic segregation than Britain and other



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European countries although there is no published evidence of this.

Irish grocery retail can be divided into three sectors: 'vertically integrated retailers', who own or operate multiple retail outlets across the state (subdivided into 'multiples' and 'foreign discount stores'); 'affiliated retailers', who typically own and operate one retail outlet under a retail brand or franchise (known as 'group and symbol stores'); and 'independent retailers' (includes independent retailers, forecourt garages and newsagents).[27] The multiples have the largest market-share, with two operators (Tesco and Dunnes) sharing 50% of the entire grocery market.[28] Multiples are the most common type of shops used in all social groups, but there is a class pattern, with more people from lower social groups shopping in group/symbol stores. There is a price differential in food costs between retail outlets. Previous work has shown that the foreign discount stores are the cheapest retail outlets within which to purchase food, but the range of items available is smaller than at the multiples who are second least expensive. The most common type of retail outlet used by low-income groups is the group/symbol stores, followed by more local independent traders.[3 14 29 30] Group/symbol stores are more common and closer to urban centres on average, but have a limited selection of fruit, vegetables and wholemeal alternatives, not many low fat products, and little or no fresh meat, fish and poultry. In contrast, groups/symbols and independents stock a variety of items from the high fat/high sugar food group.

In this paper we explore whether the distance to and density of food outlets within the local area has an impact on individual dietary quality, controlling for the socioeconomic characteristics of individuals and their households.

## METHOD

### General study design

The Irish Survey of Lifestyle, Attitudes and Nutrition (SLÁN) was conducted in 2007[5 31–33] and collected data on 10 364 respondents (62% response rate) aged 18+ through face-to-face interview.[31] It used a multi-stage sample design with random selection of geographic clusters, households within clusters and (eligible) individuals within households. In addition, 7501 (72%) completed a Willett Food Frequency Questionnaire (FFQ) which was validated for use in the Irish population.[34 35] The FFQ asked respondents to report their average consumption of a large number of foods over the previous year and includes all foods consumed including restaurant and take-away meals. A paper version of the FFQ was left at the respondent's household and was mailed back to the research team following completion. The sample was weighted to approximate census figures.

### Dietary quality assessment

DASH (Dietary Approaches to Stop Hypertension) scores were calculated for each participant.[36] For each food group, consumption was divided into quintiles and participants were classified according to their intake ranking. Consumption of healthy food components were rated on a scale of 1–5; the higher the score the more frequent the consumption of that food—that is, those in quintile 1 had the lowest consumption and received a score of 1, and those in quintile 5 had the highest consumption and received a score of 5. Less healthy dietary constituents, where low consumption is desired, were scored on a reverse scale, with lower consumption receiving the higher scores. Component scores were then summed and an overall DASH score ranging from 9 to 42 for each person was calculated.

### Measuring food availability

Food availability can be conceptualised along a number of dimensions. First, the distance to any food outlet may influence availability. If individuals need to travel longer distances for food it is likely that this will increase the cost of the food obtained. Second, if shops carrying less nutritious food are closer, this may have an influence on diet by increasing the incentive to purchase these foods over more nutritious alternatives in more remote stores. Third, the density of food stores in a local area may also play a role by increasing competition and providing choice to the consumer. All three conceptualisations of food availability are used in this study. We measure the distance from the individual's home to the nearest food store of different types. We also measure the density of different types of food stores within a given radius of the respondent's household.

The distance and density (ie, number) of local food stores was obtained by relating the geographic coordinates of the household to all food retailers in Ireland. We divide shops into two groups: the vertically integrated retailers (which we refer to has 'multiples'); and the group/symbol and independent retailers (which we refer to as 'convenience'). Vertically integrated retailer stores are larger and carry a more extensive range of fresh foodstuffs, as well as being cheaper on average than the group/symbol and independent retailers, referred to here as 'convenience' stores. Distances were calculated between each survey household and its nearest food store of each type using ArcGIS v.9.3.1 (in metres). It is now normal practice[37] to measure the 'network' distance between household and service of interest (ie, the distance taking into account road networks) rather than the Euclidean distance (the shortest direct distance). In this paper we focus largely on network distances but refer to results using Euclidean distances from the multivariate models. The effects of network distance to multiple and convenience stores are estimated in separate models.

The raw distance variables are not normally distributed and the impact of distance on diet was found to be non-linear. Different parameterisations of the distance variables were tested, including linear, log, spline and linear plus quadratic. The logged distance variable was found to provide the best fit to the data and is thus used in the multivariate analysis.

The number of shops of each type (ie, multiple or convenience) within a given distance (our measure of outlet density) is counted for distances of 500 m, 1 km and 2 km. The effects of the densities of multiple and convenience stores are estimated in separate models, with three parameters fitted in each model to represent the density of outlets from 0 to 500 m, from 500 to 1000 m and from 1000 to 2000 m. The density of outlets within 2 km is thus the sum of the three variables.

### Independent predictors and control variables

#### Socioeconomic status

We examine the effect of household income using a variable measuring current net household income (after tax and other deductions) equivalised for the number of individuals in the household using the modified OECD equivalence scale. This measure is divided into quintiles for descriptive analysis and used in a continuous, logged form for multivariate analysis.

The education of the respondent is measured using a five-level variable which differentiates between having primary level education alone, lower secondary education (to age 16), higher secondary education (to age 18), post-secondary education in the form of diplomas/certificates, and lastly, third-level qualifications (primary or higher degrees).

### Population density

To control for population density we use a variable which measures whether the household is in open country, a village (<1500 population), a small town (1500+ population), a city (other than Dublin) or in Dublin City or County.

### Sociodemographic variables

Age is measured as a seven-category variable with groupings: 18–24, 25–34, 35–44, 45–54, 55–64, 65–74, and 75+. Sex is also controlled for in analyses as is marital status. This is represented with a variable with categories: single, cohabiting, married, and separated/divorced/widowed.

### Access to a car

Respondents were asked whether they 'have the use of a car (including vans, minibuses, etc)'. Access to a car is represented by a dichotomous variable.

## Statistical analysis

Arithmetic mean Euclidean and network distance to food outlets (by type) and DASH score were calculated along with 95% CIs for the impact of each variable. Although standard ordinary least squares would produce estimates of the effect of distance on DASH it is possible that the rurality of the household and the differential population composition of areas would dominate the analysis. To counter this we use a fixed-effects or 'within' estimator. In this approach the mean deviation of the individual's DASH score from the mean DASH score in their area (ie, the units from the first stage of sampling) is regressed on the mean deviation of the variables of interest (including distance to food outlet). The fixed-effects estimator is shown in equation 1:

$$\hat{y} = (yij - \bar{y}j) = \alpha + \beta(\chi ij - \bar{\chi}j) + \varepsilon ij \qquad (1)$$

where $y_{ij}$ is the DASH score of person $i$ in sampling cluster $j$, $\bar{y}j$ is the mean DASH score within sampling cluster $j$, $\chi_{ij}$ is a vector of predictor variables, $\bar{\chi}j$ the mean value of these predictor variables and $\varepsilon_{ij}$ the individual residual. We thus control for all differences *between* sampling clusters and confine analysis to the impact of distance on DASH *within* clusters. Sample clusters are units of 500 to 1000 households. These are divisions of electoral wards in urban areas but represent 'townlands' in more rural areas.

Two models are estimated for each type of food shop. The first fits all variables for the complete sample and tests the hypothesis that log (network distance) to the nearest multiple or

**Table 1** Descriptive statistics for network distance to nearest food outlet by outlet type and individual characteristics

| | Network distance to nearest convenience store | | | Network distance to nearest multiple store | |
|---|---|---|---|---|---|
| **Variable** | **N** | **Mean distance (m)** | **95% CI** | **Mean** | **95% CI** |
| All | 7501 | 2110.697 | 2053.77 to 2167.63 | 5011.724 | 4874.64 to 5148.81 |
| Age group | | | | | |
| 18–24 | 776 | 1990.23 | 1812.39 to 2168.07 | 4183.83 | 3800.18 to 4567.48 |
| 25–34 | 1459 | 1719.46 | 1609.49 to 1829.42 | 3868.02 | 3608.44 to 4127.60 |
| 35–44 | 1604 | 2057.89 | 1945.63 to 2170.14 | 5173.32 | 4886.22 to 5460.42 |
| 45–54 | 1238 | 2228.49 | 2088.39 to 2368.59 | 5065.12 | 4747.64 to 5382.60 |
| 55–64 | 1028 | 2531.69 | 2347.22 to 2716.16 | 6159.94 | 5731.07 to 6588.80 |
| 65–74 | 815 | 2398.97 | 2210.59 to 2587.34 | 6180.82 | 5665.55 to 6696.09 |
| 75+ | 581 | 2452.00 | 2228.04 to 2675.96 | 6649.28 | 6088.06 to 7210.51 |
| Gender | | | | | |
| Male | 3144 | 2149.24 | 2058.58 to 2239.91 | 5004.41 | 4796.72 to 5212.11 |
| Female | 4357 | 2073.36 | 2000.99 to 2145.73 | 5018.81 | 4835.64 to 5201.97 |
| Income quintile | | | | | |
| Lowest | 1203 | 2296.06 | 2118.21 to 2473.90 | 5387.51 | 5017.06 to 5757.97 |
| 2nd | 1415 | 2271.26 | 2161.30 to 2381.22 | 5699.59 | 5353.95 to 6045.24 |
| 3rd | 1381 | 2231.73 | 2119.48 to 2343.98 | 5293.30 | 4963.14 to 5623.45 |
| 4th | 1351 | 2039.41 | 1899.31 to 2179.51 | 4522.57 | 4241.11 to 4804.03 |
| Highest | 1406 | 1732.04 | 1547.57 to 1916.51 | 3780.96 | 3540.31 to 4021.62 |
| Highest educational qualification | | | | | |
| Primary alone | 1242 | 2494.94 | 2328.23 to 2661.65 | 6578.49 | 6166.81 to 6990.18 |
| Lower secondary | 1489 | 2205.84 | 2076.83 to 2334.84 | 5424.48 | 5117.05 to 5731.90 |
| Higher secondary | 1932 | 1970.43 | 1866.50 to 2074.35 | 4680.24 | 4424.13 to 4936.35 |
| Post-secondary | 1358 | 2124.52 | 1994.81 to 2254.22 | 4717.46 | 4409.46 to 5025.46 |
| Degree or higher | 1480 | 1823.44 | 1709.49 to 1937.40 | 3820.30 | 3577.08 to 4063.53 |
| Car ownership | | | | | |
| Yes | 5795 | 2309.53 | 2243.07 to 2375.99 | 5412.93 | 5253.86 to 5572.00 |
| No | 1515 | 1369.09 | 1267.75 to 1470.43 | 3465.74 | 3199.33 to 3732.15 |
| Marital status | | | | | |
| Single | 2196 | 1886.00 | 1782.45 to 1989.55 | 4247.33 | 4015.28 to 4479.39 |
| Cohabiting | 480 | 1718.52 | 1525.19 to 1911.85 | 4067.16 | 3629.70 to 4504.61 |
| Married | 3732 | 2351.19 | 2268.02 to 2434.36 | 5664.75 | 5459.10 to 5870.39 |
| Separated/divorced/widowed | 1080 | 2007.04 | 1866.33 to 2147.75 | 5176.24 | 4801.21 to 5551.26 |
| Location | | | | | |
| In open country | 2293 | 4602.31 | 4486.33 to 4718.28 | 10117.02 | 9855.57 to 10378.47 |
| In a village (<1500) | 819 | 2175.74 | 1987.21 to 2364.27 | 8924.04 | 8459.95 to 9388.12 |
| In a town (1500+) | 1813 | 914.47 | 869.64 to 959.29 | 2447.67 | 2270.36 to 2624.98 |
| In a city (not Dublin) | 823 | 766.03 | 732.00 to 800.05 | 1222.48 | 1137.62 to 1307.34 |
| In Dublin City | 1656 | 856.19 | 825.88 to 886.50 | 1373.05 | 1329.19 to 1416.91 |

convenience store is associated with a higher quality diet as measured by DASH score. To test the hypothesis that a higher density of shops will be associated with a better diet, we restrict analysis to those respondents who have a shop within a given radius of their home. A large proportion of the sample will have zero shops within N metres of their home, with the proportion increasing inversely with distance. This reduces variance in the sample and conflates the distance hypothesis with the density hypothesis. To test the latter we restrict the sample to those with a shop N metres from their household and then fit both the log(network distance) measure and the measure of number of shops (of each type). Radii of 500 m, 1000 m and 2000 m were used to create concentric rings within which the number of shops of each type were counted.

## RESULTS

Mean distance to a multiple food store was 5012 m across the sample, although 25% lived within 1000 m and 6% within 500 m. The larger number of convenience stores in Ireland means that the average distance to these food shops is significantly shorter at 2111 m. Age and rurality are correlated in Ireland: table 1 shows that younger individuals are more likely to live closer to a multiple (mean of 3868 m among those aged 25–34 compared to 6649 m for respondents aged 75+), and respondents in open countryside have the longest mean distance to a multiple at 10 117 m followed by those in 'a village' of less than 1500 people. Single and cohabiting respondents tend to have shorter distances, again reflecting that fact that younger people are more likely to be single or cohabiting and live in urban areas. These same patterns hold for the convenience stores also although absolute distances are shorter.

Individuals in the highest income group have the lowest mean distance to travel to a multiple with distance increasing on average as household income falls. Similarly, higher levels of education are associated with lower distances. Respondents with a degree or higher level qualification have the lowest average distance at 3820 m and those with primary education alone, the highest at 6579 m. This pattern is also correlated with age and rurality as older individuals are far more likely to have primary education—free secondary education after age 14 only became available in Ireland after 1967.

Although the correlation between Euclidean and network distances is 0.99 for multiple food stores, the mean Euclidean distances for each characteristic are shorter, with the overall mean Euclidean distance to a multiple being 3899 m compared to 5012 m using network distances.

Table 2 gives descriptive statistics for DASH scores across the predictor variables used in the analysis. DASH scores are curvilinear with age, with scores increasing until age 64 before declining again among the two oldest age groups. Female respondents have significantly higher scores than male respondents, as do married respondents. DASH scores increase steadily with income. The lowest income quintile has an average score of 24.4 compared to 26.0 in the highest income quintile. DASH score also increases with level of education. Respondents with a car have higher DASH scores when compared to those who do not. The final 10 rows of table 2 show that there is very little association between network distance to multiple store and DASH score, with no significant difference between the distance quintiles in DASH scores.

To assess the net effect of different predictors within sample clusters, we fit fixed effect models which estimate the effect of the predictor variables (including distance) within each of the areas in the sample while controlling for all differences (including rurality) between the sample clusters. Table 3 confirms the effects of the bivariate analyses, with age retaining a curvilinear effect, and being female and married associated with higher DASH scores. More income and education are associated with significantly better dietary quality. The fact that the effect for access to a car remains significant even controlling for income and education suggests that having greater mobility improves diet above and beyond the association of car ownership with material wealth and greater resources. Table 3 shows that the log of network distance to the nearest multiple food

**Table 2** Descriptive statistics for DASH score by individual characteristic

| | DASH score | | |
|---|---|---|---|
| | N | Mean DASH score | 95% CI |
| All | 7501 | 24.86 | 24.75 to 24.97 |
| Age group | | | |
| 18–24 | 776 | 23.18 | 22.84 to 23.52 |
| 25–34 | 1459 | 24.57 | 24.32 to 24.82 |
| 35–44 | 1604 | 24.90 | 24.68 to 25.13 |
| 45–54 | 1238 | 25.54 | 25.29 to 25.80 |
| 55–64 | 1028 | 25.95 | 25.65 to 26.24 |
| 65–74 | 815 | 25.59 | 25.26 to 25.92 |
| 75+ | 581 | 24.65 | 24.28 to 25.01 |
| Gender | | | |
| Male | 3144 | 23.87 | 23.71 to 24.04 |
| Female | 4357 | 25.82 | 25.68 to 25.95 |
| Income quintile | | | |
| Lowest | 1203 | 24.11 | 23.84 to 24.38 |
| 2nd | 1415 | 24.39 | 24.14 to 24.64 |
| 3rd | 1381 | 24.92 | 24.66 to 25.17 |
| 4th | 1351 | 25.18 | 24.93 to 25.44 |
| Highest | 1406 | 25.95 | 25.71 to 26.20 |
| Highest educational qualification | | | |
| Primary alone | 1242 | 24.19 | 23.93 to 24.45 |
| Lower secondary | 1489 | 24.12 | 23.88 to 24.36 |
| Higher secondary | 1932 | 24.50 | 24.29 to 24.71 |
| Post-secondary | 1358 | 25.23 | 24.98 to 25.49 |
| Degree or higher | 1480 | 26.43 | 26.19 to 26.67 |
| Car ownership | | | |
| Yes | 5795 | 25.16 | 25.04 to 25.29 |
| No | 1515 | 23.87 | 23.63 to 24.12 |
| Marital status | | | |
| Single | 2196 | 23.92 | 23.72 to 24.13 |
| Cohabiting | 480 | 24.57 | 24.13 to 25.01 |
| Married | 3732 | 25.53 | 25.38 to 25.68 |
| Separated/divorced/widowed | 1080 | 25.24 | 24.97 to 25.51 |
| Location | | | |
| In open country | 2293 | 24.91 | 24.71 to 25.11 |
| In a village (<1500) | 819 | 24.95 | 24.61 to 25.28 |
| In a town (1500+) | 1813 | 25.12 | 24.90 to 25.35 |
| In a city (not Dublin) | 823 | 24.27 | 23.93 to 24.60 |
| In Dublin City | 1656 | 24.84 | 24.62 to 25.06 |
| Distance to 'multiple' retailers | | | |
| Shortest | 1488 | 24.85 | 24.60 to 25.10 |
| 2nd | 1487 | 24.88 | 24.64 to 25.12 |
| 3rd | 1465 | 24.93 | 24.68 to 25.18 |
| 4th | 1567 | 24.99 | 24.75 to 25.23 |
| Longest | 1494 | 24.65 | 24.41 to 24.88 |
| Distance to 'convenience' retailers | | | |
| Shortest | 1534 | 24.68 | 24.43 to 24.92 |
| 2nd | 1471 | 24.90 | 24.66 to 25.14 |
| 3rd | 1470 | 24.82 | 24.57 to 25.07 |
| 4th | 1532 | 25.21 | 24.98 to 25.45 |
| Longest | 1494 | 24.69 | 24.45 to 24.94 |

**Table 3** Fixed effects (within sample cluster) ordinary least squares models of DASH by food outlet type

| | Multiples | | Convenience stores | |
|---|---|---|---|---|
| **Variable** | **Coefficient** | **95% CI** | **Coefficient** | **95% CI** |
| 18–24 | Ref. | – | Ref. | – |
| 25–34 | 1.19 | 0.73 to 1.64 | 1.19 | 0.73 to 1.65 |
| 35–44 | 1.48 | 1.00 to 1.96 | 1.47 | 0.99 to 1.95 |
| 45–54 | 2.57 | 2.06 to 3.09 | 2.58 | 2.06 to 3.09 |
| 55–64 | 3.26 | 2.72 to 3.79 | 3.26 | 2.72 to 3.80 |
| 65–74 | 3.01 | 2.43 to 3.58 | 3.00 | 2.43 to 3.58 |
| 75+ | 2.23 | 1.60 to 2.87 | 2.24 | 1.61 to 2.88 |
| Male | Ref. | – | Ref. | – |
| Female | 2.02 | 1.79 to 2.25 | 2.01 | 1.79 to 2.24 |
| Single | Ref. | – | Ref. | – |
| Cohabiting | −0.13 | −0.62 to 0.37 | −0.14 | −0.63 to 0.36 |
| Married | 0.38 | 0.07 to 0.69 | 0.37 | 0.06 to 0.68 |
| Separated/divorced/widowed | 0.10 | −0.32 to 0.51 | 0.10 | −0.32 to 0.51 |
| Log of income | 0.49 | 0.29 to 0.68 | 0.49 | 0.30 to 0.69 |
| Primary alone | −2.75 | −3.20 to −2.29 | −2.75 | −3.21 to −2.30 |
| Lower secondary | −2.31 | −2.70 to −1.92 | −2.31 | −2.71 to −1.92 |
| Higher secondary | −1.68 | −2.03 to −1.33 | −1.68 | −2.03 to −1.33 |
| Post-secondary | −1.06 | −1.42 to −0.70 | −1.06 | −1.42 to −0.70 |
| Degree or higher | Ref. | – | Ref. | – |
| In open countryside | −0.68 | −1.84 to 0.48 | −0.78 | −1.94 to 0.39 |
| In a village (<1500) | −0.83 | −2.01 to 0.35 | −0.95 | −2.12 to 0.23 |
| In a town (1500+) | −0.71 | −1.85 to 0.43 | −0.70 | −1.84 to 0.44 |
| In a city (not Dublin) | −0.73 | −1.70 to 0.25 | −0.71 | −1.68 to 0.27 |
| In Dublin City | Ref. | – | Ref. | – |
| No car | Ref. | – | Ref. | – |
| Car | 0.53 | 0.21 to 0.85 | 0.52 | 0.20 to 0.84 |
| Log of network distance | −0.20 | −0.40 to 0.00 | −0.05 | −0.19 to 0.09 |
| Constant | 22.36 | 20.22 to 24.49 | 21.16 | 19.44 to 22.89 |
| Individuals (n) | – | 6586 | – | 6586 |
| Areas (n) | – | 455 | – | 455 |
| $R^2$ within | – | 0.12 | – | 0.12 |
| $R^2$ between | | 0.10 | | 0.10 |
| $R^2$ overall | – | 0.13 | – | 0.13 |
| % Variance explained by area differences | | 19% | – | 19% |

shop is significant at a 90% level (p=0.054) and negative on DASH score controlling for all other factors in the model. A unit increase in the log of distance to the nearest multiple supermarket leads to a 0.2 reduction in the DASH score. The log of distance to nearest convenience store has a coefficient of −0.05 but has a t ratio of less than one, suggesting low levels of statistical significance. Analysis of Euclidean distances shows almost identical results, with the coefficient for distance to multiples −0.22 and marginally more significant (p=0.026). Distance to convenience store remains insignificant and low using Euclidean distances. Although distance was not associated with DASH in the descriptive analyses of table 2, preliminary models showed that the relationship is negative but insignificant until the fixed effects estimator is applied. The coefficient becomes significant once terms for age and sex are added.

Table 4 gives the results for the stratified models of DASH score, including the variable for the density of multiple food and convenience stores. The restriction of the sample to those cases with a multiple outlet within a radius of 2 km around the household and including the three density measures leads to an increase in the size and significance of the distance coefficient to a multiple (from −0.2 to −0.45; p<0.01). The distance to convenience store coefficient remains insignificant. Using Euclidean distances the coefficient for distance to multiple in the stratified models is marginally larger at −0.54 than found using network distances. The density measures for the multiples and convenience stores are all positive, suggesting that diet improves with increasing density but only the density of multiples between 1 and 2 km is significant at a probability of 95% or more (p<0.01). For each additional supermarket within a 2 km radius of the respondent's household, DASH score improves by 0.59 of a unit (same when using Euclidean distances).

## CONCLUSIONS

Economic resources at the household and individual level will impact on the economic affordability of food and thus the makeup and quantity of food consumed. However, the local food environment may also shape the availability of different types of foodstuffs, their cost and quality net of individual and household characteristics. If so, even socioeconomically advantaged households in poorly served communities may have a poorer diet than their peers in better served areas. This would imply that poorer households in poorer areas are doubly disadvantaged in terms of diet and nutrition. Studies of the local food environment in North America have found variations in the number and kinds of shops across communities which differ by socioeconomic status, and that these variations independently contribute to differentials in diet and nutrition at the individual level. However, these results have not been replicated outside of North America until now.

Analysis of the DASH dietary score showed that individual and household socioeconomic status had a powerful impact on

**Table 4** Fixed effects (within sample cluster) ordinary least squares models of DASH by food outlet type; sample with an outlet (by type) within 2 km

| | Supermarkets | | Convenience stores | |
|---|---|---|---|---|
| **Variable** | **Coeff.** | **95% CI** | **Coeff.** | **95% CI** |
| 18–24 | Ref. | – | Ref. | – |
| 25–34 | 1.32 | 0.78 to 1.87 | 1.37 | 0.86 to 1.88 |
| 35–44 | 1.43 | 0.85 to 2.02 | 1.40 | 0.86 to 1.94 |
| 45–54 | 2.57 | 1.93 to 3.21 | 2.63 | 2.05 to 3.22 |
| 55–64 | 2.97 | 2.29 to 3.65 | 3.26 | 2.63 to 3.88 |
| 65–74 | 2.92 | 2.19 to 3.64 | 3.18 | 2.52 to 3.84 |
| 75+ | 2.45 | 1.63 to 3.27 | 2.22 | 1.48 to 2.97 |
| Male | Ref. | – | Ref. | – |
| Female | 1.81 | 1.52 to 2.11 | 1.86 | 1.59 to 2.12 |
| Single | Ref. | – | Ref. | – |
| Cohabiting | −0.47 | −1.08 to 0.13 | −0.26 | −0.80 to 0.29 |
| Married | 0.46 | 0.06 to 0.85 | 0.44 | 0.08 to 0.80 |
| Separated/divorced/widowed | −0.05 | −0.57 to 0.47 | 0.08 | −0.40 to 0.55 |
| Log of income | 0.48 | 0.23 to 0.73 | 0.49 | 0.26 to 0.72 |
| Primary alone | −2.64 | −3.25 to −2.03 | −2.63 | −3.17 to −2.09 |
| Lower secondary | −2.37 | −2.89 to −1.86 | −2.26 | −2.72 to −1.80 |
| Higher secondary | −1.58 | −2.02 to −1.13 | −1.65 | −2.06 to −1.25 |
| Post-secondary | −0.96 | −1.42 to −0.51 | −0.98 | −1.39 to −0.56 |
| Degree or higher | Ref. | – | Ref. | – |
| In open countryside | −0.08 | −1.59 to 1.43 | −0.29 | −1.57 to 0.99 |
| In a village (<1500) | −0.82 | −2.35 to 0.70 | −0.57 | −1.86 to 0.72 |
| In a town (1500+) | −0.17 | −1.47 to 1.13 | −0.40 | −1.62 to 0.81 |
| In a city (not Dublin) | −0.75 | −1.77 to 0.28 | −0.84 | −1.84 to 0.15 |
| In Dublin City | Ref. | – | Ref. | – |
| No car | Ref. | – | Ref. | – |
| Car | 0.54 | 0.17 to 0.92 | 0.56 | 0.21 to 0.91 |
| Log of network distance | −0.45 | −0.76 to −0.15 | −0.03 | −0.22 to 0.15 |
| Density <500 m | 0.32 | −0.42 to 1.05 | 0.30 | −0.05 to 0.65 |
| Density <1000 m | 0.25 | −0.21 to 0.71 | 0.19 | −0.10 to 0.47 |
| Density <2000 m | 0.59 | 0.20 to 0.97 | 0.03 | −0.29 to 0.35 |
| Constant | 23.35 | 20.57 to 26.13 | 20.52 | 18.41 to 22.63 |
| Individuals (n) | – | 3971 | – | 4928 |
| Areas (n) | – | 347 | – | 440 |
| $R^2$ within | – | 0.12 | – | 0.12 |
| $R^2$ between | – | 0.06 | – | 0.14 |
| $R^2$ overall | – | 0.12 | – | 0.13 |
| % Variance explained by area differences | | 25% | – | 22% |

the quality of diet. Individuals with less education or living in a household with lower levels of income had significantly lower DASH scores controlling for a number of other factors and confounders. This underlines the importance of socioeconomic variables in structuring inequalities in diet and nutrition, and ultimately in health. Our analyses showed that a measure of distance to the nearest supermarket operated by the multiple and discount chains did significantly influence diet. Each unit increase in the log of the distance between household and supermarket decreased the DASH score by 0.2. This is an elasticity of around 1% (0.2/24.86 at the mean DASH score), suggesting a small but significant effect. The density of shops operated by these retail groups was also important. For each additional supermarket between 1 and 2 km of the household, the DASH score increased by 0.59 of a DASH unit. This is an elasticity of 2.5%. The effect of density of larger supermarkets closer to the household was also positive but was not significant. We found no significant effect for either the distance to the nearest convenience store or density of local convenience stores.

Some limitations of our study should be mentioned. First, our survey is cross-sectional so it is impossible to rule out the possibility that the positioning of supermarkets is the result of a demand led process, with retailers responding to the patterns of demand in local areas when choosing sites to place their supermarkets. If true this could mean that number of supermarkets and distance to nearest would be endogenous to the socioeconomic measures in the model. Longitudinal or semi-experimental designs of this issue are rare, although there has been some research which has studied the impact which the building of a new supermarket had on the diets of the local community in Britain.[38 39] The results of this more powerful methodological design suggested no clear impact.

Second, the food frequency questionnaire used in this analysis includes all food consumed by the individual and so includes food purchased in outlets other than supermarkets and convenience stores such as fast-food and take-away outlets. As such, it is possible that the effect of distance to 'multiple' food store that we observe is actually due to omitted differences in the density or distance to fast-food outlets in the sample. This is possible, but for it to be true, shorter distance to a take-away would need to be a positive influence on diet (unlikely) and this measure reasonably correlated with our measure of distance to multiple. If anything, we would argue that the omitted distance to take-away would be more strongly correlated with our measure of

### What is already known on this subject

- Ireland has significant socioeconomic inequalities in diet, nutrition and cardiovascular mortality.
- The physical availability of food is known to vary by socioeconomic status in North America but not elsewhere.

### What this study adds

- Results show a clear impact of distance to larger food outlets and density of outlets for the first time outside of North America.
- Interventions to reduce socioeconomic inequalities in diet related mortality and morbidity in Ireland will need to address inequalities in physical access to food.

distance to convenience store and we find no significant effect for this variable.

Third, it could be argued that we should include an area level measure of socioeconomic status since our findings on distance to food outlet may result from correlation with an omitted measure of deprivation or disadvantage at the area level. We would argue that by fitting a fixed-effect estimator we actually control for all differences between areas when estimating the distance effect within the area (we are estimating the effect of differences in distance *within* each sampling cluster) while simultaneously controlling for variation in individual level socioeconomic characteristics within the area.

Fourth, we have shown an association between the distance to and density of food outlets in the local area and dietary quality but this does not establish a causal relationship. To establish this it is necessary to measure the influence of food availability in the local area on patterns of purchasing and then relate this to the quality of food consumed. Nonetheless, we feel that our findings are strongly suggestive of a relationship between local food availability and dietary quality.

The clear negative association of supermarket distance and density with diet in our study could suggest that Ireland is closer to the USA and Canada than it is to European countries and Australia in this regard. There is some research for Ireland which has suggested that Irish urban planning and development has had a negative influence on food availability by allowing large out of town shopping facilities to develop at the expense of smaller shops within urban areas.[26] It may be that the increased distances required to buy food and social segregation that this had introduced has had a negative impact on the diets of Irish citizens and poorer Irish citizens in particular and may contribute to inequalities in health in Ireland.

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