Healthy Food Diversity and Supermarket Interventions: Evidence from the Seacroft Intervention Study

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Abstract

Supermarket interventions have been a commonly used treatment to problems of fresh fruit accessibility in areas of previously limited availability, their wide product ranges and lower-prices making them seemingly perfect for promoting better diets. Empirical studies likewise fall in favour. However, this diversity also serves to give consumers opportunity to entrench their habits and simply purchase more of the bad foods they enjoy. In this paper we develop a new health index based upon UK government guidelines and look to the Seacroft Intervention Study for emprical evidence of supermarket impact thereupon. Using fixed effects unconditional quantile regression to provide robustness to our parameter estimates against covariate specification, we reinforce the message that supermarkets are not a panacea for dietary improvement. Whilst diversity increases it is unlikely to be healthful, entrenching poor dietary habits rather than delivering improvement as intended. Careful consideration of planning policy, health education and sector regulation is needed.

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JEL Classifications: I14, I18

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Urban food environments have undergone tremendous change in the past half century, with enormous potential impact for the diet of residents. Phase one saw supermarkets growing on towns' peripheries, attracting car owners and leaving food deserts in poorer areas where the potential custom for supermarkets was smaller. Ambiguity exists in what precisely constitutes a food desert, but unanimity is arrived at in the integration of access, affordability and income within the definition (Shaw, 2006; Walker et al., 2010; Wright et al., 2016). Indeed, so deep was the concern about those who had to rely on local convenience stores that an intervention programme was designed to bring supermarkets into under-served communities, alleviating access issues. Supermarkets here are defined as selling a full range of food items, including fresh bread, fruits, vegetables and meats[1]. Such large format stores were seen as cheaper and as offering more variety of healthy and nutritious foodstuffs; perfect for improving diet in low income areas. Contributing to the debate on the wisdom of this development strategy, this paper is the first to make use of food diary data from one such United Kingdom intervention, the Seacroft Intervention Study of Wrigley et al. (2004a) in Leeds, to analyse the wider dietary consequences of a new supermarket in a food desert. Donald (2013) identifies Seacroft as the only before and after intervention review making it an invaluable case study for both understanding implications of new supermarkets in food deserts, and for driving policy.

To evaluate the dietary impact, a healthy food diversity (HFD) index is developed, building on Drescher et al. (2007) but using the UK eatwell plate[2] to provide a unique tool for intervention assessment. A stated aim of the new stores is providing greater access to a greater variety of healthier items and hence an increase in the HFD index is targeted. Food diary data from Wrigley et al. (2004a) is given a major overhaul, combining with household characteristics after Wrigley et al. (2002b,a, 2003). Unconditional quantile regressions, used in this literature for the first time, inform caution on accepting early conclusions of health improvement; new stores' shoppers are more likely to have a lower HFD value than others. As well as proposing the index, this paper explores three key research questions across their distributions for the first time. Firstly does the opening of a new supermarket lead to greater and more healthy variety in food consumption? Secondly, what further factors might increase healthful diversity? Finally, what drives healthy food diversity index levels? We demonstrate supermarkets deliver signigificant increases in dietary diversity at the lower end of the distribution but that this increase does not translate into healthier diets, indeed significant divergence from the recommended healthy diet is seen around the median.

Reviewing the literature on food deserts, diversity indices and dietary impact Section 1 contextualises this discussion within the international literature. The Seacroft study area and the diversity indices employed are introduced in Sections 2; particular attention is given to the distinction between diversity and healthfulness. Econometric modelling techniques are then exposited in Section **??**. Factors driving change are explored using unconditional quantile regressions in Section **??** to bring through the distributional impact of the new store. Section **??** concludes on the suitability of supermarkets for dietary improvement

[1]The US definition of Supermarket also includes a turnover of at least $\$2m$ but no turnover data is available for the stores in this study. The UK uses a sales floor area of 1400 square metres, but there are other stores not selling the full range of products but meeting this definition Ellickson (2013).

[2]The eatwell plate first appears as FSA (2007) and a full guide is available from the UK Government through Public Health England (2014).

interventions.

1 Background

Patterns of access to healthy foodstuffs and improvement strategies are well documented in developed nations; large product range, lower price supermarkets being a typical solution[3]. Wrigley et al. (2002a) notes the Tesco Extra in Seacroft, alongside Asda at Manchester's Sport City as early examples of a retail led regeneration agenda, but such developments continue apace[4]. Whilst empirically this paper is UK sited, similar issues and concerns exist globally Mahadevan and Suardi (2013); Morgan (2015); Howlett et al. (2016). Results presented here have therefore clear implications for the impact of supermarkets globally.

Empirical support for supermarket interventions is strong and typically premised on fruit and vegetable intake Wrigley et al. (2003); Adams et al. (2012); Aggarwal et al. (2014). However, concerns were raised by Cummins et al. (2005) and Gill and Rudkin (2014) about what might happen when other foodstuffs were considered and where the worst of the negative impact might fall. Recent works such as Ghosh-Dastidar et al. (2014) have sought to expand the food range for Seattle in the USA, but lack the pre- and post-intervention data available in Seacroft (Donald, 2013). For a new store to be successful, consumers must reappraise their shopping choices, embrace their new healthy options and simultaneously resist new, less healthy products. Changes in behaviour are thus equally as interesting as the values of the diversity indices.

Alternative interventions have been trialled too, including many which lack the potential danger of equally promoting cheap, unhealthy items that supermarkets pose. Hosler and Kammer (2015) review the history of interventions in a New York district, considering the relative effectiveness of each. Farmers markets, despite limited opening hours, increase availability of fresh fruit and vegetables, and they have been found to be effective in the USA (Weatherspoon et al., 2013; Sadler, 2016). This is especially true when combined with financial inducements (Pearson et al., 2014; Gustat et al., 2015). For other suburbs it is financially supporting healthy food within convenience stores which is most beneficial, as Gittelsohn et al. (2009) confirm in a US study, but Adams et al. (2012) support less in Northern England. However these studies also indicate self-selection, particularly with farmers markets which tend to attract affluent customers seeking out fresh fruits and vegetables. To help those who do not purchase fruit and vegetables regularly, convenience and financial incentives are found to be effective (Dimitri et al., 2015). A similar average improvement versus variable distribution effects are thus hinted at along the lines of that shown in supermarkets here.

Households' demand for food is driven by the head of household, money and access to retailers. Aggarwal et al. (2014) note the importance of attitude, while OBrien et al. (2015) reflect on the impressions of access and the lack of familiarity that new options possess. A key tenant of OBrien et al. (2015) is the existence of a battle between the self-motivation

[3]See Dobson and Waterson (2008) and Rudkin (2014) amongst others for verification of the price and variety relationships with smaller stores.

[4]Tesco report having built 40 by 2011 and have continues since, including an opening 12 months ago of a store in central Rotherham, South Yorkshire Tesco (2011).

of food consumption and the need to provide the best for the family; particularly when considering what to buy for children (Wingert et al., 2014; OBrien et al., 2015). However, children like sugary and processed options like breaded chicken or fish fingers, each of which can be seen as unhealthy (Wrigley et al., 2004b; Wingert et al., 2014). Parents must strike a balance, with the presence of children in a household expected to lead to lower HFD values.

From the work of the initial Policy Action Teams in the UK, and similar governmental agencies in the USA, access has been defined by straight line distances of 500 metres and 1 mile respectively[5]. This paper is in a limited set using the Ordnance Survey Integrated Transport Network (ITN) layer to capture the accessibility of the store. Schwanen (2015) presents a broad review of the study of accessibility, noting the benefits that the ITN approach has in replicating the real journeys households make when travelling to shop. Caspi et al. (2012) comment on the importance of walkability, something which Wrigley et al. (2003) had already found was difficult for the new ring-road facing Tesco store[6]. For a number of reasons consumers do not use their nearest store (Gustat et al., 2015; Clary et al., 2017). Here, with a clear intervention store, distance thereto can be seen as important to its new neighbours and those furthest from the outlet alike.

Evaluation of healthfulness was primarily undertaken using fruit and vegetables, with health advice often focused on the "five a day" concept. Even a simple concept such as this had teething problems, only really becoming effective after a couple of years (Capacci and Mazzocchi, 2011), and having had limited effectiveness by failing to account for what else people eat. Ashfield-Watt et al. (2004) presents a review of the effectiveness discussion, a debate that led to overall diversity and later healthy food diversity becoming established yardsticks for health measurement. Diversity indices have been analysed worldwide to support supermarkets (Darmon and Drewnowski, 2008; Liu et al., 2014), although some caution in adopting some measures alone is urged Ruel (2003).

Education has often been reported as holding a critical role in food choice, including in the Seacroft Intervention Study (Wrigley et al., 2002b; Thiele et al., 2004). Hence it is essential to contextualise the discussion within the advice and thinking of the locale in which the data was collected. For this reason the use of the eatwell plate is natural, as the evolution of nutrition education in the UK. Elsewhere studies have made use of their respective relative healthy diversity indexes, such as Drescher et al. (2007) using German values and Volpe et al. (2013) and Bhattacharya et al. (2004) using varying incarnations of the American Healthy Eating Index, allowing diet to be consistently explored.

Guidelines for consumption risk complicating the issue and alienating those that the policy is designed to help. The UK has been developing an index for decades Hunt et al. (1995) arriving eventually at the eatwell plate, with its simple segments and no within segment, direct stipulation of shares. This challenges index construction compared to a measure as prescriptive as the United States measure, or as complex as the pyramid area

[5]Policy Action Teams (PATs) were set up by the incoming Labour government in 1997 to report on various issues in which exclusion problems had been identified. PAT13 was responsible for food deserts, coining a definition of a lack of access to fruit and vegetables within 500m Wrigley et al. (2002a). The United States definition of 1 mile can be found in Widener et al. (2013) and many others.

[6]Focus groups revealed in Wrigley et al. (2004b) that there is a perception that the new store is non-porous for pedestrians with too great a focus on the ring road and those who arrive by car. This confirmed Wrigley et al. (2003) analysis.

measurement of Drescher et al. (2007). Given that Seacroft lacks the nutrition information of the foods consumed it would be difficult to align past data with nutrition values, so we avoid the potential pitfalls of Volpe et al. (2013). Bhattacharya et al. (2004) benefits from having Healthy Eating Index values provided from their American dataset, allowing them to find statistically significant links between poverty and healthfulness. However they do not link diversity of consumption into the story as is done here. What emerges from our consideration is a measure that captures diversity and nutrition, which can be understood, is easily taught to children and adults alike and which most importantly can be constructed with reasonable confidence from historic data like the Seacroft Intervention Study. Further it is an index which builds on the basic diversity specifications of Berry (1971) and Shannon (1948), detailed subsequently, to include a large amount of health influence.

A large number of different measures seek to capture the broader issue of food security, in which dietary diversity nests. Jones et al. (2013) and Leroy et al. (2015) offer wide reaching reviews of the literature which studies food security and the measurements adopted, delineating on the inclusion of quality and range. The proposed index here includes range and references quality through the groupings of the eatwell plate, but there are many measures which extend quality into nutrient measures and capture portion size controls. Neither review concludes that these more accurate measures are necessarily better since they require data of a kind rarely found in live population observations.

Weightings become an issue when constructing indices, whether informed on the micro-nutrient level or broader categorisation as here. Santeramo (2015b) deconstructs the relative robustness of dietary studies to reveal that weightings and normalisation of measures have the least significant influence on results. Provided that processes are explained carefully, then the resultant index will have value for governments, regulators, consumers and retailers alike (Santeramo, 2015a). Since Bhattacharya et al. (2004) and Drescher et al. (2007) the number of categories included in the American Healthy Eating Index has been increased, the scores that were used in constructing the Drescher et al. (2007) weightings have been updated to cover more groupings and offer more detail (Radwan et al., 2015), but following Santeramo (2015b) it is unlikely that the conclusions will change notably.

Here we employ the unconditional quantile regression technique of Fortin et al. (2009) recognising fixed effects using the specification of Borgen et al. (2016). Both are new to the study of food deserts and stem from alternative economic applications. Livesey (2014) is amongst many to identify the benefits of quantile regression for highlighting factors that drive diet across the distribution, particularly at the poorer diet end. By using the unconditional formulation these benefits persist but the distributions of the parameters are no longer dependent on the choice of explanatory variables. Many variables do impact differently across the distribution, and that the new store consistently reduces the probability of dietary quality improving; Wrigley et al. (2003) assertion that there are both direct and indirect positive impacts of the intervention on diet (Page 175) is shown to be premature ahead of the rich depth of detail brought out here.

2 Data and Measurements

This section plays two key roles, first describing the study area to motivate its treatment as a food desert and then explaining the process by which the index values are produced. Both the household food diaries and questionnaires are utilised here and necessarily the latter inform the precise way in which the final figures for healthfulness are derived. Because identically formulated consumption logs are completed before and after the opening of the new supermarket, it is possible to delve into great depth on dietary issues and explore impacts down to deep levels of accuracy. We finally provide summary statistics for the data used in the modelling of later sections.

2.1 Seacroft Intervention Study

A before and after study exploring the impact of a large supermarket in an area of limited retail access, the Seacroft Intervention Study (Wrigley et al., 2004b) offers many insights into potential impact of retail interventions in a food desert. Investigators targeted 1000 households responding to both waves, achieving 1009 to wave one in 2000, but just 615 respondents having completed the 2001 follow-up. There is still a large dataset to analyse (Wrigley et al., 2004a). This survey involved a one week food diary, a series of questions about shopping habits and the collection of a wide range of demographic data. For their involvement respondents were paid in food vouchers, distributed after the survey to avoid influence on results (Wrigley et al., 2003)[7]. After dropping those households with important missing information this paper uses 581 observations, attributable to matching postcode data to the Ordnance Survey ITN layer, missing observations for education and unrecorded smoking status.

Table 1 summarises the Seacroft Intervention Study area as clearly fitting all definitions of food desert, both in lack of access and low income. It comprises two parliamentary wards, Seacroft and Whinmoor wards were in the top quintile of deprivation in the UK, with the Seacroft ward being in the top 4% of deprived wards nationally[8]. Despite a large number of households refusing to provide income details, the computations on the Wrigley et al. (2004a) data highlight a crude average household income of £11,325 in 2000, compared to the Leeds average of £21,500[9]. One motivation for this is the large numbers who are unemployed or retired. Between waves there were 99 households which saw a fall in income category, 104 which saw an increase and 197 which maintained the same; the overall make up was broadly unaltered. High levels of renting, lack of car access and unemployment can also be clearly seen in both waves of the survey. Not reported in the table is that 87% of respondents are female, a statistic that by design does not change between periods.

[7]Wrigley et al. (2002b) provides an introduction to the area, using the full respondent set, while Wrigley et al. (2003) gives fuller details on the two waves of the survey.

[8]Seacroft ward is calculated as having a Townsend (1987) index score of 8.14, and a Carstairs (1995) index score of 7.76. This represents half of the study area, with the remainder coming from a Whinmoor ward which also includes more rural and affluent areas heading out on the York road. Whinmoor has a Townsend (1987) score of 2.44 and still features in the highest quintile of deprivation in the UK. Data from UKDA (2013) is used here.

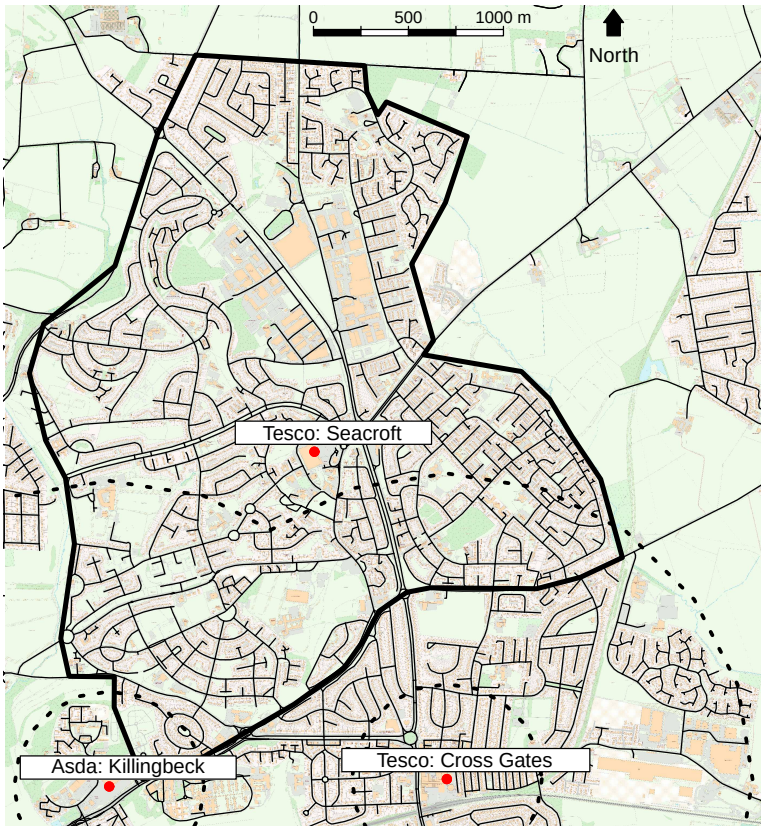
[9]The average per head in Leeds was £10,633 and hence, using the average number of adults per household, that would equate to a household income of £21,691 ONS (2011).

2000	% reporting	Measure	2001	% reporting
		Household annualised income		
91	18.9%	£0 to £4,999	91	18.9%
160	33.3%	£5,000 to £9,999	138	28.7%
85	17.7%	£10,000 to £14,999	88	18.3%
61	12.7%	£15,000 to £19,999	64	13.3%
84	17.5%	Greater than £20,000	79	16.4%
£11325		Average	£11435	
		Respondent employment status		
110	18.9%	Full-time employment	116	20.0%
111	19.1%	Part-time employment	115	19.8%
30	5.2%	Unemployed	26	4.5%
160	27.5%	Retired	163	28.1%
6	1.0%	Full-time education	6	1.0%
151	26.0%	Housewife / Househusband	149	25.6%
246	42.3%	No access to motor vehicle	235	40.4%
77	13.3 %	Household member unemployed	75	12.9%
343	59.0%	Rent home	334	57.5%
1.938		Adults per household	2.024	

Table 1: Summary statistics for Seacroft intervention study area.

Notes: Percentages calculated based on the number of respondents out of the 581 households used in the regressions later who give answers to that question and not the full 581 used in the sample. Based on own calculations on data from Wrigley et al. (2004a).

Figure 1: Seacroft Study Area. ©Crown Copyright and Database Right 2015. Ordnance Survey (Digimap Licence).



Labels denote the large supermarkets that were operating in the study area in 2001, with the Tesco Seacroft store in the centre of the map opening that year. Dashed circles show 500, and 1-mile radii from the two large stores trading in the pre-intervention period. Full road network is depicted with likes, the major roads being the centre bottom to top-left Leeds ring road and the bottom-left to top-right; these two roads coming for a section running south from Tesco Seacroft.

A look at the geography of the area confirms that any definition of food desert would indeed fit Seacroft, the study area indicated by a thick solid black line in the mapping of Figure 1. The extant supermarkets, Asda Killngbeck and Tesco Cross Gates, are located at the foot of the map. Their 500m and 1 mile bands, based on as-the-crow-flies distance, are plotted as thick dashed lines and include just 30% of the respondents. Figure 1 illustrates just how central the new supermarket is, compared to the previous large format locations. All other stores mentioned in the study, such as Tesco Roundhay, are not within the map extent. Smaller stores with limited fresh offerings are not illustrated for clarity. The bisection of the study area by the major road arteries onto which Tesco faces is clear; a proximity which brings opportunities for often more affluent passing trade. This has implications for goods stocked and perceptions of access for local residents, as identified in Wrigley et al. (2004b).

2.2 Constructing Health Indices

A large number of methods have been proposed for analysing diet but the most commonly applied are the Entropy Index (EI) (Shannon, 1948) and the Berry Index (BI) (Berry, 1971). This paper builds on these two with a third index after the Healthy Food Diversity (HFD) measure of Drescher et al. (2007), combining the Berry Index with the health value of each constituent food group. Because items like diet fizzy drinks, squash, hot water, hot drinks and evaporated milk do not offer much in the nutrition these are dropped from the discussion. Consequently a reduced set of items is considered in all indexes in keeping with similar works that use diversity measures.

Following Thiele and Weiss (2003) the two purely diversity measures for the N available foodstuffs are constructed using:

$$BI_{it} = 1 - \sum_{j=1}^{N} s_{ijt}^2 \tag{1}$$

$$EI_{it} = \sum_{j=1}^{N} s_{ijt} log(s_{ijt}) \tag{2}$$

Where s_{ijt} details the share of food j in the diet of household i at time t, $t \in \{pre, post\}$. Following Drescher et al. (2007) the healthy food diversity index, HFD, is constructed as:

$$HFD_{it} = \left(1 - \sum_{j=1}^{N} s_{ijt}^2\right) \frac{1}{\theta} \sum_{j=1}^{N} w_g w_{jk} s_{ijt} \tag{3}$$

Key here is the use of weightings w_g and w_{jk} which provide the weight of group g in the healthy diet, and the relative weight of food j in group k. Our grouping uses the UK Eatwell Plate (Public Health England, 2014) and is exposited fully as part of a detailed exposition of the index construction in Appendix **??**. θ is a scaling parameter to ensure that the range remains from 0 to 1, and is calculated as the maximum possible value that the final summation term can take; in this paper $\theta = 0.0375$. Table 2 gives summaries of the Eatwell Plate recommended proportions, used as w_g and the actual observed proportions for the five groups.

Table 2 highlights again how poor the diet of the respondents is relative to national guidelines, both in terms of low fruit and vegetable consumption and in the large proportion of diet coming from the High Fat/High Sugar grouping. Although improvements are seen between the two waves there is still a big gap between what the average household is doing and the suggested intakes. This paper represents the first exploration of these figures at the average and distributional levels.

Prior to undertaking any statistical analysis of the indices it is necessary to perform a log transformation of each to permit the use of normal distribution assumptions. For the pre-intervention Berry Index the process has:

$$TBI_{pre} = log(\frac{BI_{pre}}{1 - BI_{pre}}) \tag{4}$$

Table 2: Food groupings for healthy food diversity index

Group	Target (w_g)	Pre-intervention	Post-intervention
Bread, Rice, Pasta and Potatoes	33%	12.5%	20.8%
Milk and Dairy	15%	13.0%	15.6%
High Fat / High Sugar	8%	47.1%	34.5%
Meat, Fish, Eggs, Beans	12%	7.8%	8.2%
Fruit and Vegetables	33%	19.6%	20.6%

Notes: Pre-intervention and Post-intervention calculated as the consumption propotion for each household averaged over the 581 respondents.

For each index and at each time the process is identical. In all that follows, the transformed versions of the index are used. This transformation ensures that anything which increases the transformed index will also increase the actual index and so, for policy implication clarity, we refer to factors increasing the index when discussing results in the coming sections.

2.3 Summary Statistics

Immediately obvious from the table are slight reductions in the average transformed diversity indices, though these differentials are small. For the newly constructed HFD index there is an improvement but the minimum value can be seen to fall. Within these average changes there are larger movements, as the following sections exposit. High levels of deprivation and the prevalence of smoking are evidenced, with less than 17% of respondents having post-16 education and around a quarter of households headed by an under-35. Major influences within the set include having a balanced diet, the foods respondents like and promotions. There are also potential impacts from other family members, either the foods they like or their presence on the shopping trip, and the regressions that follow also reflect this. A key absentee variable is the household income, which is noted to be missing for too many data points, but the influence of cost and budget does come through for most households.

3 Modelling

Table 3 provides summary statistics for the 581 housheols included in our final sample, being those from the 615 who completed the second wave of the survey for whom all required information was available. We employ the unconditional quantile regression (UQR) specification of Fortin et al. (2009) estimated with each of the three transformed indices being a dependent variable for consideration. This enables the estimation of the impacts of explanatory variables across the distribution of interest in much the same way as the original quantile regression specification of Koenker and Bassett Jr (1978). UQR maintains the advatanges of QR but critically benefits from the distributions of estimated parameters being independent of the choice of explanatory variables. To achieve this a recentered influence function, $R(Y, q_\tau, F_Y)$ which is based solely on the dependent variable Y via its distribution F_Y.

Table 3: Variables used in regression analysis

Name	Mean	Standard deviation	Min	Max
Transformed Dietary Indices:				
Pre-intervention Berry index, TBI_{pre}	2.649	0.416	0.950	3.767
Post-intervention Berry index, TBI_{post}	2.619	0.403	0.924	4.030
Pre-intervention entropy index, TEI_{pre}	0.997	0.378	-0.714	2.551
Post-intervention entropy index, TEI_{post}	0.995	0.379	-0.445	4.145
Pre-intervention healthy food diversity index, $THFD_{pre}$	-0.023	0.356	-1.300	0.792
Post-intervention healthy food diversity index, $THFD_{post}$	0.004	0.337	-1.383	0.807
Shopping Distance:				
Distance to Seacroft (km), $DTSK$	1.585	0.529	0.312	2.949
Deprivation controls (1 = Is deprived):				
No access to motor vehicle	0.404	0.491	0	1
Unemployed	0.129	0.336	0	1
Rent	0.575	0.423	0	1
Single parent family	0.103	0.305	0	1
Lifestyle variables (1 = Has characterisitic):				
Regular smoker	0.448	0.498	0	1
Child in household	0.392	0.489	0	1
GCSE or Above	0.172	0.378	0	1
Aged 17-34	0.231	0.423	0	1
Shop choices for main weekly food shopping:				
Main shop: Tesco Seacroft	0.449	0.498	0	1
Main shop: Asda Killingbeck	0.327	0.470	0	1
Factors influencing purchasing decisions of households (1 = Does influence):				
Cost or budget	0.728	0.445	0	1
Health advice	0.162	0.369	0	1
Foods spouse eats	0.477	0.500	0	1
Foods children eat	0.446	0.497	0	1
Balanced diet	0.534	0.499	0	1
Foods liked	0.635	0.482	0	1
Convenience	0.375	0.485	0	1
Spouse present	0.182	0.387	0	1
Child present	0.172	0.378	0	1
Hunger	0.275	0.447	0	1
Promotions	0.640	0.480	0	1
Personal beliefs	0.040	0.195	0	1

Notes: This table reports the log transformation exemplified in (4).Summary statistics generated using own calculations on Wrigley et al. (2004a)

$$R(Y, q_\tau, F_Y) = q_\tau + \frac{\tau - I(y \leq q_\tau)}{f_y(q_\tau)} \tag{5}$$

Here q_τ is the observed value of the τ^th quantile of Y, $I(y \leq q_\tau)$ is an indicator function that takes the value 1 whenever the observed value of the dependent variable is less than the τ^{th} quantile of that dependent variable. f_Y is the marginal distribution of index Y. At the second stage these RIF values are used as dependent variables of a regression to determine the effect of the independent variables. Although custom is to use OLS for its simplicity the framework has the flexibility to permit many other econometric estimation techniques to better fit the application.

Motivated by the lack of income data and similarity of the postcode sectors found in the previous section paper adopts a fixed effects specification after Borgen et al. (2016). Default in the code provided by Borgen et al. (2016) is to use cluster robust standard errors, but these can not be supported by the testing methodologies open to us and hence only standard robust errors are used. For the tests of parameter equality we employ seemingly unrelated regressions based on the same independent variables but different Y. Our strategy sees the production of five $R()$ functions, at $\tau = 0.2$, $\tau = 0.4$, $\tau = 0.5$,$\tau = 0.6$,$\tau = 0.8$. Moving further into the tails than 0.2 generates much more erratic behaviour and so we stay further out in the reporting that follows. However, $\tau \in [0.1, 0.9]$ remains the range used for the graphical analysis.

4 Results

Diversity and healthfulness represent the major themes of this paper, each being a major part of the policy debate that is as yet unstudied for the Seacroft data. Diversity is captured through the Berry and Entropy indices, whilst healthfulness is measured using our proposed new HFD index. Tables 5 and 4 provide estimates on density and healthfulness resepctively. Both tables report the coefficients from the fixed effects OLS estimation and the UQR results; in each case we report five quantiles and a test for parameter equality across the reported quantiles. Because of the importance of recognising the effects that are present in this important dataset a significance level of 10% is used; the majority of the food deserts literature does likewise.

Our primary focus is on the role that the new Tesco Seacroft superstore plays in shaping behaviour. Table 5 reveals a very limited role but that in all cases the impact of using the larger outlet is to increase the diversity of intake. For the Entropy index there is a significant effect at both the 20th and 40th percentiles but this does not translate into the OLS meaning that it is a role that could be missed by simpler policy evaluation methods. When we introduce the consideration of healthyness in Table 4 the benefits of this diversity are not diet improving but in fact there is a reduction across the distribution of healthfulness. There is some suggestion that the new store places a constraint on shoppers who would have liked a healthier diet as there was no reduction in overall diversity but the new measure accounting for health does fall.

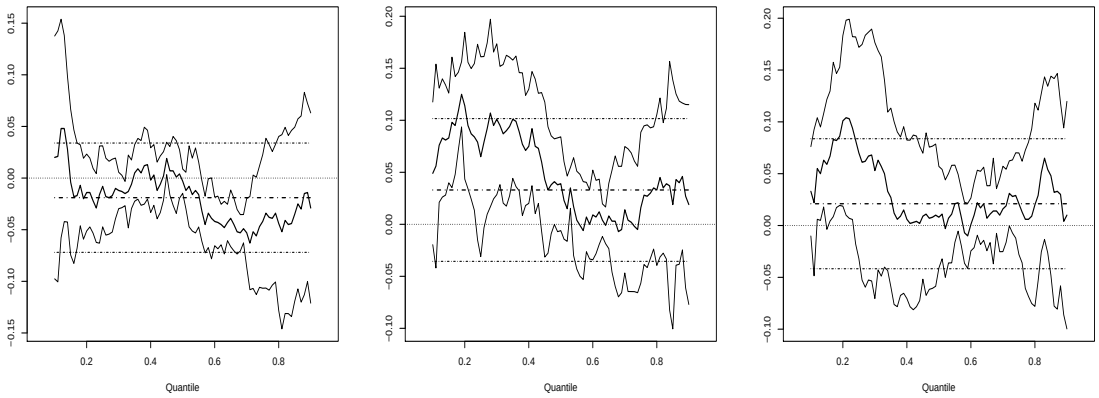
Table 4: Unconditional Quantile Regression Estimates for Transformed Healthy Food Diversity Index

Variable	OLS	$\tau = 0.2$	$\tau = 0.4$	$\tau = 0.5$	$\tau = 0.6$	$\tau = 0.8$	Equal?
Pre-intervention value ($THFD_{pre}$)	0.036	0.038	0.018	0.054	0.021	0.022	1.581
	(0.038)	(0.030)	(0.070)	(0.060)	(0.062)	(0.050)	
Distance to Tesco (km)	-0.005	-0.035*	0.035	0.003	-0.026	-0.041*	27.45***
	(0.026)	(0.011)	(0.025)	(0.011)	(0.012)	(0.015)	
Tesco Seacroft shopper	-0.019	-0.014	-0.002	-0.003	-0.042**	-0.044	16.68***
	(0.027)	(0.019)	(0.016)	(0.006)	(0.012)	(0.043)	
No car access	-0.057*	-0.015	-0.051	-0.054	-0.077	-0.081	2.442
	(0.030)	(0.079)	(0.056)	(0.064)	(0.068)	(0.065)	
Unemployed	-0.088**	-0.131**	-0.079*	-0.126***	-0.099***	-0.103***	3.114
	(0.040)	(0.030)	(0.028)	(0.006)	(0.014)	(0.017)	
Rent home	-0.047	-0.073	-0.028	-0.034	-0.033	-0.018	1.317
	(0.031)	(0.062)	(0.057)	(0.028)	(0.039)	(0.037)	
Children in household	-0.064*	-0.113	-0.034	-0.051	-0.040	-0.082*	6.664*
	(0.037)	(0.074)	(0.048)	(0.038)	(0.039)	(0.031)	
Smoker	-0.040	-0.014	-0.073*	-0.085*	-0.032	-0.019	5.016
	(0.028)	(0.041)	(0.029)	(0.030)	(0.053)	(0.017)	
Post-16 education	-0.021	-0.032	-0.046	-0.063	-0.057	-0.020	5.273
	(0.036)	(0.047)	(0.040)	(0.066)	(0.086)	(0.043)	
Aged 17-34 years	-0.098***	-0.188**	-0.094	-0.069*	-0.055	0.000	39.09***
	(0.035)	(0.054)	(0.045)	(0.026)	(0.048)	(0.016)	
Single-parent family	0.009	0.033	-0.009	0.000	-0.026	-0.063	3.485
	(0.050)	(0.071)	(0.078)	(0.060)	(0.058)	(0.028)	
Cost/budget	-0.011	-0.006	-0.029	0.021	0.015	-0.017	32.28***
	(0.030)	(0.069)	(0.046)	(0.030)	(0.016)	(0.025)	
Health advice	-0.001	-0.060	0.032	0.047	0.047	0.050	3.916
	(0.037)	(0.034)	(0.058)	(0.046)	(0.056)	(0.058)	
Child's tastes	-0.023	-0.002	-0.038	-0.060	-0.079**	-0.046**	1.051
	(0.030)	(0.061)	(0.029)	(0.026)	(0.023)	(0.010)	
Spouse's tastes	-0.019	0.033	-0.010	0.037	-0.013	0.003	5.001
	(0.038)	(0.058)	(0.040)	(0.037)	(0.057)	(0.070)	
Balanced diet	0.174***	0.221***	0.175***	0.188**	0.178**	0.161**	17.53***
	(0.028)	(0.016)	(0.026)	(0.035)	(0.036)	(0.049)	
Foods liked	-0.098***	-0.079**	-0.083**	-0.099**	-0.136***	-0.073*	67.18***
	(0.028)	(0.019)	(0.025)	(0.024)	(0.020)	(0.031)	
Convenience	-0.066**	-0.077	-0.057	-0.077	-0.106*	-0.088	3.764
	(0.028)	(0.038)	(0.049)	(0.037)	(0.037)	(0.042)	
Child on trip	0.006	0.022	0.057	0.084	0.021*	-0.064	6.222
	(0.037)	(0.069)	(0.052)	(0.036)	(0.008)	(0.075)	
Spouse on trip	0.048	0.064	0.036	-0.026	0.039	-0.016	5.613
	(0.041)	(0.043)	(0.045)	(0.016)	(0.030)	(0.059)	
Hunger	0.004	-0.011	-0.052	-0.019	0.019	0.014	383.8***
	(0.030)	(0.076)	(0.052)	(0.045)	(0.044)	(0.028)	
Promotions	-0.008	-0.072	-0.092	-0.040	-0.005	0.001	77.24***
	(0.029)	(0.085)	(0.054)	(0.031)	(0.041)	(0.033)	
Personal beliefs	0.015	0.012	0.117	-0.001	-0.023	-0.004	0.530
	(0.067)	(0.159)	(0.089)	(0.084)	(0.051)	(0.066)	
Constant	0.166**	-0.049	0.089***	0.167***	0.333***	0.524***	
	(0.065)	(0.034)	(0.013)	(0.018)	(0.030)	(0.081)	
Observations	581	581	581	581	581	581	
R-squared	0.200	0.117	0.141	0.161	0.147	0.115	

Notes: *OLS* provides coefficients for Ordinary Least Squares regression with robust standard errors. τ denotes the regression quantile at which the unconditional model is estimated. UQR models fitted with cluster robust standard errors at the postcode sector level. Equal? reports a chi-squared test of parameter equality across the five estimated quantiles. Significance denoted by $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Figure 2: Impact of Tesco Seacroft on Dietary Diversity

(a) $THFD$ Index (b) TBI Index (c) TEI Index



Notes: Graphs are plotted using the outcomes of the unconditional quantile regressions for τ between 0.1 and 0.9 at intervals of 0.01. Solid lines indicate unconditional quantile regression results and horizontal dot-dash lines denote linear regressions. Coefficients are plotted as thick lines. Confidence intervals are plotted with thinner lines and are constructed at the 95% level to show significance of estimates.

Table 5: Unconditional Quantile Regression Estimates for Transformed Div

Variable	Transformed Berry index							Transformed Entropy index		
	OLS	$\tau = 0.2$	$\tau = 0.4$	$\tau = 0.5$	$\tau = 0.6$	$\tau = 0.8$	Equal?	OLS	$\tau = 0.2$	$\tau = 0$
Pre-intervention value	0.042	0.012	0.013	-0.010	0.009	0.033	0.24	0.072	0.015	-0.01
	(0.042)	(0.024)	(0.073)	(0.060)	(0.052)	(0.058)		(0.044)	(0.082)	(0.038
Distance to Tesco (km)	0.013	0.041	0.041	0.026	0.014	-0.046	24.90***	0.016	0.035	-0.00
	(0.034)	(0.069)	(0.027)	(0.012)	(0.015)	(0.052)		(0.032)	(0.044)	(0.045
Tesco Seacroft shopper	0.033	0.114*	0.075*	0.039	0.009	0.033	8.225**	0.021	0.101*	0.006
	(0.035)	(0.036)	(0.028)	(0.023)	(0.022)	(0.037)		(0.032)	(0.042)	(0.039
No car access	-0.014	-0.027	0.015	0.037	0.007	-0.068	12.84***	-0.031	-0.023	0.021
	(0.038)	(0.145)	(0.085)	(0.065)	(0.027)	(0.038)		(0.036)	(0.070)	(0.071
Unemployed	-0.055	-0.117	-0.115	-0.055	-0.066	0.037	11.53***	-0.027	-0.119	-0.10
	(0.052)	(0.111)	(0.116)	(0.086)	(0.055)	(0.056)		(0.049)	(0.099)	(0.103
Rent	-0.013	-0.008	-0.050	-0.022	0.004	-0.049	1.838	-0.017	-0.025	-0.02
	(0.040)	(0.075)	(0.115)	(0.109)	(0.086)	(0.065)		(0.037)	(0.060)	(0.053
Child in household	-0.037	-0.036	-0.057	-0.050	-0.032	-0.062	0.988	0.010	-0.026	-0.02
	(0.048)	(0.153)	(0.091)	(0.111)	(0.061)	(0.081)		(0.045)	(0.076)	(0.083
Smoker	-0.123***	-0.176*	-0.183**	-0.156***	-0.114***	-0.115**	2.456	-0.086**	-0.097***	-0.116
	(0.035)	(0.073)	(0.043)	(0.011)	(0.009)	(0.024)		(0.033)	(0.007)	(0.031
Post-16	-0.038	-0.070	-0.003	-0.020	-0.017	-0.094	12.49***	-0.033	0.008	-0.01
	(0.046)	(0.053)	(0.026)	(0.034)	(0.046)	(0.062)		(0.043)	(0.022)	(0.029
Aged 17-34	-0.017	-0.017	0.010	0.013	-0.044	-0.026	3.722	-0.087**	-0.111*	-0.09
	(0.045)	(0.081)	(0.058)	(0.063)	(0.051)	(0.081)		(0.042)	(0.042)	(0.055
Single-parent family	-0.063	-0.085	-0.045	0.001	0.018	-0.014	2.500	-0.029	-0.066	0.027
	(0.064)	(0.053)	(0.085)	(0.041)	(0.083)	(0.076)		(0.060)	(0.042)	(0.073
Factors influencing foods purchased:										
Cost/budget	-0.003	-0.025	-0.043	0.018	-0.022	-0.007	860.7***	0.038	0.006	0.021
	(0.039)	(0.026)	(0.034)	(0.043)	(0.039)	(0.039)		(0.036)	(0.029)	(0.033
Health advice	0.005	-0.024	-0.036	-0.019	0.039	0.023	57.14***	-0.027	-0.058	-0.086
	(0.048)	(0.053)	(0.020)	(0.059)	(0.019)	(0.033)		(0.045)	(0.073)	(0.031
Foods children eat	0.016	0.061	0.036	0.059	0.009	-0.046	13.32***	-0.001	0.005	0.058
	(0.038)	(0.127)	(0.026)	(0.042)	(0.035)	(0.051)		(0.036)	(0.037)	(0.025
Foods spouse eats	-0.018	-0.107	-0.015	0.031	0.009	0.077	15.01***	-0.023	-0.021	-0.03
	(0.048)	(0.055)	(0.054)	(0.066)	(0.038)	(0.077)		(0.045)	(0.083)	(0.057
Balanced diet	0.048	-0.062	0.058	0.080	0.049	0.057	47.79***	0.087***	-0.000	0.049
	(0.035)	(0.099)	(0.079)	(0.047)	(0.043)	(0.048)		(0.033)	(0.043)	(0.055
Foods liked	0.044	0.044	0.011	0.032	0.059	0.081	18.71***	0.050	0.011	0.067
	(0.036)	(0.031)	(0.053)	(0.034)	(0.033)	(0.049)		(0.034)	(0.044)	(0.044
Convenience	0.022	0.037	0.022	-0.004	0.011	0.022	14.59***	0.003	-0.028	-0.02
	(0.036)	(0.044)	(0.027)	(0.039)	(0.051)	(0.046)		(0.033)	(0.039)	(0.028
Child present	0.016	-0.013	-0.057	0.039	0.008	0.110**	26.92***	0.024	0.028	0.040
	(0.048)	(0.062)	(0.030)	(0.049)	(0.047)	(0.031)		(0.045)	(0.048)	(0.044
Spouse present	0.098*	0.216	0.107**	0.063	0.082	0.008	4.882	0.074	0.128*	0.07
	(0.053)	(0.176)	(0.030)	(0.036)	(0.051)	(0.055)		(0.050)	(0.044)	(0.079
Hunger	0.077**	0.089	0.086*	0.053	0.064	0.062	265.3***	0.084**	0.047	0.095
	(0.039)	(0.072)	(0.034)	(0.040)	(0.066)	(0.099)		(0.036)	(0.037)	(0.030
Promotions	0.014	0.051	0.064	0.041	0.040	0.007	1.161	0.017	0.073	0.042
	(0.037)	(0.043)	(0.038)	(0.039)	(0.018)	(0.074)		(0.035)	(0.049)	(0.053
Personal beliefs	0.098	0.130*	0.094*	0.118	0.045	0.038	4.250	0.104	-0.023	0.079
	(0.086)	(0.049)	(0.031)	(0.051)	(0.060)	(0.124)		(0.080)	(0.095)	(0.093
Constant	2.466***	2.217***	2.455***	2.529***	2.654***	2.942***		0.830***	0.632**	0.876*
	(0.139)	(0.164)	(0.232)	(0.156)	(0.142)	(0.220)		(0.090)	(0.109)	(0.117
Observations	581	581	581	581	581	581		581	581	581
R-squared	0.081	0.073	0.078	0.059	0.042	0.057		0.091	0.084	0.084

Notes: *OLS* provides coefficients for Ordinary Least Squares regression with robust standard errors. τ denot
unconditional model is estimated. UQR models fitted with cluster robust standard errors at the postcode se
test that all parameters for the given variable are equal across the five estimated quantiles. Significance denote

To show the impact of Tesco Seacroft more clearly we use the full set of estimates to plot graphs of the UQR coefficients against the OLS counterparts. Figure 2 includes three plots, with the new HFD measure on the left, the Berry index in the middle and the Entropy index on the right. Upon first inspection the larger effect on the two traditional measures is clear, as are comparatively higher values at the lower end of the distribution. All three OLS coefficients are insignificant, as evidenced by the confidence intervals featuring the zero line, but as can also be seen there are many instances where the UQR confidence interval does not contain zero, diversity increases under the Berry index in panel (b) and healthy food diversity reductions just above the median in panel (a).

It is shown that Tesco increases the range of products consumed by household heads amongst those who consume the least, but from the left hand panel the insignificance of the health change is striking. Indeed of those who use the supermarket the significant effects come further up the range. Our argument that supermarket improvements to diversity should not be assumed to be improvements to diet simultaneously is well evidenced here. For policymakers considering intervention stores the primary results come from the left panel, and the negative coefficients are notable. There is a large range above the median where Tesco has a reducing effect and whilst this is not for those with the worst diets, it will still be concerning in an area where the diet was on average poor compared to the Eatwell Plate[10]. These results confirm the concerns of Cummins et al. (2005) applied to Seacroft empirically for the first time.

Inability to accurately measure income, or prices, means that the constant terms are highly significant in all of the regressions. However, our interest is in what can be captured by the available dataset, and as evidenced in Tables 5 and 4 there are many significant coefficients to analyse. Pre-intervention values are not significant in the way that might have been expected, this indicates that households do vary their diet from year to year. Only in the Entropy index is the difference across quantiles significant with higher coefficients in the upper quantiles pointing to a greater taste for variety leading to greater variety in the future.

Food deserts are defined on accessibility and deprivation (Wright et al., 2016). Distance to the new Tesco store has significant negative impacts on the HFD at both $\tau = 0.2$ and $\tau = 0.8$ but is insignificant otherwise. Accessibility is important to these households but alternative stores, and other shop characteristics appear to dominate within the study. Of the three measures of deprivation included in the study the lack of access to a motor vehicle is the one which fits both elements of the definition, but only in the OLS model for HFD is any significance seen. Unemployment of the head of household by contrast effects disposable income, and is shown to significantly reduce HFD at all quantiles and in the OLS. Figure **??** presents the full set of unemployment coefficients across the full range from $\tau = 0.1$ to $\tau = 0.9$. Suggested here is that prices are lower on less healthy good, meaning that diversity can be achieved with lower income provided deviations from the Eatwell Plate are larger. Our observations on unemployment echo the fruit and vegetable effect identified in Wrigley et al. (2003). Home ownership has no notable impact on any measure. Bringing the prices that prevent diversity falling with unemployment into healthier goods emerges as the natural suggestion for policy. Farmers markets have been used on accessibility and price Dimitri et al. (2015) and lessons from their effectiveness, such as vouchers to lower consumer

[10]See Table **??** for the aggregate comparison

prices, can translate.

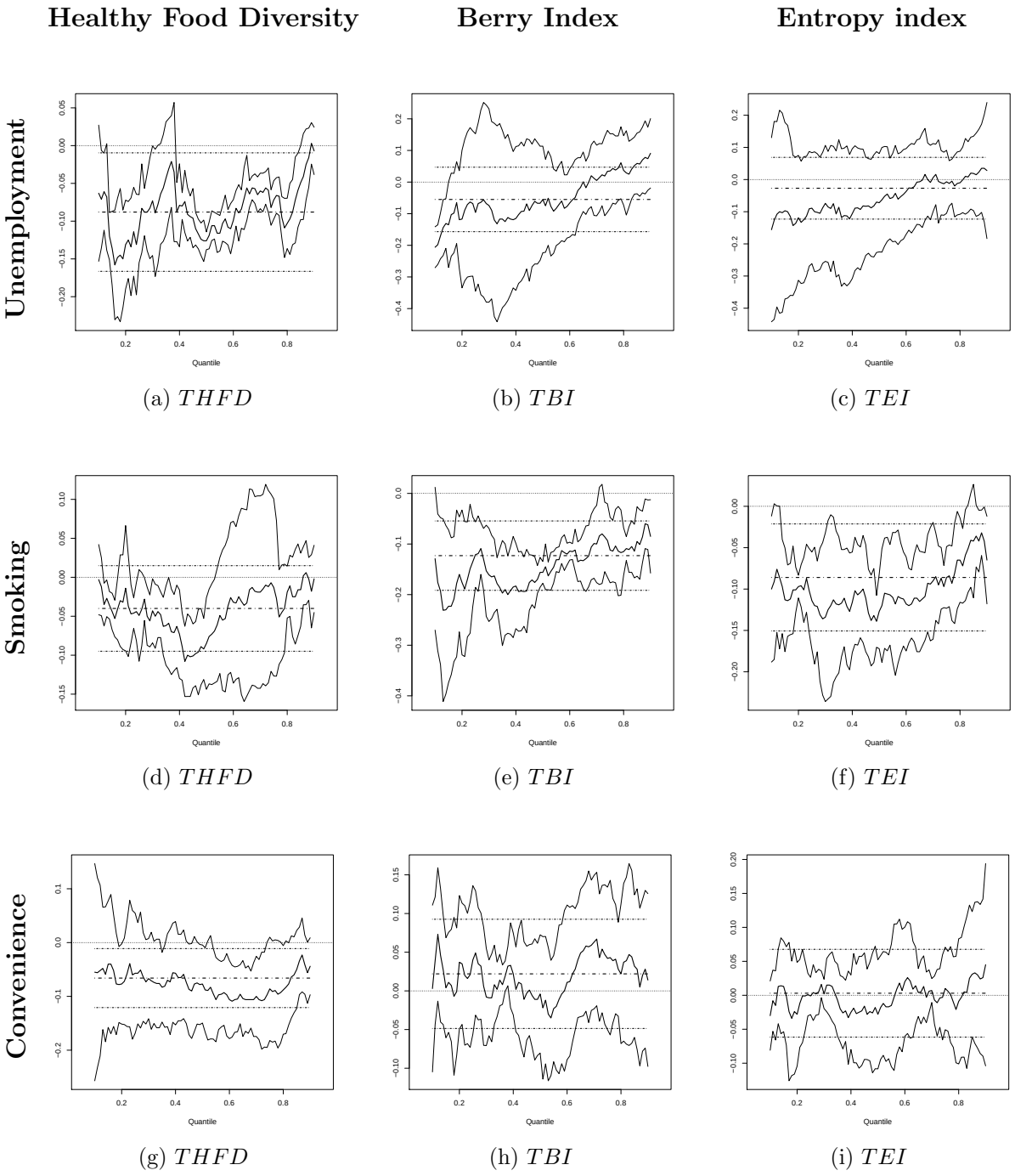
Smoking was highlighted by Wrigley et al. (2003) as being a major impediment to improved fruit and vegetable consumption. Tables 5 and 4 confirm this extends to diversity and HFD respectively. This effect is noted to be stronger at the lower quantiles, as Figure **??** panels (d) to (f) attest. Wingert et al. (2014) and OBrien et al. (2015) identify children's eating habits as exerting negative influences on that of parents and the OLS regression for HFD confirms this aggregate conclusion for Seacroft. Children's tastes influencing shopping decisions increases diversity but reduces healthfulness as would be predicted, whilst the presence of Children on the trip only heightens this pester-power result. No significant effects of education are found, and unlike the work on fruit and vegetables, no influence from health advice is seen either; this supports Ashfield-Watt et al. (2004) and Capacci and Mazzocchi (2011) observations that sometimes only simple messages like the "five a day "work. We also see no significant effect from single parent families.

Cost/budget is the closets proxy to price but does not have notable influence on our dietary measures and nor does the related promotions influence. Further investigation would be needed to identify whether promotions were ineffective or if they were actually neutralising other price differentials. Like the influence of children's tastes the foods liked by the spouse or partner of the respondent, or the presence of that person on the shopping trip, increase variety. However, unlike the influence of children, there is also a positive impact on the THFD. Being hungry encourages respondents to try new things, but has no significance on the healthfulness of what is purchased. Personal beliefs encourage some of those with low variety to increase their Berry index, but again there is no health effect. Convenience is a critical part of modern shopping, and in the Seacroft Intervention Study we see that being influenced by what is readily accessible has no impact on variety purchased but does reduce the healthfulness of diet. In panels (g) to (i) of Figure **??** we can see the relative consistency between the OLS and UQR models. On this measure accessibility returns for evaluation; making healthy foods convenient is an important task.

Extending to the full set of food diary data yields important additional insights and offers a strong reinforcement to the messages coming out of the fruit and vegetable analysis. Across the three models there are two consistent messages. Firstly the fit of the model is high for a quantile framework, particularly in the healthy food diversity case. Secondly, there are significant differentials across the five estimated quantiles for the majority of variables. In the diversity case there are 15 which show variation in the Berry index and 14 for the Entropy index, whilst for the healthy food diversity index 9 show differences. As well as the key Tesco shopper dummy diversity in attitudes to having a balanced diet and the wide range of foodstuffs that respondents like also show as significantly different in all three indices. Our results reaffirm the benefits of quantile regression and direct policy toward those covariates which can improve diet amongst the least healthful.

5 Summary

Supermarket interventions remain a cornerstone of urban planning and governmental policy to improve diet. Appraisal of their success has focused on fruit and vegetables and has been predominantly interested in mean effects. However, contemporary econometric techniques



(a) $THFD$ (b) TBI (c) TEI

(d) $THFD$ (e) TBI (f) TEI

(g) $THFD$ (h) TBI (i) TEI

Figure 3: Further analysis of key policy variables

Notes: Graphs are plotted using the outcomes of the unconditional quantile regressions for τ between 0.1 and 0.9 at intervals of 0.01. Solid lines indicate unconditional quantile regression results and horizontal dot-dash lines denote linear regressions. Coefficients are plotted as thick lines. Confidence intervals are plotted with thinner lines and are constructed at the 95% level to show significance of estimates.

allow issues of health and diversity to be revisited and valuable new insights to emerge. This study is the first to apply unconditional quantile regression, and most importantly, is able to apply such to a full diary of consumption data for the first time. Interventions do improve diversity, particularly amongst households that previously saw their choices constrained, but when weightings for healthfulness are applied these positives disappear. Constructing a unique measure based on the UK eatwell plate recommendations we show that for some households using the new store reduces healthfulness despite increased variety. In all cases simple linear models show no significant effect of the new store, highlighting once more the importance of considering quantiles. We also highlight a stronger negative effect from unemployment, smoking status and the influence of convenience, is felt compared to the OLS regressions used elsewhere; further importance is attached to considering policy beyond the mean. Improved education on diet, promotion of healthier lifestyles and providing more convenient healthy food options are thus seen as better policy suggestions than simply opening intervention stores.

It is now more than 15 years since the Seacroft Study took place and the growth of alternative food retail mechanisms, such as farmers markets, have started to change the landscape of the sector. However, whilst it is valuable to investigate new means of healthy food access, it remains important to quantify the effects of supermarkets for those who do not have easy access to new mechanisms. Understanding more from one of the only two wave studies of store opening remains critical, and distributional regressions are a major part of that story for their continuing ability to uncover effects that studies of the average would miss. Likewise development of more meaningful measures of diet will ensure that the models are capturing the targeted variables. Through this process it can be ensured that some of the mistakes that have been made in the mass roll-out of superstores in food deserts are not replicated. An increasing number of alternatives have been posited, such as the farmers markets and convenienece store interventions, and the processes applied here can be applied well in their study. Discovering the most effective retail mix is a key task for food policy and urban planning research. From Seacroft the message is clear; supermarkets increase diversity but the healthfulness need not necessarily follow. Policy-makers and planners must pay attention to distributional impacts and think carefully to ensure that it is indeed those with the least healthy diets that are benefiting.

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A Measures of Diet

In the main paper there are three measures of dietary diversity used. The Berry Index after Berry (1971) and the Entropy Index after Shannon (1948) are primarily measures of the range of foods consumed and do not capture health. A third measure, developed within this appendix, and forwarded in the main paper, considers the health value of the foods being consumed and has its roots in the work of Drescher et al. (2007). This appendix talks through the construction of the three indices, their value and provides summary statistics to help the reader understand more about the relationships between them.

Construction of the basic indices follows Thiele and Weiss (2003) starting by evaluating the share of each food within the total intake of the household at time t, $t = (pre, post)$:

$$s_{ijt} = \frac{q_{ijt}}{\sum_{j=1}^{N} q_{ijt}} \tag{6}$$

Where q_{ijt} is the number of consumption incidences of food type i consumed by consumer j. Although portion size information is not available within the full dataset, this subset approach is still highly valuable as it does reflect the primary shopper's belief about what constitutes a portion. These shares also feature strongly in the new index as well.

Using the shares from (1) the two basic indices, Berry Index BI_{it} and Entropy Index EI_{it}, are arrived at via the following formulae:

$$BI_{it} = 1 - \sum_{j=1}^{N} {s_{ijt}}^2 \tag{7}$$

$$EI_{it} = \sum_{j=1}^{N} [s_{ijt} log\,(s_{ijt})] \tag{8}$$

Whilst these two measures are widely studied they do not say a great deal about the healthfulness of the food being consumed. For this we turn to the work of Drescher et al. (2007) and make use of weightings from the UK eatwell plate to fit the data. Table 1 details the constituent parts of the eatwell plate, the food groupings in the Seacroft Intervention Study that appear under each heading and the actual proportions of consumption that come from each group

It is very apparent that a large proportion of the foods in the diary belong in the least healthy of the five categories and that, as a result, the proportion of diet in that group far outweighs the level it should. However there are increases in the healthier groups with a compensating large drop in the high fat group but the differences between actual levels and targets remain marked post-intervention. By no means is Seacroft alone in that regard but it is indicative of the level of concern that measures like that which follows illuminate.

Drescher et al. (2007) propose a Healthy Food Diversity (HFD) index which is based on the healthfulness of each individual food item within a group, and the weighting that each group has within the overall recommended diet. Here the Eat Well proportions provide the latter, and are denoted by w_g for group g. Because the diary did not provide detailed nutritional breakdowns it is not possible to replicate the level of detail in Drescher et al.

Group	Constituents [a]	Target	Pre [b]	Post[c]
Bread, Rice, Potatoes, Pasta	Museli, Cereal, Brown Bread, White Bread, Boiled Potatoes, Roast Potatoes, Rice, Pasta, Crackers	33%	12.5%	20.8%
Milk and Dairy	Full Fat Milk*, Skimmed Milk, Low Fat Yoghurt, Full Fat Yoghurt*	15%	13.0%	15.6%
High Fat / High Sugar	Ready Meals, Pizza, Processed Poultry, Processed Meat, Processed Fish, Battered Fish, Meat Pies, Vegetable Pastries, Fizzy Drinks, Beer, Wine, Lard, Oil, Take Away, Low Fat Margerine, Normal Margerine, Cream, Fruit Pudding, Other Puddings, Packet Mix Puddings, Cakes, Sweet Biscuits, Chocolate Biscuits, Other Sweets, Crisps, Ice Cream, Chips.	8%	47.1%	34.5%
Meat, Fish, Eggs, Beans	Eggs, Poultry, Meat, Other Fish, Soup, Baked Beans	12%	7.8%	8.2%
Fruit and Vegetables	Real Fruit Juice, Apples, Oranges, Bananas, Peaches, Other Fruits, Dried Fruits, Carrots, Peas, Broccoli, Tomatoes, Salads, Processed Vegetables, Other Vegetables	33%	19.6%	20.6%

[a] An * indicates that the food is the unhealthy option of a pair but remains outside the High Fat / High Sugar group in the Eat Well Plate.

[b] Pre-Intervention consumption proportions averaged across all households

[c] Post-Intervention consumption proportions averaged across all households

Table A1: UK eatwell plate food groupings and headings from the Seacroft Intervention Study food diaries

	Pre-Intervention				Post-Intervention			
	Mean	s.d.	Min	Max	Mean	s.d.	Min	Max
BI_t	0.929	0.031	0.721	0.977	0.927	0.030	0.716	0.983
EI_t	0.724	0.073	0.329	0.928	0.724	0.071	0.391	0.984
HFD_t	0.495	0.086	0.214	0.688	0.501	0.082	0.201	0.692

Table A2: Summary statistics for dietary diversity indicators

(2007) and so each constituent part is afforded an equal proportion of the total. A notable exception is provided by those foods which are within a group but are the less healthy alternative of a pair, such as low fat yoghurt and full fat yoghurt, in which the least healthy has its factor halved relative to the healthy one. This is following the interpretation of the plate provided by Pearson and Grace (2012) and can be equally rationalised when thinking of the comparison between semi-skimmed and full fat milk. Health factors are thus $\frac{1}{n_g}$ for a group of n_g food types, with the exception of those which are the unhealthy option. In those cases the values are recalculated to maintain the total of one for the whole group.

Construction of the new healthfulness index follows using:

$$hv = \frac{1}{0.0375} \sum_{j=1}^{N} w_g w_{jk} s_{ijt} \tag{9}$$

$$HFD_{it} = (1 - \sum_{j=1}^{N} {s_{ijt}}^2) hv \tag{10}$$

Health values, hv, are calculated as the sum of the products of the within group weightings, the group weight and the share of each individual food consumed by the household. Because the maximum value this can achieve is only 0.0375 the value is then normalised by division to obtain a range between 0 and 1. It is still desirable to reflect the diversity of consumption and hence the newly constructed health value is multiplied by the Berry index to obtain the healthy food diversity index for household j as is done in Drescher et al. (2007). Table 2 summarises the values of the indices. From this point forward all i subscripts are removed for clarity of exposition.

As there is very little difference between the means on any of the index values one is tempted to conclude that there are no changes, and that analysis should focus directly on the index values rather than concerning itself with explaining differences. However, a quick look at the correlations across periods quickly reveals that there is a lot to explain. For example the correlation with each index is always low, as it is with the same index but in the other period. Only the Berry Index and Entropy Index within the same period show any real correlation, with a strong value of more than 0.9 seen.

	BI_{pre}	EI_{pre}	HFD_{pre}	BI_{post}	EI_{post}	HFD_{post}
BI_{pre}	1					
BI_{pre}	0.920	1				
HFD_{pre}	-0.012	0.044	1			
BI_{post}	0.036	0.050	-0.049	1		
EI_{post}	0.045	0.059	-0.040	0.911	1	
HFD_{post}	-0.066	-0.098	0.02	0.010	0.066	1

Table A3: Correlations between dietary diversity indicators

B Parameter Equality Tests

In the main paper we report models based on three indices of dietary diversity. This appendix reports the pairwise tests for parameter equality across quantile pairings for each of the three measures. The test employed uses the two stage nature of unconditional quantile regression to treat each quantile as a the regression of a different dependent variable on the same sample of independent variables. All tests are implemented in STATA using seemingly unrelated regressions.

Table A4 shows only the influences of what the respondents spouse eats, and the desire for a balanced diet, as being significantly different between the 20th percentile and either $\tau = 0.4$ or $\tau = 0.5$. Opening up to $\tau = 0.6$ sees a differential appear in the effect of using the new Tesco Seacroft store, as well as a changed influence of personal beliefs. Between the two ends of the range considered the distance to Tesco Seacroft, shopping at Tesco Seacroft, the head of household being unemployed and the influence of the foods the spouse eats have significantly different coefficients. Between $\tau = 0.4$ and the higher percentiles we see many significant variations in the coefficients, particularly between $\tau = 0.4$ and $\tau = 0.5$ where promotions is one of the identified factors. From the median upwards the unemployment effect gets increasingly significant, the much lower effect of being unemployed that was picked up in the main paper is the cause of this. Overall just under 20% of the pairwise tests report significant differentials adding weight to the conclusion that there are different effects at different quantiles first provided by the final column joint test of equality for all parameters.

Turning to the entropy index in Table A5 there is immediately evidence of a more diverse effect of Tesco Seacroft, particularly with regard to $\tau = 0.2$. For those with the least diverse diets the difference in coefficients is picked up against all but those with the most diverse. This is also seen for the belief that balanced diets are important. The lower single parent family coefficient is also shown to be significantly different from both $\tau = 0.4$ and $\tau = 0.8$ reaffirming there is a stronger negative effect on diet. Deprivation measures have a greater negative impact amongst the diets with least range, something which will concern policy-makers further as the main paper notes. As with the Berry index there are many differentials between $\tau = 0.4$ and higher coefficients. The impact of cost and budget is one which stands out for $\tau = 0.4$ and $\tau = 0.5$ when compared against the higher two quantiles. Here we see less variation in the Tesco Seacroft intervention effect coefficients. Convenience has a different effect at the very highest quantiles than the median, as does obtaining an education beyond the compulsory 16 years old. Around the median it is also clear that respondents are

Table A4: Berry index parameter equality tests

Variable	$\tau = 0.2$				$\tau = 0.4$			$\tau = 0.5$		$\tau = 0.6$	All
	$\tau = 0.4$	$\tau = 0.5$	$\tau = 0.6$	$\tau = 0.8$	$\tau = 0.5$	$\tau = 0.6$	$\tau = 0.8$	$\tau = 0.6$	$\tau = 0.8$	$\tau = 0.8$	
Pre-intervention value	0.000	0.097	0.003	0.098	0.592	0.004	0.043	0.343	0.270	0.171	0.240
Distance to Seacroft (km)	0.000	0.067	0.210	12.927	0.297	1.096	2.771	1.326	3.364	1.773	24.899
Tesco Seacroft shopper	0.742	2.468	3.452	24.268	7.674	4.353	1.421	1.618	0.021	0.195	8.225
No car access	0.188	0.588	0.084	0.061	0.291	0.015	0.607	0.621	1.457	1.821	12.836
Unemployed	0.001	2.484	0.522	5.781	3.203	0.649	6.857	0.076	8.647	88.860	11.529
Rent home	0.526	0.092	0.232	1.041	1.990	1.313	0.000	0.747	0.235	1.128	1.838
Child in household	0.068	0.015	0.001	0.064	0.016	0.221	0.029	0.118	0.120	1.327	0.988
Smoker	0.034	0.111	0.868	0.490	0.719	2.781	1.250	14.689	1.577	0.001	2.456
Post-16 education	1.119	1.106	1.644	0.199	0.560	0.086	2.976	0.007	5.185	8.131	12.493
Aged 17-34	0.272	0.263	0.520	0.099	0.015	1.967	0.489	2.368	0.674	0.386	3.722
Single-parent family	0.119	0.943	0.934	0.396	0.704	15.020	2.040	0.082	0.133	0.935	2.500
Cost / budget	0.145	0.533	0.005	0.117	27.281	0.500	1.389	1.018	0.676	0.073	860.735
Health advice	0.063	0.002	0.934	0.426	0.095	16.343	4.388	1.976	1.823	0.725	57.140
Child's tastes	0.059	0.000	0.122	0.409	0.456	0.299	1.344	1.185	3.178	2.744	13.322
Spouse's tastes	7.605	54.610	5.754	10.749	3.038	0.152	5.758	0.131	1.081	1.044	15.008
Balanced diet	19.617	7.738	3.856	1.767	0.412	0.069	0.000	6.655	0.220	0.036	47.785
Foods liked	1.433	2.205	0.650	0.344	1.012	4.926	0.874	4.048	0.571	0.160	18.710
Convenience	0.096	0.314	0.104	0.035	0.858	0.098	0.000	0.855	5.675	0.296	14.588
Child on shopping trip	0.368	0.355	0.046	2.064	23.870	5.404	17.703	1.568	1.635	4.741	26.920
Spouse on shopping trip	0.540	0.971	0.987	1.083	5.769	0.439	2.973	0.352	1.445	1.015	4.882
Hunger	0.001	0.136	0.039	0.032	3.189	0.233	0.114	0.157	0.022	0.005	265.264
Promotions	0.039	0.029	0.039	0.155	5.460	0.349	0.543	0.001	0.179	0.337	1.161
Personal beliefs	0.395	0.017	3.797	0.611	0.294	1.306	0.217	0.733	0.254	0.004	4.250

introducing increasing variety due to the influence of others, as picked up in the main paper this effect falls away at the highest quantiles. Similarly smoking is shown to be a significant negative factor in dietary diversity at all but the $\tau = 0.8$ level and hence we see the reduction in coefficient being significant in the pairwise comparisons. For the Entropy case just over 20% of the pairwise comparisons reveal significant benefits from quantile regression.

Table A5: Entropy index parameter equality tests

Variable	$\tau = 0.2$				$\tau = 0.4$			$\tau = 0.5$		$\tau = 0.6$	All
	$\tau = 0.4$	$\tau = 0.5$	$\tau = 0.6$	$\tau = 0.8$	$\tau = 0.5$	$\tau = 0.6$	$\tau = 0.8$	$\tau = 0.6$	$\tau = 0.8$	$\tau = 0.8$	
Pre-inteverntion value	0.343	0.000	0.053	0.643	5.641	5.622	3.633	0.888	1.525	1.396	64.589
Distance to Tesco (km)	0.602	1.804	0.000	0.351	0.941	3.211	0.012	12.528	0.013	0.569	4.587
Tesco Seacroft shopper	8.856	4.944	11.166	1.876	0.017	0.030	0.106	0.129	0.065	0.200	9.959
No car access	3.531	0.025	0.193	0.082	0.806	0.217	0.774	1.447	0.311	1.183	5.508
Unemployed	0.558	0.572	3.298	3.631	0.304	2.157	2.935	2.453	2.059	0.902	4.753
Rent home	0.030	0.212	0.206	9.227	0.151	0.353	2.273	2.321	1.817	0.145	8.832
Children in household	0.225	0.387	1.855	0.221	0.541	0.454	0.103	7.192	1.024	0.023	41.171
Smoker	0.319	2.015	0.718	2.804	0.199	0.001	0.998	0.614	3.495	3.387	17.376
Post-16 education	0.881	3.155	0.288	0.689	0.028	0.004	0.136	0.004	0.250	0.371	37.335
Aged 17-24 years	0.106	1.798	0.579	0.117	0.953	3.573	0.024	0.243	1.801	0.392	25.978
Single-parent family	6.816	1.992	1.461	38.793	1.649	3.078	0.188	0.022	0.202	0.108	44.812
Cost/budget	0.084	0.042	0.621	3.939	1.182	0.037	0.373	0.987	1.175	0.380	2.548
Health advice	0.132	0.023	0.844	1.257	0.700	8.014	40.836	10.485	23.493	1.426	28.824
Child's tastes	4.099	2.051	0.503	0.587	0.273	4.931	1.516	41.651	2.695	0.322	118.037
Spouse's tastes	0.067	0.165	0.696	2.481	6.905	59.645	9.351	11.099	7.747	1.003	7633.160
Balanced diet	3.836	12.408	5.591	22.210	9.505	0.969	3.179	0.112	0.421	2.075	64.181
Foods liked	4.434	1.074	0.559	9.047	1.073	0.446	0.094	0.024	0.084	0.153	6.568
Convenience	0.004	0.000	0.512	0.072	0.026	2.770	0.351	3.742	0.593	9.904	1.967
Child on trip	0.084	0.008	0.021	0.111	0.840	0.729	0.003	0.169	0.046	0.803	5.300
Spouse on trip	1.894	10.383	1.669	2.436	0.056	0.007	0.252	0.118	0.788	1.118	13.949
Hunger	0.778	1.230	0.008	0.150	0.040	0.768	0.033	0.324	0.007	0.773	3.151
Promotions/offers	2.054	2.195	0.753	1.053	0.002	0.075	0.328	0.051	0.611	0.387	3.194
Personal beliefs	2.497	0.125	1.242	3.232	0.416	0.187	0.767	165.169	0.630	0.003	4.204

Finally we consider the novel healthy food diversity index that was constructed for this paper. With this index there is less significance in the pairwise comparison of the Tesco Seacroft impact, but the distance that must be travelled to get to the new store has different effects in almost all tests. It was seen that younger respondents have a poorer diet, a result which continues from Wrigley et al. (2003) and Wrigley et al. (2002b) early works. The negative coefficients are larger at the lower end of the distribution is underlined in the parameter testing. Though it was not statistically significant in the regressions the strong negative impact of promotions below the median, particularly from $\tau = 0.4$ against the healthier end of the distribution, is notable and suggests that there may be a tendency to

Table A6: Healthy food diversity parameter equality tests

Variable	$\tau = 0.2$				$\tau = 0.4$			$\tau = 0.5$		$\tau = 0.6$	All
	$\tau = 0.4$	$\tau = 0.5$	$\tau = 0.6$	$\tau = 0.8$	$\tau = 0.5$	$\tau = 0.6$	$\tau = 0.8$	$\tau = 0.6$	$\tau = 0.8$	$\tau = 0.8$	
Pre-intervention Value	0.177	0.259	0.257	0.406	3.525	0.004	0.005	1.474	0.821	0.002	1.581
Distance to Tesco (KM)	14.862	14.581	0.195	0.759	1.426	3.571	24.062	4.949	6.881	0.354	27.454
Tesco Seacroft shopper	2.091	0.607	1.399	1.026	0.008	6.503	2.306	6.038	1.025	0.003	16.680
No car access	2.007	2.429	12.970	1.447	0.061	2.230	0.518	1.332	0.474	0.007	2.442
Unemployed	2.616	0.032	1.368	0.791	2.129	0.475	0.350	4.059	3.524	0.037	3.114
Rent home	0.927	0.745	1.017	1.133	0.052	0.069	0.121	0.017	0.804	0.924	1.317
Child in household	1.440	0.491	0.441	0.106	0.319	0.009	0.415	0.062	0.255	1.723	6.664
Smoker	1.981	2.427	0.082	0.009	0.120	0.441	2.169	3.758	9.320	0.122	5.016
Post-16 education	0.181	0.650	0.150	0.671	0.392	0.056	1.568	0.038	2.292	0.452	5.273
Aged 17-34	11.577	5.306	8.200	14.752	0.395	3.861	7.418	0.156	22.959	2.734	39.087
Single-parent family	0.882	0.372	0.638	1.280	0.032	0.072	0.342	1.303	1.127	0.519	3.485
Cost/budget	0.287	0.343	0.156	0.017	5.836	1.642	0.052	0.127	0.884	0.863	32.284
Health advice	3.160	3.966	2.000	2.238	0.461	0.097	0.088	0.000	0.005	0.006	3.916
Child's tatses	0.550	0.951	1.837	0.685	0.686	5.441	0.072	4.289	0.214	1.502	1.051
Spouse's tastes	0.261	0.004	0.545	0.213	1.598	0.002	0.017	0.868	0.243	0.967	5.001
Balanced diet	3.268	1.627	1.962	1.540	0.569	0.060	0.376	1.077	0.773	0.648	17.526
Foods liked	0.125	7.158	11.096	0.023	1.788	3.415	0.043	3.581	0.379	6.512	67.177
Convenience	1.476	0.005	0.563	0.036	2.256	1.191	0.230	0.600	0.039	0.782	3.764
Child on trip	1.032	1.131	0.000	3.877	0.690	0.527	3.022	4.589	3.471	1.315	6.222
Spouse on trip	0.147	2.981	0.479	4.205	4.660	0.006	0.712	5.544	0.031	2.193	5.613
Hunger	2.082	0.023	0.684	0.147	2.400	39.998	2.867	4.335	1.576	0.035	383.779
Promotions	0.258	0.250	1.011	0.998	3.148	7.919	4.770	9.257	6.078	0.125	77.241
Personal beliefs	1.846	0.006	0.046	0.010	1.358	2.318	1.901	0.403	0.002	0.105	0.530

promote less healthy products in the area's grocery stores. Deprivation measures, such as unemployment, appear to have consistent quality reducing effects, whilst the positive impact of considering balanced diet is also equal across the quantiles. Smoking was found to reduce the index significantly around the median; pairwise comparisons confirm this and again show that the ordinary least squares regression was missing important factors. Overall 47 of the 230 tests reveal significant differentials, the same as was seen for the entropy index.

Through a closer look at the three indices this appendix has demonstrated that there is value in the employment of quantile regression techniques to this dataset. In each case the majority of variables have coefficient inequality across the five studied quantiles. Importantly all three indices are affected differently across their distributions by the respondent being a Tesco Seacroft shopper after the intervention.