Title: Planning policies to restrict fast food and inequalities in child weight in England: A quasi-experimental analysis

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What is already known:

Using planning policy to restrict food outlets reduces the number of fast-food outlets

Public health impact of these policies is not known

New Findings:

In local areas with the highest concentration of fast-food outlets restricting new outlets significantly reduces the prevalence of childhood overweight and obesity compared to control areas

There is no impact of the policy on childhood overweight and obesity at the population level

How might the results change research:

Planning policy may be an effective tool to reduce childhood overweight and obesity rates in areas with high concentration of outlets. This is the first study from the UK to provide evidence on the public health impact of planning policy to shape the food environment.

Abstract

Objectives:

England has one of the highest childhood obesity rates in Europe. To promote a healthier food environment in 2015, Gateshead Council in the North-East of England introduced planning guidelines effectively banning any new fast-food outlets. Our aim was to investigate if this policy led to any reductions in childhood overweight and obesity prevalence and inequalities in these outcomes.

Methods:

We used data from National Child Measurement Programme, Food Standard Agency Food Hygiene Rating Data, and Office of National Statistics between 2012-2020. We estimated a difference in difference model employing propensity score matching to identify a control group.

Results:

We found no significant change in population level childhood overweight and obesity in Gateshead compared to control areas. In sub-group analysis by area level deprivation, we found that the quintile of deprivation with the highest proportion of fast-food outlets had a statistically significant reduction of 4.80% in the prevalence of childhood overweight and obesity compared to control areas.

Conclusion:

Restricting fast food outlets in areas with a high concentration of these outlets as part of a package of policies to reduce childhood obesity may help to reduce prevalence and inequalities in childhood overweight and obesity.

Keywords: Food environment; childhood overweight and obesity; England; difference in difference; propensity score matching

1. Introduction

Childhood obesity rates in the UK are some of the highest in Europe [1]. In 2006/07, 31.7% of children in year 6 (aged 10 to 11) were living with overweight or obesity which rose to 35.2% in 2019/20 and further increased to 40.9% in 2020/21 [2]. This rise has been partially exacerbated by the Covid-19 pandemic [3].

There is robust evidence showing that childhood obesity can have adverse impacts on health in the short term (childhood) and long term (adulthood). Obesity in childhood is associated with increased risk for anxiety and depression, low self-esteem, lower reported quality of life, increased risk of bullying and facing stigma, and increased risk of obesity in adulthood [4, 5, 6]. Childhood obesity is strongly associated with increased risk of type II diabetes, cardiovascular diseases, as well as mental disorders in adulthood [7, 8, 9, 10]. The estimated costs to the NHS on treating OWOB related diseases was £6.1 million in 2015 and is forecast to reach £9.7 billion by 2050 [11].

The causes of childhood obesity are complex and multifaceted. However, environmental factors, play an important role in the prevalence of childhood obesity [12, 13]. There is evidence showing that the out-of-home food environment has impacts on childhood energy intakes [14,15,16,17]. In particular, fast-food consumption and location of fast-food outlets are strongly associated with a higher energy intake and a higher prevalence of childhood obesity [17, 18, 19, 20]. The relationship with obesity is also strongly socio-demographically and socio-economically patterned, with the highest prevalence of OWOB found in our most economically deprived communities [21, 22, 23, 24].

The density of fast-food outlets is the number of fast-food outlets per 100,000 residents [25], across England has been rising. Data from the Food Standards Agency shows that the average density of fast-food outlets increased from 142 to 170 per 100,000 residents between 2019 to end of 2021. Areas of higher deprivation have five times as many fast-food outlets compared to those more affluent areas [26]. This may be a contributing factor to inequalities in childhood weight.

Since the enactment of the Health and Social Care Act 2012, local authorities (local government) in England have had a statutory duty with regards to improving population health [27]. Because of the clear and consistent evidence base demonstrating a relationship between childhood obesity and the food environment [15, 17], national public health guidance was developed to encourage and support local authorities to use the planning system to create environments that are supportive of promoting a healthy weight [28]. Approximately 50% of local authorities have employed planning guidelines restricting planning permission for new fast-food outlets to promote a healthier food environment [29]. There are three different types of planning guidelines used by local authorities outlined in Appendix A.

In England, for planning purposes, fast-food outlets are defined as premises which sell hot food for consumption off the premises (Town and Country Planning (Use Classes) Order 1987 (as amended)). However, the data used to monitor the food environment by the UK public health agency (Office of Health Inequalities and Disparities) is based upon the Food Standards Agency data collected by environmental health officers. In our analysis, we use this definition to classify fast-food outlets. Fast-food outlets in our study include businesses which for planning terms would be considered planning class E such as sushi bars and sandwich shops. But, in terms of public health, these outlets were considered fast food.

In 2015, Gateshead, implemented all three types of the planning guidance outlined in Appendix A. Gateshead is in the top 15% of the most deprived local authorities in England [30]. It is located in the North East of England. In 2014, 36.7% of year 6 children (aged 10 to 11 years) were living with overweight or obesity in Gateshead compared with 36.1% in the North East and 33.5% in England [31]. This is equivalent to a blanket-ban on obtaining planning permission for change of use or building of a new premise to be designated as a fast-food outlet. The ambition of the policy is to reduce the year 6 (10-11 year-old children) obesity rate from 23% in 2015 to less than 10% by 2025 [32]. Research found the planning guidance led to statistically significant reduction in the density and proportion of fast-food outlets in Gateshead compared to other neighbouring local authorities which did not have similar planning policy in place [34].

The aim of this paper is to explore if a reduction in fast-food outlets is associated with a change in childhood OWOB and inequalities in childhood OWOB. We know that the food environment has an indirect effect on body weight by influencing what food is available and subsequently what is consumed. We do not know how long it takes for the changes in the food environment to filter down to observed changes in weight. Thus, our first objective is to explore if, at the population level, there is a significant change in childhood OWOB within the first 5 years of a change in planning guidance. We know that more deprived areas on average have a higher concentration of fast-food outlets and that the density and proportion of fast-food outlets has decreased in Gateshead as a result of the change in planning guidance [34]. Our second objective is to explore if the policy is *more effective* in areas of higher deprivation which previously had a higher concentration of outlets, leading to a reduction in inequalities in childhood OWOB.

There is currently limited evidence on the effectiveness of planning policy on health outcomes. Understanding how and for who planning policy works is essential so that local government can use planning policy as a cost-effective mechanism to improve population health and reduce health inequalities.

2. Data and Methods

Data sources

All datasets used in this study are publicly available. The pre-treatment period is 2011-2014 and the post-treatment period is 2015-2019. We exclude data from the Covid period because data on child weight was not collected for all children in 2020 and 2021 [2]. Data on children's weight came from the National Child Measurement Programme (NCMP) from 2011-2020. NCMP is a statutory programme delivered annually by NHS Primary Care Trusts before 2013 and local authorities after 2013. It collects data on the height and weight of all school children in reception (aged 4/5) and year 6 (age 10/11) across England [35]. Children are classified as living with overweight if their BMI is on or above the 85th centile (or 95th centile for living with obesity) of the British 1990 growth reference according to age and sex [36].

Data on food outlets were from the Food Standard Agency Food Hygiene Rating Scheme (FSA FHRS) between 2012-2020 [37]. We did not use data post 2020 because of the Covid pandemic and the resulting temporary changes brought into planning guidance and how food businesses could operate [38, 39]. The FSA FHRS records information (including business name, type of food outlet, location, and hygiene rating) on all premises that serve hot food in the UK and is updated regularly (between 4-8 weeks). All premises that serve hot food must register with the local authority at least 28 days before opening [40]. Premises will then be inspected by an environmental health officer from the local authority and given a food hygiene rating. Subsequent inspections will occur between every 6 months to every 2 years depending upon the potential risk to public health from the food premises [37]. There is evidence that the FSA FHRS dataset has a broad coverage of food outlets and a high spatial accuracy of the food environment in the North East of England [41].

We cross-checked our data based upon the planning guidance to ensure that we were not missing any outlets [32]. Our data is a conservative estimate of the number of fast-food outlets as the FSA/environmental health definition is broader than the planner's definition.

We also used data on population size between 2012-2020 [42] and Index of Multiple Deprivation (IMD) 2019 [43]. IMD is a composite measure of seven distinct domains of deprivation which include 1) income; 2) employment; 3) health and disability; 4) education, skills and training; 5) crime; 6) barriers to housing and services; and 7) living environment.

Geography

We undertook all analysis at the middle layer super output area (MSOA) level because the NCMP data is not publicly available at a smaller geography. A MSOA is a geographical area with an average population of 7200 people [44].

Outcome variable: Prevalence of year 6 overweight and obesity

The main outcome of interest is the prevalence of OWOB for children in year 6 (aged 10-11). The prevalence of OWOB was the ratio of number of children living with OWOB to the total number of children who had height and weight data. In our sample, NCMP collected an average of 232 children's weight in each MSOA and year (a total of 425,715 children over the sample years). Appendix Table A1 presents the number of children in each MSOA in Gateshead over the study period.

Density of fast-food outlets

We calculated the density of fast-food outlets by MSOA and year between 2012 and 2020. It is defined as the number of fast-food outlets per 100,000 residents. A higher density of fast-food outlets indicates that the year 6 children have a higher exposure to unhealthy food. This measure has been used in previous studies [25, 34]. To count the number of fast-food outlets within each MSOA, we extracted the postcode and location information of all fast-food outlets from the FSA FHRS dataset [37]. We have data on 13,074 food outlets in the control and treatment groups over the study period. A food outlet may have multiple observations over the study period The population in each MSOA was estimated from data by the Office for National Statistics in 2021 [42].

Area Level deprivation

To measure the relative deprivation for each MSOA, we used a population weighted IMD score following the method described in the English indices of deprivation 2019 research report [45]. A higher IMD score indicates a higher level of deprivation. Then, we ranked the IMD scores to identify the IMD quintiles. The first IMD quintile is the most deprived MSOAs and the fifth IMD quintile is the least deprived MSOAs in Gateshead.

Identification of control groups

MSOAs in Gateshead are the areas that underwent the planning changes (treatment group). To identify an appropriate group of MSOAs for comparison (control units), the selection of control groups is restricted to the MSOAs located in the North East of England belonging to local authorities that had not adopted any of the three types of planning guidance over the study period. There are five local authorities which met the criteria: 1) Stockton on Tees, 2) Durham, 3) Northumberland, 4) Darlington, and 5) Hartlepool. Durham and Hartlepool were within the 20% most deprived local authorities in England. The other three local authorities were within the 40% most deprived local authorities in England [45].

The decision to utilise planning policy restricting new fast-food outlets was not a coincidence given that Gateshead had a higher density of fast-food outlets and a higher level of deprivation compared to the other five local authorities in the North East as shown in Table 1. Furthermore, there is significant heterogeneity in the distribution of fast-food outlets between the MSOAs in Gateshead and the other five local authorities. In Figure 1, we identified the IMD quintile for MSOAs within Gateshead and the other five local authorities. In both groups, MSOAs with a higher level of deprivation tend to have a higher density of fast-food outlets. However, the 1st IMD quintile of MSOAs in Gateshead had a lower density of fast-food outlets than the 2nd and 3rd IMD quintiles. The MSOAs in Gateshead also had a relatively higher variation in the density of fast-food outlets over time. These dynamics make it difficult to identify an appropriate control group.

To overcome the heterogeneous fast-food outlet distribution, we employed a propensity score matching (PSM) approach. A one-to-one matching without replacement was performed. Specifically, using the pre-intervention data and a logit regression model, we employed the average density of fast-food outlets and IMD scores as predictors to estimate the propensity scores for MSOAs. There are 27 MSOAs in Gateshead, and therefore 27 MSOAs from the other five local authorities with the nearest propensity scores were identified as the control groups.

Table 1 compares the characteristics of MSOAs in the treatment and control groups before and after the matching. As shown, before the matching, the control groups have a lower IMD score with a higher standard deviation and a lower density of fast-food outlets with a higher standard deviation compared to the treatment groups. After the matching, the differences between the control and treatment groups become smaller as shown in column (5) and (6). Results from t-tests show that there are no statistically significant differences in IMD scores and density of fast-food outlets between the matched control and treatment MSOAs. This suggests that we might have identified an appropriate group of MSOAs as the control groups.

Figure 1 shows the average prevalence of year 6 OWOB across the matched MSOAs by IMD quintile over the study period. The most deprived MSOAs (i.e., IMD quintile 1) tend to have the highest prevalence of year 6 OWOB, and the least deprived MSOAs (i.e., IMD quintile 5) tend to have the lowest prevalence of year 6 OWOB in all years.

In Figure 2, we investigated changes in inequalities in childhood OWOB comparing the treatment and control groups. The inequality in childhood OWOB in Gateshead is relatively constant for IMD quintiles 2-5 but increases sharply for those in IMD quintile 1 (most deprived) from 2016. The most deprived MSOAs in Gateshead on average have a higher turnover in housing [30]. This suggests that the increase in childhood obesity we observe may because of a change in the sample composition. However, since we use aggregate data, we cannot explore this in the data. For the control groups, inequality between quintiles of deprivation is increasing up until 2019 when it stabilises or starts to decrease.

Econometric analysis

This study employs a difference-in-differences (DID) model to quantitively examine the changes in the prevalence of OWOB in children in year 6 in Gateshead compared to other similar local authorities by the relative deprivation quintile. The planning policy was adopted in 2015. Thus, the pre-treatment period is 2012-2015 and the post-treatment period is 2015-2020. We started with modelling the overall relationship between the policy intervention and the prevalence of childhood OWOB using the matched sample from the propensity score matching model. Equation (1) shows the model. All analyses were conducted using STATA v.17.

$$OWOB_{it} = \alpha + \delta_1 Treat_i + \delta_2 Post_t + \beta Treat_i * Post_t + \gamma Dep_i + \varepsilon_{it} \quad (1)$$

Where, the subscript i and t indicates a MSOA and year respectively; $OWOB_{it}$ is the prevalence of year 6 OWOB in MSOA i in year t; $Treat_i$ is a dummy variable that is set to 1 if an MSOA i is within Gateshead, 0 otherwise; $Post_t$ is a dummy variable that is set to 1 for the post-intervention years and 0 for the pre-intervention years; Treat*Post is the impact of the intervention on childhood obesity rates in MSOAs in Gatehsead; Dep_i indicates the deprivation quintile for MSOA i; ε_{it} is the error term; α is the constant term. β, δ_1, δ_2, and γ are the parameters of coefficients to be estimated. We expect β to be negative if the planning policy has had positive impacts on reducing the prevalence of childhood OWOB.

Because fast-food outlets tend to cluster in more deprived area, the impact of the planning policy on year 6 OWOB is likely to partially depend on area level deprivation. To see the heterogeneous effects of planning policy, we also estimated the DID model by the deprivation quintile.

Sensitivity Analysis:

We perform a range of different tests on the robustness of our results checking the underlying assumptions of the model. This sensitivity analysis is described in greater detail in Appendix A2.

3. Results

Summary Statistics

Table 2 reports the prevalence of year 6 OWOB, number and density of fast-food outlets, number of children's weight collected over the 27 MSOAs in Gateshead and the 156 in the five control local authorities by year. Gateshead's MSOAs had a higher prevalence of year 6 OWOB in all years compared with MSOAs in the other five local authorities. We observed a decreasing trend in Gateshead pre-intervention from 38% in 2011 to 35.5% in 2015 which then reversed to 37.7% in 2020. In the control MSOAs, the prevalence of year 6 OWOB was increasing throughout the sample years from 34.4% in 2011% to 36.4% in 2020. However, the differences between these two groups, in general, became smaller over time. The second and third rows in each panel show the number and density of fast-food outlets. Gateshead MSOAs had a higher density of fast-food outlets compared with the five control local authorities in all years.

Population level results

Table 3 reports the estimates of the impact of planning guidance on year 6 OWOB on the matched MSOAs. Columns (1) and (2) include different set of covariates. As shown in Table 3, the relationship between the planning guidance and the prevalence of year 6 OWOB is not statistically significant in any model (first two rows). In the bottom half of Table 3 we can see that there is a strong and significant gradient in the prevalence of year 6 OWOB by area level deprivation. Compared to the most deprived quintile of MSOAs (IMD quintile 1), the prevalence of year 6 OWOB in the IMD quintile 2, 3, 4, and 5 are 2.18%, 4.59%, 6.60%, and 11.03% lower, respectively. The R-squared increased from 0.025 to 0.440 suggesting that the multiple deprivation index may explain more than 40% of the prevalence of year 6 OWOB.

The heterogeneous effects of the planning policy by area level deprivation

Because of the significant association between area level deprivation and childhood OWOB in Table 3, in Table 4 we estimated the impact of the policy by area level deprivation. Examined by the most deprived quintile of MSOAs, we observed that the prevalence of year 6 OWOB had a statistically significant reduction of 4.79% ($p<0.01$) in the second deprived quintile and 4.11% ($p<0.01$) in the third deprivation quintile in Gateshead following the adoption of the planning policy compared with the control groups. In other deprivation quintiles, there were no statistically significant changes in the prevalence of year 6 OWOB in Gateshead compared to the control groups after the adoption of the planning guidance.

Sensitivity Analysis:

The results for the sensitivity analysis are presented in Appendix A3. The results suggest heterogeneity in the robustness of the results by deprivation quintile. The results for deprivation quintile 2 are robust across all sensitivity analysis providing confidence that the policy was associated with the reduction of childhood OWOB for children in these areas compared with the control group.

4. Discussion

In this study we provided empirical evidence on the effectiveness of local planning policy on reducing the prevalence of childhood OWOB at age 10/11 years (year 6) within a 4-year post implementation period. We know that there is a higher concentration of fast-food outlets in areas of high deprivation [26]. There is evidence to suggest that children from more deprived areas are more likely to be overweight or obese [2, 21, 24]. Across all model specifications, we found that for children living in the 2nd most deprived quintile (which had the highest concentration of fast-food outlets pre-intervention) there was a decrease in the prevalence of OWOB compared to control groups. Results from other quintiles of MSOAs are less robust to alternative specifications.

At the population level we found no significant impact of the policy on childhood OWOB in Gateshead compared to the control areas in this relatively short time period. This may be because the policy had no effect, or the effect of the policy may happen in the longer term so we do not observe a change within 4 years of post-policy data we use in our analysis. Evidence from Gateshead showed a 10% reduction in the density and proportion of fast-food outlets within 4 years of the policy intervention [34].

The food environment is changing with a growing presence of online delivery food available. Future research needs to consider if and how the online food environment may impact to exposure of unhealthy food and if existing guidance and legislation needs to be changed to reflect this changing food environment.

Policy Implications

Our finding of a significant association between a decrease in childhood OWOB and a reduction in the density of fast food in a more deprived quintile with a higher pre-policy density of fast-food outlets is important to highlight how the policy may contribute to reducing inequalities in childhood OWOB. This means that planning may be an effective mechanism to reduce inequalities in childhood overweight and obesity; a policy goal that has not been achieved to date with the long history of government policy to increase the prevalence of healthy weight children [46]. Our results provide evidence to support an 'upstream' or structural approach to improving health outcomes rather than a reliance on individuals as drivers of behaviour change.

Planning policy has direct impacts on the food environment which then have indirect impacts on weight. A priori it is difficult to know how long it may take for this change in the food environment to impact on energy intake from food resulting in changes to weight.

Strengths and limitations

The present study offers several notable strengths, we employ a quasi-experimental method with sensitivity analysis.

Despite these strengths, several limitations should be acknowledged. We were unable to identify the timeframe required for changes in the food environment to translate into observed changes in childhood OWOB. While efforts were made to control MSOA characteristics, we were unable to incorporate some time-varying variables, such as changing sample composition. The outcome measure contains the weight information about children who attended the school within the MSOA, rather than specifically representing the weight of children residing in that MSOA. We also do not know how and if children engage with their local food environment with the data available to us.

5. Conclusion

This research finds evidence to support that planning could be used as part of an arsenal of tools to reduce inequalities in childhood OWOB. This policy may only be effective in areas with a high concentration of fast-food outlets. Those who have authority over planning in communities should consider how the planning approach can be adjusted accordingly and applied within their area to promote healthy weight in their communities.

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Table 1. Characteristics of MSOAs in the treatment and control groups before and after propensity score matching

	Treatment: Full sample		Control: Full sample		Control: Matched		t-tests	
	Mean	SD	Mean	SD	Mean	SD	Diff.	P-value
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
IMD 2019 scores	28.25	12.07	26.29	13.60	28.67	13.34	0.42	0.90
Density of fast-food outlets	113.82	77.13	95.39	94.45	107.86	77.14	-5.97	0.78
No. of MSOAs	27		156		27			
No. of fast-food outlets	2,109		10,965		2,263			
No. of children	55,440		370,275		22,770			

Note: Results from the t-tests, columns (7) and (8), show the differences between the matched control (i.e. column(5)) and treatment MSOAs (i.e. column (1)). Number of fast-food outlets reports the total number of fast-food outlets observed over the study period. A fast-food outlet may be repeated observed in different years. Number of children shows the total number of children observed over the whole study period.

Table 2. Characteristics of MSOAs in Gateshead and five control local authorities in the North East

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Gateshead MSOAs:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
% of year 6 OWOB	38.0	37.9	36.8	36.2	35.5	36.6	36.9	37.8	37.4	37.7
Total number of fast-food outlets	-	230	234	233	231	222	237	239	240	243
Density of fast-food Outlets	-	113.1	115.2	114.4	112.6	108.0	114.4	115.2	115.1	116.9
Total number of children	5465	5335	5385	5385	5400	5495	5605	5710	5760	5900
Number of MSOAs	27	27	27	27	27	27	27	27	27	27
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Other MSOAs:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
% of year 6 OWOB	34.4	35.0	35.3	35.3	35.1	35.5	36.0	36.4	36.4	36.4
Total number of fast-food outlets	-	1109	1130	1178	1190	1249	1260	1269	1273	1307
Density of fast-food Outlets	-	91.9	93.8	97.6	98.2	102.6	103.1	103.5	103.7	106.8
Total number of children	37015	36200	35125	35220	36185	37175	38095	38710	39590	36960
Number of MSOAs	156	156	156	156	156	156	156	156	156	156

Note: This table shows the prevalence of year 6 overweight and obesity, number of fast-food outlets, density of fast-food outlets, and number of children across the treatment MSOAs and the control MSOAs over the study period.

Table 3. The impact of planning policy on year 6 overweight and obesity estimated using a difference-in-difference equation

	Base Model (1)	Includes IMD (2)
Gateshead (Treat)	1.976***	1.976***
	(0.616)	(0.488)
Post (Implementation of SPD)	1.365*	1.365**
	(0.712)	(0.571)
Treat * Post	-0.961	-0.961
	(0.981)	(0.746)
IMD Quintile		
Quintile 2		-2.181***
		(0.555)
Quintile 3		-4.587***
		(0.593)
Quintile 4		-6.595***
		(0.594)
Quintile 5		-11.031***
		(0.686)
N (Number of MSOAs×Years)	540	540
R-squared	0.025	0.440

Note: IMD Quintile 1 is an indicator of the most deprived MOSAs and is omitted in this table. IMD Quintile 5 is an indicator of the least deprived MOSAs. Constants are included but not reported. Robust standard errors are shown in parentheses. N is the number of MSOAs×Years. * p < 0.10, ** p < 0.05, *** p < 0.01

Table 4. The impact of planning policy on childhood overweight and obesity by IMD quintile estimated by a difference-in-difference equation

	Q1 (1)	Q2 (2)	Q3 (3)	Q4 (4)	Q5 (5)
Gateshead (Treat)	2.669**	3.537***	1.986*	0.930	0.652
	(1.036)	(0.991)	(1.156)	(1.031)	(1.211)
Post (Implementation of SPD)	1.778	4.357***	2.225*	-0.165	-1.661
	(1.082)	(0.892)	(1.207)	(1.314)	(1.688)
Treat * Post	1.168	-4.789***	-4.106***	1.811	1.321
	(1.715)	(1.289)	(1.527)	(1.580)	(2.075)
N (Number of MSOAs× Years)	100	120	100	120	100
R-squared	0.189	0.184	0.071	0.061	0.030

Note: Q1-5 refer to the IMD quintile 1-5 respectively. Constants are included but not reported. Robust standard errors are shown in parentheses. N is the number of MSOAs×Years. * p < 0.10, ** p < 0.05, *** p < 0.01

Appendix

Box A1: *Types of Planning Guidance*

Types of Planning Guidance

1) School exclusion zone (restricting planning permission for new fast-food outlets usually within 400 metres of a school)

2) Limiting the density of fast-food outlets (planning permission for new fast-food outlets will be rejected if a certain threshold number of fast-food outlets has been reached)

3) Restricting new fast-food outlets based upon local childhood obesity rates (restricting planning permission for new fast-food outlets in areas where more than a certain threshold percentage of children are living with obesity)

Table A1. Count of Children in each MSOA in Gateshead by year

MSOA code	2011 (1)	2012 (2)	2013 (3)	2014 (4)	2015 (5)	2016 (6)	2017 (7)	2018 (8)	2019 (9)	2020 (10)
E02001682	230	235	220	235	230	225	245	240	260	265
E02001683	250	250	245	230	220	240	240	265	245	270
E02001684	175	175	175	195	190	170	160	175	200	215
E02001685	270	260	270	250	240	250	260	270	275	280
E02001686	195	190	165	150	150	175	175	180	175	185
E02001688	180	165	160	165	170	205	220	215	210	220
E02001689	155	130	165	160	180	140	140	135	145	160
E02001690	240	215	185	180	190	190	190	205	250	245
E02001691	165	165	185	185	205	195	195	195	205	220
E02001692	230	225	235	245	235	235	230	230	230	255
E02001693	145	145	160	150	160	170	165	165	140	165
E02001694	195	210	190	185	170	170	175	200	190	185
E02001695	190	190	170	190	190	190	180	185	180	170
E02001696	320	295	310	310	315	310	330	350	320	280
E02001697	180	195	230	230	230	230	250	225	205	200
E02001698	200	185	190	175	185	185	185	180	185	195
E02001699	205	215	205	200	195	180	185	175	180	180
E02001700	300	310	295	315	325	360	345	310	330	335
E02001701	105	115	160	175	155	145	135	150	160	185
E02001702	275	245	275	270	290	295	315	320	315	315
E02001703	190	185	155	165	145	165	150	155	150	165
E02001704	260	225	205	180	190	205	200	195	195	195
E02001705	185	180	170	170	170	190	205	215	225	235
E02001706	180	180	205	205	225	215	230	235	250	260
E02001707	250	240	225	230	235	250	275	290	290	270
E02006841	100	110	115	115	95	95	100	120	120	130
E02006842	95	100	120	125	115	115	125	130	130	120

Appendix A2: Sensitivity Analysis

Sensitivity analysis: The dynamic treatment effects

One of the key assumptions of DID model is the `parallel trends assumption' between the treatment and control groups. To address this concern, we estimated the dynamic effects of policy intervention using the model as shown in Equation (2).

$$OWOB_{it} = \beta_1\, Treat_i \times Pre_t^{-4} + \beta_2\, Treat_i \times Pre_t^{-3} + \beta_3\, Treat_i \times Pre_t^{-2} + \beta_4\, Treat_i \times Post_t^{-1} + \beta_5\, Treat_i \times Post_t^{+1} + \beta_6\, Treat_i \times Post_t^{+2} + \beta_7\, Treat_i \times Post_t^{+3} + \beta_8\, Treat_i \times Post_t^{+4} + \beta_9\, Treat_i \times Post_t^{+5} + \alpha_i + \tau_t + \varepsilon_{it} \quad (2)$$

Where, Pre_t^{-4}, Pre_t^{-3}, ..., $Post_t^{+4}$, and $Post_t^{+5}$, are the year dummy variables for 2011, 2012, …, 2019, and 2020 respectively. The interaction term for the intervention year 2015, $Treat_i*Pre_t^0$, is the base case, and therefore is omitted from the equation. α_i is the MSOA dummy variable. τ_t is the time dummy variable. We are interested in β_1, β_2, β_3, and β_4. If our setting did not violate the parallel trend assumption, β_1, β_2, β_3, and β_4 should not be statistically significantly different from 0.

An alternative parallel trend test is conducted as an additional robust test for the parallel trends assumption. This test used the Stata command `estat ptrends'. This test assumes that there was a linear trend in both treatment and control groups and then estimates pre-intervention slope differences between the two groups.

Sensitivity analysis: Placebo tests

As an additional sensitivity analysis, we used the pre-intervention data from 2011 to 2015. Three placebo treatment periods (2012, 2013, and 2014) are introduced. Then, we estimated a DID model to examine the `effects' of the placebo interventions on year 6 OWOB. We would expect to see no significant association.

Sensitivity analysis: Alternative propensity score matching approach

There is an alternative way to define the density of fast-food outlets. This may lead to a different selection of the control groups and therefore lead to a different estimate of the treatment effects. The alternative definition is the number of fast-food outlets per km^2. Following the same PSM method, a different set of control groups is identified. Then, the new control groups are used to examine if our main results are sensitive to the alternative control groups.

Appendix A3: Sensitivity Analysis Results

The dynamic treatment effects

Table A2 presents results estimating the dynamic effects of planning policy as well as examining the parallel trend assumption. We found that, for the overall estimates at the MSOA level, some of the pre-intervention interaction terms (i.e., Treat * Pre^{-4} – Treat * Pre^{-1}) are statistically significant suggesting violation of the parallel trend assumption. Looking at the analysis by area level deprivation, the pre-intervention interaction terms are statistically insignificant for the 2nd and 5th deprivation quintiles, which means the parallel trends hold in these two quintiles. However, this is not the case in the 1st, 3rd, and 4th deprivation quintiles. An alternative parallel trend tests (estat ptrends) finds similar results (see Appendix Table A3).

Sensitivity analysis: Placebo tests

In Table A4, we report results from the pre-treatment placebo tests. We proposed three placebo interventions in 2012, 2013, and 2014, respectively. The placebo interventions should have no statistically significant impacts on the prevalence of year 6 OWOB as the actual intervention was adopted after 2015. We found no statistically significant association in the second and the fifth IMD quintiles. Results from the fourth IMD quintile show a weakly significant placebo impact. Some of the placebo interventions in IMD quintile 1 and 3 have statistically significant 'impacts' on the prevalence of year 6 OWOB. This suggests that our results from IMD quintile 2 and 5 are robust to the placebo tests, in keeping with our findings from the sensitivity in analysis in Tables A2 and A3.

Sensitivity analysis: Alternative propensity score matching approach

In Table A5, we present estimates from the alternative control group. The overall results and results from IMD quintiles 1, 2, 3, and 5 are similar to our estimates presented in Table 3 and 4. Results from the IMD quintile 4 is sensitive to the alternative PSM approach.

Sensitivity Analysis: Sub-sample analysis

Our sensitivity analyses suggest some violations of the parallel trend assumption for the analysis at MSOA level and sub-group analysis for IMD quintiles 1, 3, and 4. Results from Table A2 imply the violation of parallel trend assumption mostly stems from data in 2011 and 2012. To address this potential concern, we re-estimated the DID model using data from 2013 to 2020. Results are reported in Table A6, which are similar with our mains results. The only difference is that the treatment effects on the 3rd IMD quintile are not statistically significant in Table A6 whereas they are in Table 4.

Table A2. The dynamic effects of planning policy (Test of Parallel Trends Assumption)

	Overall	Q1	Q2	Q3	Q4	Q5
	(1)	(2)	(3)	(4)	(5)	(6)
Treat * Pre^{-4} (2011)	2.446**	6.933	3.340	4.998**	5.978**	-1.909
	(0.958)	(3.797)	(2.019)	(2.173)	(2.491)	(2.614)
Treat * Pre^{-3} (2012)	2.316**	7.523**	3.996	7.174***	4.040	-3.148
	(0.948)	(3.136)	(3.634)	(1.265)	(2.528)	(3.040)
Treat * Pre^{-2} (2013)	1.216	5.333*	1.581	5.810**	3.337	-2.632
	(0.893)	(2.723)	(2.100)	(2.410)	(2.288)	(2.399)
Treat * Pre^{-1} (2014)	0.657	1.514	0.482	1.371	0.687	-0.085
	(0.802)	(1.772)	(2.213)	(1.540)	(1.901)	(1.772)
Treat * $Post^{+1}$ (2016)	-0.346	0.815	-1.202	-0.899	2.687**	0.445
	(1.143)	(1.286)	(0.882)	(3.265)	(1.211)	(1.367)
Treat * $Post^{+2}$ (2017)	0.001	3.887	-1.232	-1.538	4.822**	0.362
	(1.169)	(3.586)	(1.487)	(2.510)	(1.750)	(3.208)
Treat * $Post^{+3}$ (2018)	0.862	6.583	-0.879	-1.462	5.396*	0.735
	(1.204)	(4.392)	(1.873)	(2.401)	(2.655)	(2.454)
Treat * $Post^{+4}$ (2019)	0.531	9.142*	-5.553***	0.940	3.949	-0.224
	(1.255)	(4.876)	(1.673)	(2.076)	(2.489)	(3.693)
Treat * $Post^{+5}$ (2020)	0.782	6.715	-5.679**	1.785	6.245**	-2.488
	(1.229)	(4.871)	(2.506)	(2.558)	(2.088)	(4.695)
Year Dummy	Yes	Yes	Yes	Yes	Yes	Yes
MSOA Dummy	Yes	Yes	Yes	Yes	Yes	Yes
N (Number of MSOAs× Years)	540	100	120	100	120	100
R-squared	0.448	0.264	0.377	0.267	0.192	0.223

Note: Column (1) contains a dummy for IMD quintile. Q1-5 refer to the IMD quintile 1-5 respectively. Constants are included but not reported. Robust standard errors are shown in parentheses. N is the number of MSOAs×Years. * p < 0.10, ** p < 0.05, *** p < 0.01

Table A3 presents the results for the parallel trend test with a Stata command `estat ptrends'. Specifically, `estat ptrends' employs the following model to test the parallel trend assumption,

$$OWOB_{idt} = \alpha + \beta Treat_{id} * Post_{td} + t\theta_1 Treat_{id} * Pre_{td} + t\theta_2 Treat_{id} * Post_{td} + \varepsilon_{idt}$$

Where, the subscript d indicates a deprivation quintile. Pre is a pre-intervention time indicator that is equal to 1 if the year is before or in 2015 and 0 otherwise. Post is a post-treatment indicator that is set to 1 if the year is after 2015 and 0 otherwise. Thus, θ_1 is the parameter of coefficient that estimates the pre-intervention trend difference between the treatment and control groups. The null hypothesis of `estat ptrends' test is that there are parallel trends before the intervention adopted (i.e. $\theta_1 = 0$). A F-test was used to test this hypothesis.

Table A3. Alternative parallel-trends test

	F-statistic (1)	P-value (2)
IMD Quintile 1	3.83	0.08
IMD Quintile 2	2.80	0.12
IMD Quintile 3	7.19	0.03
IMD Quintile 4	5.92	0.03
IMD Quintile 5	0.86	0.38

Note: This table reports results from the parallel trend test with a Stata command `estat ptrends' by IMD quintile. The null hypothesis is that the parallel trends exist between the treatment and control groups before the intervention. A F-test was used to test the null hypothesis.

Table A4. Pre-treatment Placebo tests (Test of parallel trends assumption)

	Overall (1)	Q1 (2)	Q2 (3)	Q3 (4)	Q4 (5)	Q5 (6)
Placebo Year 2012	-2.776**	-4.945**	3.340	-3.692	-3.668*	1.623
	(1.228)	(1.964)	(2.019)	(2.207)	(2.106)	(2.403)
Placebo Year 2013	-3.118**	-5.839***	3.996	-5.309**	-4.108*	2.521
	(1.267)	(2.087)	(3.634)	(2.217)	(2.076)	(2.426)
Placebo Year 2014	-2.825*	-5.326*	1.581	-4.838**	-3.511	1.943
	(1.619)	(2.874)	(2.100)	(2.268)	(2.711)	(3.395)
N (Number of MSOAs×Years)	270	50	60	50	60	50

Note: This table reports results from placebo tests by IMD quintile. 2012, 2013, and 2014 are the proposed timing for three different placebo treatments. Constants, Gateshead dummies, and post-intervention dummies are included but not reported. Robust standard errors are shown in parentheses. N is the number of MSOAs×Years. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A5. Alternative matched sample using number of fast-food outlets per km^2

	Overall	Q1	Q2	Q3	Q4	Q5
	(1)	(2)	(3)	(4)	(5)	(6)
Treat	2.331***	2.427**	3.706***	1.436	3.219***	-0.066
	(0.439)	(0.934)	(0.759)	(1.065)	(0.937)	(1.221)
Post	1.439***	0.960	3.822***	4.609***	-1.994*	-0.347
	(0.482)	(0.717)	(0.686)	(1.059)	(1.085)	(1.293)
Treat * Post	-1.072	1.986	-4.255***	-6.490***	3.640**	-0.418
	(0.703)	(1.511)	(1.155)	(1.413)	(1.396)	(1.918)
N (Number of MSOAs× Years)	520	100	120	100	120	80
R-squared	0.484	0.231	0.204	0.246	0.337	0.006

Note: Column (1) contains a dummy for IMD quintile. Q1-5 refer to the IMD quintile 1-5 respectively. There are 80 number of observations in IMD quintile 5 because one Gateshead MSOA was not able to be matched with any MSOA in the other local authorities. Constants are included but not reported. Robust standard errors are shown in parentheses. N is the number of MSOAs×Years. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A6. Sub-sample (from 2013 to 2020) analysis

	Overall	Q1	Q2	Q3	Q4	Q5
	(1)	(2)	(3)	(4)	(5)	(6)
Treat	0.865	0.690	2.345**	0.509	-0.537	1.302
	(0.599)	(1.334)	(1.086)	(1.607)	(1.272)	(1.410)
Post	0.957	1.019	3.114***	1.788	-1.018	-0.156
	(0.643)	(1.267)	(0.953)	(1.580)	(1.461)	(1.858)
Treat * Post	0.149	3.146	-3.597***	-2.629	3.278*	0.672
	(0.821)	(1.915)	(1.365)	(1.894)	(1.751)	(2.204)
N (Number of MSOAs× Years)	432	80	96	80	96	80
R-squared	0.472	0.173	0.105	0.051	0.066	0.028

Note: Column (1) contains a dummy for IMD quintile. Q1-5 refer to the IMD quintile 1-5 respectively. Constants are included but not reported. Robust standard errors are shown in parentheses. N is the number of MSOAs×Years. * p < 0.10, ** p < 0.05, *** p < 0.01