UCD GEARY INSTITUTE FOR PUBLIC POLICY
DISCUSSION PAPER SERIES

Childhood obesity and maternal education in Ireland

David Madden
Geary Institute for Public Policy and School of Economics,
University College Dublin

Geary WP2016/14
November 21, 2016

Childhood Obesity and Maternal Education in Ireland

David Madden

(University College Dublin)

November 2016

Abstract: This paper analyses the socioeconomic gradient of chilidhood obesity in Ireland using the Growing Up in Ireland data with three innovations compared to previous work in the area. A different measure of socioeconomic status, maternal education, is employed. In addition, the depth and severity of obesity are examined as well as the incidence. Finally, the use of two waves of longitudinal data permits the analysis of the persistence of obesity. Results show that overall childhood obesity stabilised between the two waves. However the socioeconomic gradient becomes steeper in wave 2 for girls and in particular when depth, severity and persistence of obesity are accounted for. Girls whose mothers fail to complete secondary education are shown to be at a particular disadvantage.

Keywords: Obesity, socioeconomic gradient, persistence

JEL Codes: I14, I31, J13.

Corresponding Author: David Madden,

School of Economics,

University College Dublin,

Belfield,

Dublin 4,

Ireland.

Phone: 353-1-7168396

Fax: 353-1-2830068

E-Mail: david.madden@ucd.ie

Childhood Obesity and Maternal Education in Ireland

1. Introduction

There has been much concern in recent years about rates of obesity and overweight among children and adolescents, in Ireland and abroad.[1] Ireland for example has seen an ongoing campaign entitled *Let's Take On Childhood Obesity, One Step at a Time*, co-ordinated between the *safe*food organisation and the Department of Health, while international concern is reflected in the review by Han et al (2010). There is also evidence that, in some countries at least, rates may have plateaued (Keane et al, 2014, Olds et al, 2011).

Childhood obesity is a cause for concern as it may be linked to a variety of serious conditions including cardiovascular dysfunction, type 2 diabetes, pulmonary, hepatic, renal and musculoskeletal complications. There are also likely to be adverse effects on health related quality of life and emotional states (Olds et al, 2011). In addition should obesity continue into adulthood, then there are increased risk factors for further serious conditions.

In this paper we examine the trend in obesity amongst a group of Irish children using a nationally representative data source, *Growing Up in Ireland (GUI).* GUI follows the same children over time, and not only are we able to provide a snapshot of obesity at two different points in time for a cohort of nine year olds and then the same cohort of 13 year olds, in addition, since it is the same children in these cohorts, we are able to account for persistence vin obesity over this period. In carrying out this analysis we apply techniques employed in the economics literature on poverty and mobility. Recent research in these areas has moved on from just analysing snapshots at a given point in time and attention is now paid to examining persistence of poverty for the same cohort of people (see for example Jenkins and van Kerm, 2006, Grimm, 2007, Gradin et al,

---

[1] For the sake of brevity we will use the generic term "children" to indicate anyone aged less than 18, while fully acknowledging that height and weight differ systematically by age. The two waves of data which we will be analysing include children aged 9 and 13, the latter age being more accurately described as early adolescence.

2012). Similarly, in our analysis of obesity below, we incorporate measures which explicitly take account of persistence between periods.

A critical feature of our analysis is that we go beyond measuring the mere incidence or prevalence of obesity. We also measure what we term the *depth* of obesity i.e. the extent to which obese children exceed the obesity thresholds, and also what we term the *severity* of obesity, which takes account of the distribution of obesity amongst obese children. These additional measures are particularly relevant if risk ratios for an obese individual increase the higher above the obesity threshold they are.

There is considerable evidence that obesity, both for children and adults exhibits a socioeconomic gradient (McLaren, 2007, Chung, 2016), whereby obesity tends to be higher amongst those with lower socioeconomic status (SES). SES can be measured using a variety of indicators, including income, social class or education. In this paper we examine the gradient of childhood obesity with respect to maternal education levels (specifically, the highest level of education achieved by the mother, or in her absence, the principal care-giver).

We have a number of reasons for choosing this particular measure of SES. First of all, in large survey-based datasets, it is likely to be measured with reasonable accuracy, more so than, for example, disposable income. Secondly, between the two waves of our data (when children are aged nine and thirteen) maternal education remains virtually unchanged. Finally, there is a long-established literature, dating from the seminal work of Grossman (1972) outlining the link between education levels and health. One of the proposed pathways whereby education may affect health is via decisions regarding diet and lifestyle and this would seem to be of particular importance with respect to obesity. It seems plausible that for most children decisions regarding diet would be made by the principal caregiver (in almost all cases the mother) and hence maternal education rather than child education may exert the more significant impact on childhood obesity.

The remainder of the paper is laid out as follows. In section 2 we discuss the measurement of obesity for children and review other work in this area for Ireland. We also refer to some of the literature on the socioeconomic gradient of childhood obesity. In section 3 we discuss our data and also provide an analysis of obesity using the snapshot method i.e. we treat the data as if it were two cross-sections and do not exploit its panel nature. In section 4 we take account of the panel nature of the data. In both sections 3 and 4 we employ some of the techniques of the inequality/poverty literature. Section 5 provides discussion and concluding comments.

2. The Measurement of Obesity in Children and Adolescents

The most common measure of obesity for adults is derived from body mass index (BMI). BMI is obtained by dividing weight (in kilos) by height (in metres) squared. The World Health Organisation suggests a threshold BMI of 25 for "overweight", a threshold of 30 for "obesity" and a threshold of 40 for "severely obese".

It is worth noting that there is criticism of BMI as a measure of obesity with some authors suggesting that other measures such as total body fat, percent body fat and waist circumference are superior measures of fatness (see Burkhauser and Cawley, 2008). However, most of the alternative measures suggested are typically not available in large-scale, nationally representative datasets. Thus we will use BMI as our indicator for obesity in this paper, while bearing in mind that the nature of the analysis presented here could also be applied to alternative measures of obesity.

There is, however, an additional issue which must be taken into account when using BMI to measure obesity in children. While the BMI thresholds for adults have general acceptance and do not change with age, the same is not true for children, where BMI can change substantially with age and gender. For example, at birth median BMI is around 13, this increases to 17 at age 1, decreases to 15.5 at age 6 and increases to 21 at age 20 (Cole et al, 2000). Cole et al (2000) provide a set of cutoff points for BMI for childhood based upon international data and which they suggest should be used for international comparisons. They obtain these by drawing centile curves which pass through the adult cut-off points at age 18 and which then can be traced back to provide "equivalent" cut-off points for different ages and genders. The cutoffs are obtained by averaging data from large nationally representative surveys from Brazil, Great Britain, Hong Kong, the

Netherlands, Singapore and the US, with in total nearly 200,000 observations aged from birth to 25.

The cutoffs are provided at half-yearly intervals. Thus for the first wave of our data, the vast majority of children are aged 9. Assuming that age is distributed uniformly within the cohort of nine year olds, it seems appropriate to take the cut-off for age 9.5. Similarly for the second wave of our data (who are mostly 13 year olds) we use the cut-off for age 13.5. For the very small number of children aged 8 and 10 we use the 8.5 and 10.5 cutoffs respectively and similarly for the second wave we use the 12.5 and 14.5 cut-offs for those aged 12 and 14. The age and gender specific cutoffs are provided in table 1. These cutoffs have also been used in previous studies which have analysed child obesity using GUI e.g. Layte and McCrory (2011).

We now briefly review some of the evidence concerning childhood obesity in Ireland. Perry et al (2009) showed that weight for children in Ireland had increased disproportionately compared to height, thus leading to a rise in BMI, over the period from the late 1940s to the mid 2000s. Keane et al (2014) provide a comprehensive review of more recent evidence concerning trends and prevalence of obesity among primary school aged children in Ireland, covering the period from 2002 to 2012. After carefully reviewing a number of studies, they confined their analysis to 14 studies which met their inclusion criteria. Sample sizes ranged from 204 to 14036 and the setting was either the home or the school. They detected a small significant declining trend in obesity prevalence over time when national and regional studies were combined. However, neither national nor regional studies on their own revealed a declining trend and no trend was evident either in studies of overweight. They also detected a consistently higher prevalence of obesity amongst girls compared to boys. Overall, the study concluded that while rates of childhood obesity and overweight in Ireland were high, they did appear to be stabilizing.

These findings are consistent with results from a number of other developed countries. Olds et al (2011) present evidence from nine countries (Australia, China, England, France, Netherlands, New Zealand, Sweden, Switzerland and the US) suggesting no change in the unweighted average of obesity prevalence in these countries over the period 1995 to 2008. Within this overall average however, rates of change differed by gender, age, socioeconomic status and ethnicity.

With respect to the socioeconomic gradient of childhood obesity, Chung et al (2016) provide a recent comprehensive review of childhood and adolescent obesity across a number of economically advanced countries, paying particular attention to differing prevalence by SES (this was measured by a variety of indicators including parental education in some studies). Their conclusion is that childhood obesity remains a serious issue in these countries, even allowing for some recent findings that it is stabilizing. Evidence regarding the socioeconomic gradient is mixed. Differences in childhood obesity by SES remain. In some cases these differences appear to have stabilized, or may even be declining, but in other countries the gradient appears to be increasing.

Using wave 1 of GUI Layte and McRory (2011) found social class inequalities in the incidence of obesity and overweight with higher proportions of children from semi-skilled and unskilled social class households classified as obese or overweight, compared to children from professional backgrounds. Walsh and Cullinan (2015) also found a significant socioeconomic gradient of obesity using the same dataset. In their case the measure of SES was equivalised disposable income and the gradient was explored using concentration indices. However, both of these papers only utilized wave 1 of GUI and in the case of Walsh and Cullinan their focus was on the decomposition of the gradient for that single cross-section.

Our study differs from and builds upon these earlier works in a number of ways. First of all, we analyse the socioeconomic gradient using a different measure of SES, maternal education. Secondly, as well as examining the incidence of obesity, we also examine the *depth* of obesity (how far above the obesity thresholds children are) and also what we term the *severity* of obesity, which takes into account the distribution of BMI amongst the obese. We also present results for two waves of GUI, and exploiting the panel nature of the data we are able to take account of persistence of obesity amongst the same children. We now discuss our data and present our first results using the snapshot approach (i.e. treating the two waves of GUI as separate cross-sections).

3. Data and results

Our data comes from the first two waves of the GUI child cohort. This tracks the development of a cohort of children born in Ireland in the period November 1997-October 1998 (see Williams et al, 2009). The sampling frame of the data was the national primary school system, with 910 randomly selected schools participating in the study. Weight was measured to the nearest 0.5 kg using medically approved flat mechanical scales and children were advised to wear light clothing. Height was measured to the nearest mm using a height measuring stick.

In all, the original sample in wave 1 consisted of 8568 children. Observations for where there were not valid height and weight measures were dropped, leaving a sample size of 8136. These children were then re-surveyed at age 13 for the second wave. Since we wish to follow trajectories of BMI over the two waves, we choose to use a balanced panel i.e. only those observations who appear in both waves. That reduces the sample size to 7165. When we then once again drop observations where valid height and weight observations are not available the final sample reduces to 6973 (3424 boys and 3549 girls).

In making these adjustments the issue of non-random attrition arises. The greatest loss of observations comes when we keep only those children who appear in both waves i.e. the attrition between waves 1 and 2. When allowance is made for families who left Ireland between waves 1 and 2, the attrition rate is less than 10 per cent (see Quail et al, 2014). However, attrition is such surveys is rarely random and this is confirmed in Quail et al (2014) who show that non-response for wave 2 is lower amongst younger and less well educated respondents (by "respondents" here we mean the principal caregiver, in almost all cases the mother). Correspondingly, the data was re-weighted so that the weight in wave 2 was the product of the original sampling weight for wave 1 and the attrition weight which took account of non-random attrition. In the analysis which follows it seems most appropriate to use these wave 2 weights as we are only carrying out analysis on the balanced panel i.e. those observations who appear in both waves.

There is one final adjustment we make to the data which facilitates our analysis. As the obesity and overweight thresholds for BMI change (since the sample is now four years older) a simple comparison of BMI can be misleading. Consequently we compare *normalized* BMI figures, where BMI is divided by the appropriate overweight/obesity threshold. Thus for example, suppose we are comparing obesity between the two waves. A normalized BMI of 1.1 indicates that the child had a BMI which was 1.1 times the relevant threshold for their age and gender. This facilitates comparisons across time and gender where these thresholds differ.

In table 2 we present, by gender and education, normalized BMI and the incidence of obesity for waves 1 and 2. The results here confirm the findings in Keane et al (2014). The figures for normalized BMI (relative to the obesity threshold) show that it falls by about 1.5% while the rate of obesity falls slightly. Even allowing for different rates of change in the thresholds this suggests some changes in the shape of the distribution, with less weight in the more extreme tail but slightly more between the 75^{th} and 95^{th} percentile. This can be seen in figure 1 where we present kernel densities for the two waves for BMI normalized to the obesity threshold.

Gender differences are also apparent, with higher rates of obesity observed for girls and the gap in obesity rates between the genders stays pretty much the same between waves 1 and 2.

We also present the results by maternal education level. We break down the sample into four maternal education categories: (i) level 1, completion of lower secondary schooling (ii level 2, completion of secondary schooling (iii) level 3, obtaining a post secondary school diploma or cert and (iv) level 4, completion of third level education. A socioeconomic gradient is observable, though in some cases the differences are not statistically significant. Between waves 1 and 2, obesity rates increase for the lowest level of maternal education, fall for the next two levels and then rise marginally for the highest level of maternal education. Overall, this suggests that the socioeconomic gradient of the incidence of obesity (by maternal education) has risen slightly between waves 1 and 2.

Note that allowing for the socioeconomic gradient and what we can call a gender gradient, there are some quite substantial differences between different cells in these two tables. For example, the obesity rate for girls whose mother left school at or before 16 is 12.7 per cent in wave 2, whereas that for boys whose mother has university education is only 1.8 per cent, which corresponds to a seven fold difference.

The difference by maternal education can also be seen by examining the cumulative distribution functions for each level of education. Figure 2 shows the CDF for normalized BMI by maternal education for wave 1, while figure 3 shows the same information for wave 2. We see that the CDF for education level 1, the lowest level of education, lies below that of the other CDFs, indicating that for almost any given percentile (on the vertical axis), normalized BMI is higher for this group than the other groups. Similarly the CDF for the highest level of education lies above that of the others. The CDFs for the two intermediate groups lie in between and are very close to one another, crossing at times. These CDFs reflect the results from table 2, indicating a clear social gradient by level of maternal education. We now analyse this gradient in more detail, employing techniques from the poverty and inequality literature.

The analysis of obesity has many parallels with that of income poverty (for a more detailed discussion, see Joliffe, 2004 and Madden, 2012). In both cases a key threshold is chosen: in the case of obesity a critical value of BMI is chosen, while for poverty a poverty line is chosen. In both cases also typically the principle of focus applies i.e. the measurement of obesity is not sensitive to developments in BMI below the threshold, while poverty is not sensitive to developments in income above the poverty line.

However, measurement of obesity rarely goes beyond the stage of calculating its incidence or prevalence. In this regard it is subject to the same criticism as measures of poverty which only employ the headcount approach. Thus measuring obesity by the simple fraction of the population with BMI above a particular threshold ignores much of the available information. It is a crude aggregate measure which is insensitive to how far above the threshold obese people are and is also insensitive to the distribution of BMI above the obesity threshold. Taking account of the depth of obesity is of importance if we believe that higher values of BMI imply higher risk ratios for the adverse conditions associated with obesity and taking account of the distribution of BMI above the threshold is important if there is evidence that these risk increase in a non-linear manner.

There is some evidence that such non-linearity is present, for some conditions at least. For example Brown et al (2000) present data on the link between BMI and hypertension and dyslipidemia for a sample of adults in the United States. For males in their sample an increase in BMI from the range 25-27 to 27-30 leads to a statistically significant increased risk ratio for high blood pressure from 2.4 to 3.1 (compared to a risk ratio of 1.0 for BMI<25). However, an increase in BMI from 27-30 to over 30 leads to a statistically significant increase in risk ratio from 3.1 to 8.7. The comparable figures for women are for increased risk ratios from 1.7 to 2.3 to 9.1 (all statistically significant). While this data is not unambiguous evidence in favour of a non-linear effect, since the authors do not present evidence on the average BMI for those people with BMI over 30, it is strongly suggestive. Haj Jee et al (2006) present graphs of hazard ratios for death from a number of different causes against BMI for a sample of Korean adults. The graphs of the hazard ratios show a clear non-linearity with a steeper slope at higher levels of BMI.

These issues have been extensively covered in the poverty literature and measures of poverty have been developed which address these problems. Perhaps the best known of these measures is the Foster Greer Thorbeck (FGT) measure of poverty. In terms of income, the FGT measure is

$$P_\alpha = \frac{1}{n}\sum_{y_i<z}\left(\frac{y_i - z}{z}\right)^\alpha$$

where y_i refers to the income of person i, z is the poverty line and α is the parameter reflecting the weight applied to each poverty gap. When α=0 we have a simple *incidence* or headcount measure, when α=1 we have a measure which adds together the poverty gaps and takes account of *depth* while α=2 addresses what we term the *severity* of poverty and incorporates the distribution of income below the poverty line assigning a higher weight to bigger gaps.

When applying the FGT measure to obesity there is one modification which must be made. In the poverty literature the focus is on those observations *below* the threshold, whereas in the case of obesity, focus is on observations *above* the threshold. Thus to align the poverty and obesity measures, we apply the FGT measure to the *inverse* of normalised BMI, with a threshold set at unity. Our measure is thus

$$NBMI_{\alpha} = \frac{1}{n} \sum_{NBMI_i < 1} \left(NMBI_i - 1 \right)^{\alpha}$$

where $NBMI_i$ is the inverse of normalised BMI for person i. A further advantage of the $NBMI_{\alpha}$ measure is that it is additively decomposable. Thus the overall value of the index is a weighted sum of the values of the index for a set of mutually exclusive and exhaustive subsets where the weights are the corresponding proportions of the population. Thus it is possible to measure the contribution of a particular subgroup (for example maternal education) to overall obesity. In subsequent analysis we calculate the value of the index by maternal education and then express it as a fraction of the measure for the overall population, thus indicating whether a particular sub-group contributes disproportionately to overall obesity.

We calculate $NMBI_{\alpha}$ for α=0,1,2 and for the overall population and by maternal education. Note that it is not meaningful to compare these measures across different values of α. Each value of α reflects a different approach and value judgement with respect to measuring obesity, and thus while measures and rankings across maternal education for given values of α are valid, comparison of measures for different values of α are not. Thus in order to facilitate such a comparison, we apply a further normalisation and express the measures for each level of maternal education relative to the overall measure for the population. Thus if this value exceeds unity for any particular subgroup, then that subgroup is contributing a greater than proportionate share of overall obesity (the actual values of the obesity measures are presented in the data appendix).

Table 3 provides relative ratios of $NBMI_{\alpha}$ for waves 1 and 2 for values of α=0, 1, 2. For each measure the relative ratio is expressed as a ratio of the relevant overall population measure in wave 1. Thus, for example, the relative ratio for $NMBI_2$ in wave 2 for girls whose mothers had lower secondary education is 2.8772. This tells us that relative to the value of this measure for the overall population in wave 1, the value for this demographic group in wave 2 is about 187% higher. Note that since we are dealing with a balanced panel the population shares by subgroup are unchanged between waves.

We also present this information graphically in figures 4a-4c. To avoid too much clutter on the graphs we simply present the obesity measures by gender and maternal education (relative to the overall population measures). The three graphs refer to the different values of α, capturing incidence, depth and severity respectively.

We can examine these relative ratios across three different dimensions, time, gender and maternal education. With respect to time, as already observed, the overall rate of obesity fell slightly between waves. The same can also be said for when α=1, 2 i.e. when account is taken of the depth of obesity and also of severity i.e the distribution of BMI amongst the obese. In both cases the change in the obesity measure is marginal.

What about the gender dimension? First we note that for all values of α, the obesity rate for girls is higher than that for boys (bear in mind that these figures refer to normalised obesity, so account has been taken of the differential thresholds for girls). For example, in wave 1 when α=0, the case of obesity incidence, girls have obesity rates about 20% above the population average, whereas boys have obesity rates about 20% below. The excess for girls is somewhat lower when α=1,2. The situation changes in wave 2 however. While excess in terms of incidence (when α=0) remains at about 20%, the excess for measures where α>0 increases to up to 50% (relative to wave 1 population averages). This indicates that between wave 1 and wave 2, what we might call the gender gradient becomes steeper when dealing with obesity measures which take account of the depth and severity of obesity.

What about the gradient with respect to the final dimension we consider, maternal education? Table 4 reveals that for both genders, for both waves and for all obesity measures (α=0, 1, 2) we observe a clear gradient. Figures 4a-4c are very helpful in this regard as the slopes of the piecewise linear curves quite literally show the gradient. For pretty much all obesity measures and both genders and waves, the clearest gradient is to be seen from the lowest level of maternal education to the next. Thus those children whose mothers do not complete secondary education appear to be at a serious disadvantage with respect to obesity. Between the next two school levels, the gradient is not so clear and it seems most reasonable to regard outcomes for these two levels of maternal education as essentially the same. Typically, we then observe another element of the gradient as we move to the highest level of maternal education, third level.

How does the gradient differ by gender and by wave? Bearing in mind that overall levels of obesity are higher for girls, the gradient does not seem to differ much by gender in wave 1, for all measures of obesity. Turning to wave 2 however, the gradient for boys is more or less unchanged, but that for girls has become noticeably steeper, in particular that portion of the gradient between education levels 1 and 2. Thus by age thirteen the comparative disadvantage suffered by girls whose mothers have the lowest levels of education has worsened, and this effect is slightly more pronounced for depth and severity of obesity.

With so much heterogeneity by factors such as gender, maternal education etc we find that for some pairwise comparisons the measures differ quite radically. Thus, to take one of the most extreme examples, in wave 2, when $\alpha=2$ (i.e. allowing for both the depth of obesity and its distribution amongst the obese), we see that the measure for girls whose mothers had lower secondary education is over fifteen times higher than for boys whose mothers had third level education.

Thus to summarise, we find an obesity gradient by wave (with wave 2 higher), by gender (with higher rates for girls) and also by maternal education, with the steepest portion of the gradient between levels 1 and 2 of maternal education. The gradients also appear to be marginally steeper as the value of α increases i.e. as we take into account the depth and severity of obesity. Thus even while the overall rate of obesity has stabilised (and even slightly dropped) between waves 1 and wave 2, this hides considerable heterogeneity in experience by gender and maternal education. The relative position of girls whose mothers have the lowest level of maternal education has deteriorated considerably.

Thus far we have analysed obesity as though we were dealing with two independent cross-sections. But of course, this is panel data we are dealing with, and it is possible to extend our analysis taking this into account, which is the subject of the next section.

4. Measuring Obesity with Longitudinal Data

In our analysis so far we have ignored the panel nature of the data available to us. Our analysis has measured obesity taking account of its incidence, depth and severity. However in the analysis so far we have applied the principle of anonymity i.e. we do not concern ourselves with the precise identity of those who are obese in the two waves and whether it is the same, or different people, who are obese. It seems plausible that we should be concerned with the identity of the obese. Thus given a situation where, for example, 5% of the population are obese in both waves of our data, we would wish to discriminate between the case where it is the same 5% who are obese in both waves, or a completely different 5%. This, of course, is an extreme example and an intermediate situation seems most likely, where some people are obese in both periods, whereas others may be obese in only one period.

Once again, we draw on the poverty literature where this issue has received much recent attention (for example, see Gradin et al, 2012). Gradin et al provide a comprehensive discussion of the issues involved in incorporating non-anonymity and the longitudinal nature of data into measures such as poverty and obesity. Essentially the one period indicator of obesity is replaced with an intertemporal measure, which takes account of obesity over multiple periods and can incorporate issues of depth and severity. This intertemporal measure is then aggregated in the standard FGT manner, also incorporating depth and severity. In addition, they also propose an intertemporal spell duration sensitivity axiom. Thus, given any two spells of obesity, the index is higher when both of the spells are consecutive. This implies that concentrating periods of obesity into a fewer number of spells should increase the individual index.

Suppose we define the intertemporal obesity index for individual i as

$$Ob_i = \frac{1}{T}\sum_{i=1}^{T}(NBMI-1)_{it}^{\gamma} w_{it}$$

where T represents the total number of time periods under review, $(NBMI-1)_{it}^{\gamma}$ is the per period normalised obesity gap for individual i and γ is the analogue of the α parameter in the one period case, in that it captures the sensitivity of the intertemporal obesity index to greater inequality of obesity experiences over time, for the same *person*. The final term in the expression above $w_{it} = \left(\frac{s_{it}}{T}\right)^{\beta}$ captures the feature that a higher weight should be placed upon consecutive spells, since each obesity spell is weighted by duration, assuming β>0.

Having obtained the intertemporal obesity index for each individual, the aggregate index is obtained as the weighted average of the individual indices

$$NBMI_{\alpha} = \frac{1}{N}\sum_{Ob_i>0} Ob_i^{\alpha}$$

where, as before, if the parameter α>1 then we have greater sensitivity of the aggregate index to the distribution of intertemporal obesity indices among obese individuals.

Following Gradin et al, these indices can be combined to give the overall expression for the index of intertemporal obesity

$$NBMI_{\alpha} = \frac{1}{N}\sum_{i=1}\left(\frac{1}{T}\sum_{i=1}^{T}(NBMI-1)_{it}^{\gamma}\left(\frac{s_{it}}{T}\right)^{\beta}\right)_i^{\alpha} \text{ if } \alpha>0$$

$$=q/N \text{ if } \alpha=0$$

Where q/N is simply the fraction of the population which has at least one period of intertemporal obesity.

We now present values of this intertemporal index for various values of α, β, and γ. Note that once again it is not appropriate to compare different absolute values of the index when different values for these parameters are assumed. However, we can normalise the value of the index at 1 for an arbitrary period and then compare relative values of the index for different levels of maternal education controlling for the values of α, β, and γ. In the analysis which follows, given that we only have two periods, the β parameter is essentially redundant and so we present results for the case where β=0.[2]

In table A2 we present the absolute values of the intertemporal index for a grid of different values of α and γ. Note that when α=0, the index is not sensitive to the values of the other parameters and the index simply collapses to the incidence of obesity. However in this case it is the fraction of people who have been obese in *either* wave 1 or 2 (or both) i.e. the fraction of the population who experience at least one spell of obesity, and this is around 8.5 per cent for the overall population.

Table 4 then presents these results by maternal education, relative to their values in table A2. Thus for maternal education level 1 (primary or lower secondary), when α=0, the index is 1.583, implying an excess intertemporal obesity rate of more than 50 per cent compared to the overall population. The corresponding graphs are shown in figures 5a-5c.

Overall, the results in table 4 pretty much mirror those in table 3. Again, the gradient is clear, with education level 1 well above population averages, education level 4 well below, and education levels 2 and 3 very close together and just below population averages. Again, the overall level of intertemporal obesity is higher for girls, though the steepness of the gradient appears quite similar by gender.

In terms of how the gradient varies with respect to the values of α, and γ, the evidence suggests that the excess rates of intertemporal obesity for education level 1 increases with higher values of the parameters. Recall again what these higher values imply: higher values of α imply we take account of the depth of intertemporal obesity amongst the obese, while a value in excess of one allows for sensitivity of the index to the distribution of intertemporal individual obesity experiences amongst the obese. Table 4

---

[2] Our results are not sensitive to the choice of β and so we impose β=0. Results for β=1, 2 are available on request.

suggests a marginal increase in the socioeconomic gradient as the value of α rises, since the value for the lowest level of maternal education increases slightly while it remains more or less unchanged for other levels of maternal education.

The γ parameter is also a type of FGT parameter, except that this time, rather than allowing for sensitivity of obesity experiences across individuals in the same period, it captures sensitivity to obesity experiences *for the same individual* across time. There seems quite considerable evidence of a higher socioeconomic gradient with higher values of this parameter, indicating that as well as a socioeconomic gradient existing with respect to the simple cross-sectional measures of obesity, it also exists with respect to the *persistence* of obesity. Thus (relative to the value for the overall sample) the excess of intertemporal obesity for the lowest level of maternal education rises from around 60% (when γ=0) to over 100% (when γ=2). The increase in the excess depends upon the underlying value of α, and in general higher values of excess are associated with higher values of both parameters. This further highlights the plight of girls whose mothers have the lowest level of education. They suffer from multiple disadvantage in that not only do they have higher incidence, depth and severity of obesity, they also exhibit greater persistence.

At the other end of the educational spectrum, we see the corollary of this, in that values of the intertemporal index for maternal levels 2 and 3, and in particular for level 4, are well below the overall population values. For education level 4, the lowest values of the intertemporal index are associated with high values of both α and γ indicating a steepening of the gradient.

Overall, the socioeconomic gradient of intertemporal obesity is not dissimilar to that of (the average) the two individual waves of data, perhaps reflecting that two waves of panel data may not be sufficient for intertemporal effects to show through clearly. However, the additional element of persistence highlights an additional layer of disadvantage experienced by children (especially girls) with the lowest level of maternal education.

5. Conclusions

This paper has examined the socioeconomic gradient of obesity amongst children in Ireland, using two waves of the GUI data. Socioeconomic status is measured via the level of education of the principal caregiver, the mother in almost all cases. There are two principal innovations in the paper compared to previous work in the area. First of all, as well as the typical measure of the incidence of obesity, we also measure the depth and severity of obesity. The inclusion of the second wave of GUI data also permits the analysis of the persistence of obesity across waves.

We find that while the overall obesity rate has stabilised, this masks considerable heterogeneity by gender and by maternal education. Obesity rates are higher for girls and so too are socioeconomic gradients, particularly in wave 2. The gradient is at its steepest between levels 1 and 2 of maternal education i.e. where mothers fail to complete secondary school education. The gradient also appears to be steeper for obesity measures which go beyond mere incidence. In addition, the gradient also appears to steepen when greater account is taken of persistence. This points to a pattern of multiple disadvantage for some children, in particular girls whose mothers have the lowest level of education, and suggests resources to combat obesity might be fruitfully targeted at this group.

Table 1: Age and Gender Specific Cutoffs for Overweight and Obesity from Cole et al

	Male		Female	
Age	**Overweight**	**Obese**	**Overweight**	**Obese**
8.5	18.76	22.17	18.69	22.18
9.5	19.46	23.39	19.45	23.46
10.5	20.20	24.57	20.29	24.77
12.5	21.56	26.43	22.14	27.24
13.5	22.27	27.25	22.98	28.20
14.5	22.96	27.98	23.66	28.87

Table 2: Normalised BMI and obesity rates by wave, gender and maternal education (standard errors in brackets)

	Overall		**Boys**		**Girls**	
	W1	**W2**	**W1**	**W2**	**W1**	**W2**
BMI (norm)						
Overall	0.76 (0.002)	0.75 (0.002)	0.76 (0.003)	0.74 (0.003)	0.77 (0.003)	0.76 (0.003)
Ed=1	0.78 (0.005)	0.77 (0.005)	0.759 (0.006)	0.750 (0.007)	0.799 (0.007)	0.794 (0.008)
Ed=2	0.76 (0.003)	0.75 (0.003)	0.760 (0.004)	0.745 (0.004)	0.764 (0.005)	0.750 (0.005)
Ed=3	0.76 (0.004)	0.74 (0.004)	0.756 (0.006)	0.737 (0.005)	0.760 (0.006)	0.744 (0.006)
Ed=4	0.74 (0.004)	0.73 (0.004)	0.742 (0.004)	0.727 (0.005)	0.742 (0.007)	0.727 (0.006)
Obesity						
Overall	0.059 (0.004)	0.057 (0.004)	0.047 (0.004)	0.043 (0.004)	0.072 (0.006)	0.071 (0.006)
Ed=1	0.085 (0.009)	0.102 (0.01)	0.062 (0.010)	0.074 (0.012)	0.105 (0.015)	0.127 (0.017)
Ed=2	0.056 (0.006)	0.040 (0.004)	0.046 (0.007)	0.037 (0.006)	0.066 (0.011)	0.044 (0.007)
Ed=3	0.056 (0.009)	0.043 (0.007)	0.053 (0.012)	0.036 (0.007)	0.060 (0.012)	0.052 (0.011)
Ed=4	0.025 (0.005)	0.028 (0.004)	0.018 (0.004)	0.018 (0.004)	0.033 (0.009)	0.041 (0.008)

Table 3: Relative NBMI$_α$ rates by wave, gender and maternal education

	Overall		Boys		Girls	
	W1	**W2**	**W1**	**W2**	**W1**	**W2**
NMBI$_0$						
Overall	1.000	0.9661	0.7966	0.7288	1.2203	1.2034
Ed=1	1.4407	1.7288	1.0508	1.2542	1.7797	2.1525
Ed=2	0.9492	0.678	0.7797	0.6271	1.1186	0.7458
Ed=3	0.9492	0.7288	0.8983	0.6102	1.0169	0.8814
Ed=4	0.4237	0.4746	0.3051	0.3051	0.5593	0.6949
NMBI$_1$						
Overall	1.000	0.9822	0.8551	0.6048	1.1525	1.3789
Ed=1	1.6345	1.8701	1.4195	1.0644	1.8278	2.5946
Ed=2	0.7692	0.6476	0.6595	0.4949	0.8876	0.8123
Ed=3	0.9404	0.7048	0.9458	0.4922	0.9341	0.9567
Ed=4	0.4725	0.4526	0.3264	0.2493	0.6413	0.6875
NMBI$_2$						
Overall	1.000	1.0022	0.8925	0.5351	1.114	1.4934
Ed=1	1.7939	2.0022	1.8004	1.0307	1.7895	2.8772
Ed=2	0.7127	0.6294	0.5592	0.4211	0.8772	0.8575
Ed=3	0.8268	0.693	0.8026	0.3728	0.8553	1.0724
Ed=4	0.432	0.3925	0.307	0.1842	0.5768	0.6316

Table 4: Relative Intertemporal Obesity Measures by Gender and Maternal Education

	Overall			Boys			Girls		
	γ=0	γ=1	γ=2	γ=0	γ=1	γ=2	γ=0	γ=1	γ=2
$NMBI_0$									
Overall	1.000	1.000	1.000	0.8272	0.8272	0.8272	1.1816	1.1816	1.1816
Ed=1	1.583	1.583	1.583	1.3071	1.3071	1.3071	1.8311	1.8311	1.8311
Ed=2	0.8631	0.8631	0.8631	0.7631	0.7631	0.7631	0.9713	0.9713	0.9713
Ed=3	0.8375	0.8375	0.8375	0.7473	0.7473	0.7473	0.9443	0.9443	0.9443
Ed=4	0.4546	0.4546	0.4546	0.3146	0.3146	0.3146	0.6162	0.6162	0.6162
$NMBI_1$									
Overall	1.000	1.000	1.000	0.7767	0.7365	0.7125	1.2347	1.277	1.3022
Ed=1	1.6095	1.7681	1.8964	1.1705	1.2531	1.4134	2.0042	2.2309	2.3306
Ed=2	0.8292	0.7147	0.6703	0.7207	0.5825	0.489	0.9464	0.8577	0.8662
Ed=3	0.8578	0.83	0.7587	0.7604	0.7255	0.5863	0.9731	0.9539	0.9629
Ed=4	0.4634	0.4667	0.4115	0.3155	0.2904	0.2452	0.6342	0.6703	0.6035
$NMBI_2$									
Overall	1.000	1.000	1.000	0.7283	0.6879	0.7774	1.2857	1.328	1.2334
Ed=1	1.635	1.9606	2.2584	1.0395	1.3358	2.0782	2.1703	2.5222	2.4202
Ed=2	0.7966	0.6537	0.5885	0.6801	0.4977	0.392	0.9226	0.8223	0.8013
Ed=3	0.8772	0.6874	0.5168	0.773	0.5622	0.2682	1.0007	0.8357	0.8111
Ed=4	0.4719	0.4056	0.1998	0.3164	0.2303	0.1129	0.6515	0.608	0.2986

Figure 1: BMI Normalised to Obesity Threshold

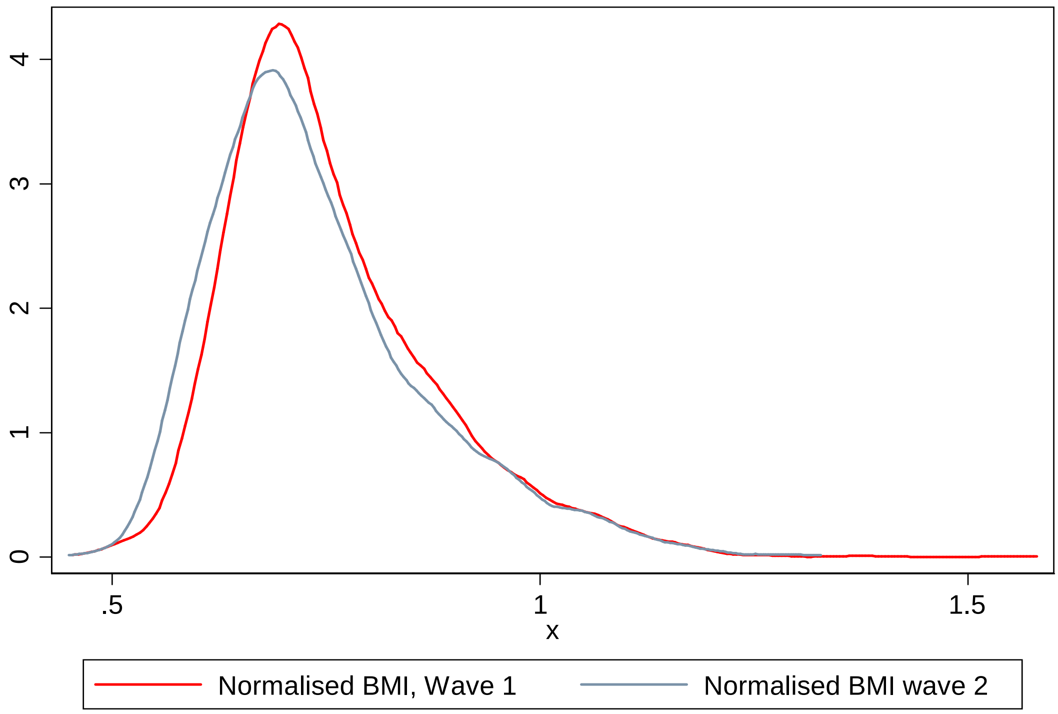


Figure 2: Cumulative Distribution Functions of Normalised BMI by Maternal Education, Wave 1

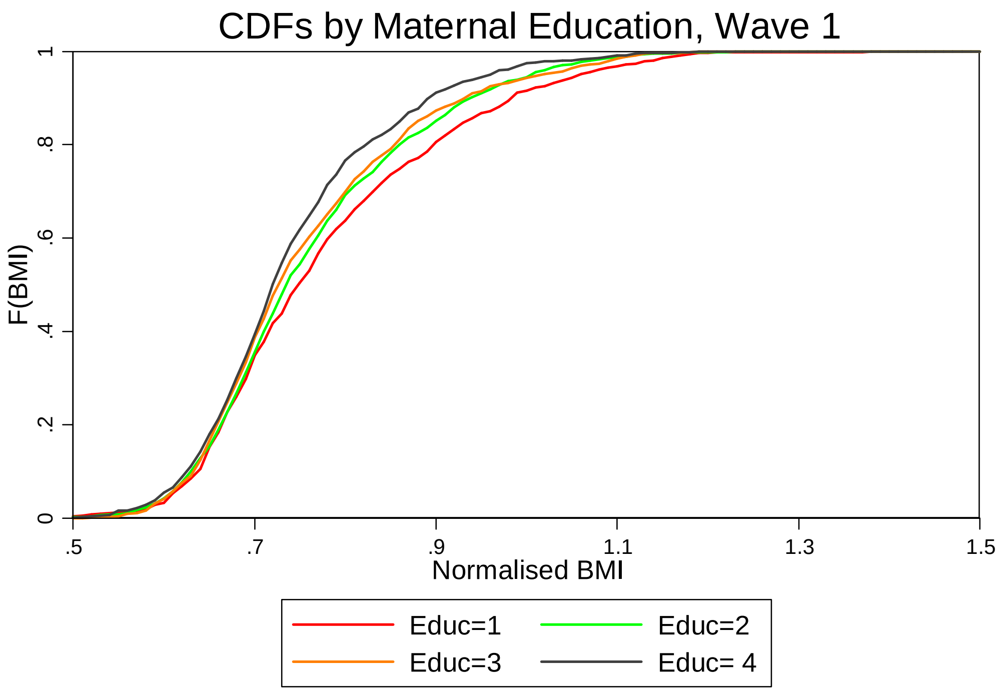
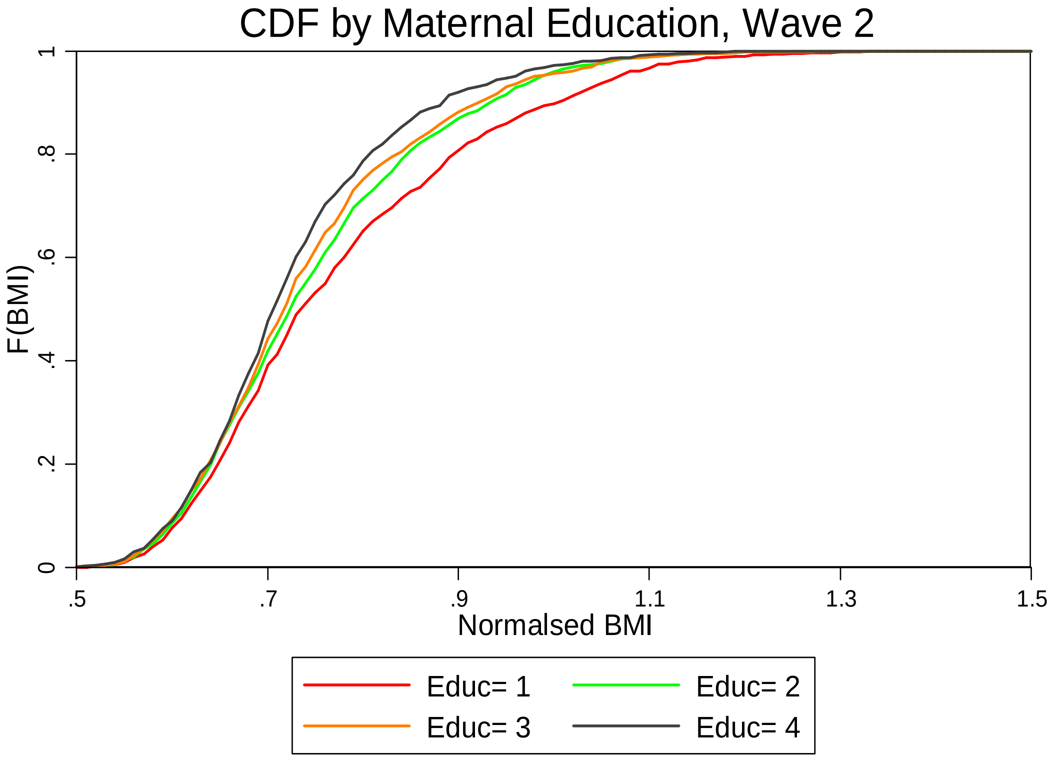
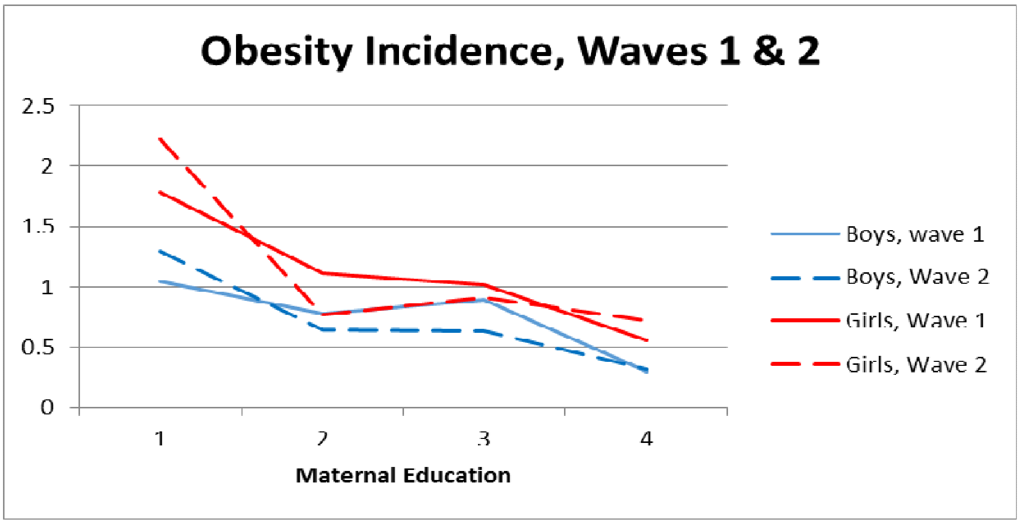
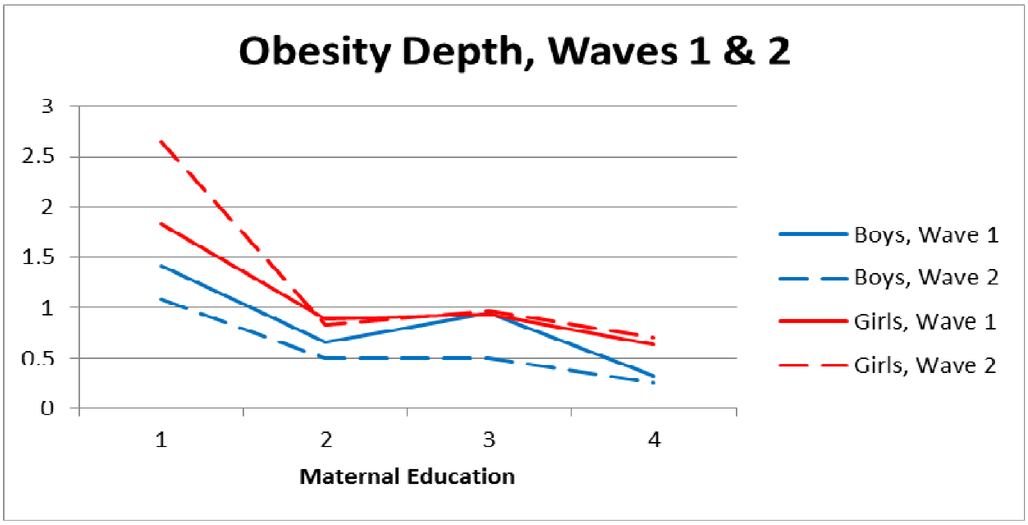


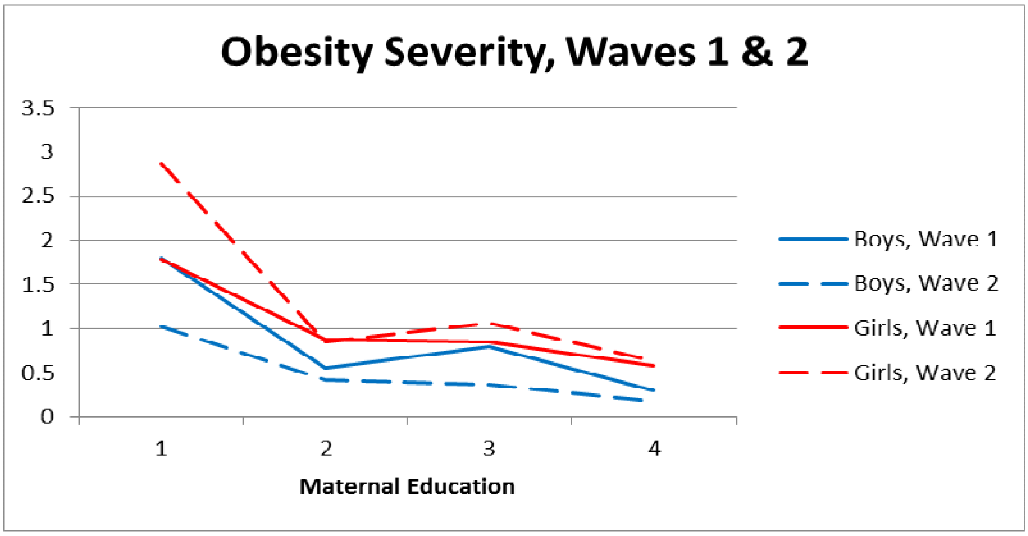
Figure 3: Cumulative Distribution Functions of Normalised BMI by Maternal Education, Wave 2



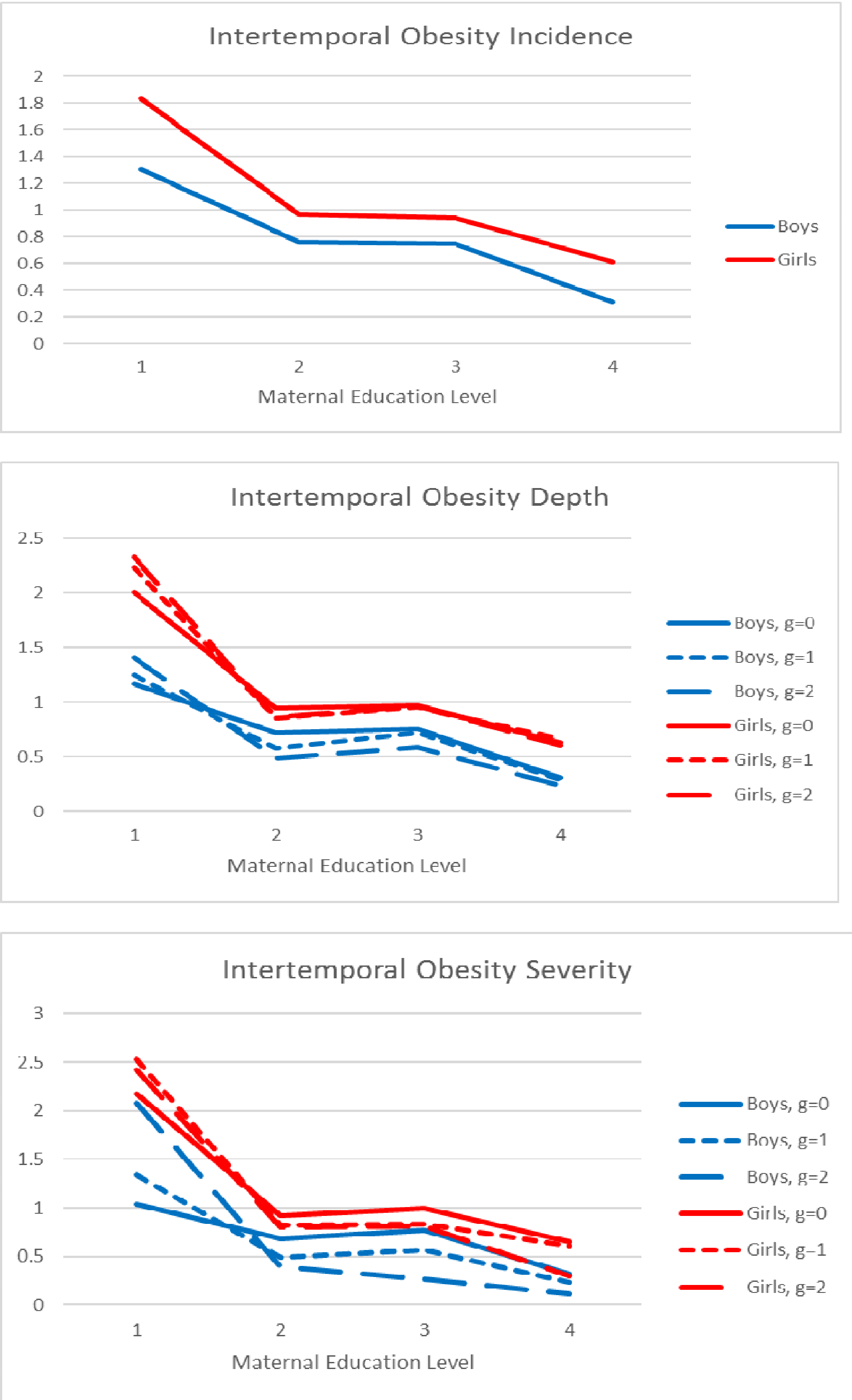
Figures 4a-4c: Obesity Incidence, Depth and Severity by Gender and Maternal Education, Waves 1 & 2







Figures 5a-5c: Intertemporal Obesity by Gender and Maternal Education



References:

Brown, C.D., M. Higgins, K. Donato, F. Rohde, R. Garrison, E. Obarzanek, N. Ernst and M. Horan (2000). Body Mass Index and the Prevalence of Hypertension and Dyslipidemia. *Obesity Research*, 8, 605-619.

Burkhauser, R. And J. Cawley (2008):. Beyond BMI: The value of more accurate measures of fatness and obesity in social science research, *Journal of Health Economics*, vol. 27, pp. 519-529.

Chung., A., K. Backholer, E. Wong, C. Palermo, C. Keeting and A. Peeters (2016): "Trends in Child and Adolescent Obesity Prevalence in Economically Advanced Countries according to Socioeconomic Position: a Systematic Review", *Obesity Reviews*, Vol. 17, pp. 276-295.

Cole, T., M. Bellizzi, K. Flegal and W. Dietz (2000): Establishing a Standard Definition for Child Overweight and Obesity Worldwide: International Survey, *British Medical Journal*, Vol. 320, pp. 1-6.

Gradín, C, C. Del Río, and O. Cantó (2012). "Measuring poverty accounting for time." *Review of Income and Wealth*, Vol. 58, pp. 330-354.

Grimm, M. (2007): Removing the anonymity axiom in assessing pro-poor growth. *J. Econ. Inequal*. Vol. 5(2), pp. 179–197.

Grossman, M (1972): "On the concept of health capital and the demand for health." *Journal of Political economy*, Vol. 80, pp 223-255.

Han, J, D. Lawlor and S. Kimm (2010): Childhood Obesity, *The Lancet*, Vol. 375, no. 9727, pp. 1737-1748.

Ha Jee S., J. Woong Sull, J. Park, S. Lee, H. Ohrr, E. Guallar and J. Samet (2006). Body Mass Index and Mortality in Korean Men and Women. *New England Journal of Medicine*, 355, 779-787.

Jenkins, S., and P. van Kerm (2006): Trends in income inequality, pro-poor income growth and income mobility. *Oxf. Econ. Pap.,* Vol. 58, pp. 531–548.

Jolliffe, D. (2004). Continuous and Robust Measures of the Overweight Epidemic: 1971-2000. *Demography*, 41, 303-314.

Keane, E. , **P. Kearney**, **I. Perry**, **C. Kelleher** and **J.Harrington (2014):** Trends and prevalence of overweight and obesity in primary school aged children in the Republic of Ireland from 2002-2012: a systematic review, *BMC Public Health* , Vol. 14**:** 974.

Layte, R., and C. McCrory (2011): *Obesity and Overweight Among Nine Year Olds*. Government Publications. Dublin.

Madden, D. (2012): "A profile of obesity in Ireland, 2002–2007." *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, Vol. 175, pp 893-914.

McLaren, L. (2007): “Socioeconomic Status and Obesity”, *Epidemiological Reviews*, Vol. 29, pp. 29-48.

Olds T, Maher C, Zumin S, Péneau S, Lioret S, Castetbon K, Bellisle, de Wilde J, Hohepa M, Maddison R, Lissner L, Sjöberg A, Zimmermann M, Aeberli I,Ogden C, Flegal K, Summerbell C. (2011): Evidence that the prevalence of childhood overweight is plateauing: data from nine countries*, Int J Pediatr Obes.*, Vol. 5-6, pp. 342-60.

Perry, I., H. Whelton, J. Harrington and B. Cousins (2009): The Heights and Weights of Irish Children from the Post-war Era to the Celtic Tiger, *Journal of Epidemiology and Community Health*, Vol. 63, pp. 262-264.

Quail, A., J. Williams, M. Thornton and A. Murray (2014): *A Summary Guide to Wave 2 of the Child Cohort (at 13 Years) of Growing Up in Ireland.* ESRI. Dublin.

Walsh, B., and J. Cullinan (2015): "Decomposing socioeconomic inequalities in childhood obesity: Evidence from Ireland." *Economics & Human Biology* Vol. 16, pp. 60-72.

Williams, J., S. Greene, E. Doyle et al (2009): *The Lives of 9 Year Olds: Growing Up in Ireland, National Longitudinal Study of Children (Report 1 of the Child Cohort).* Dublin; The Stationery Office.

Table A1: NBMI$_{\alpha}$ rates by wave, gender and maternal education

	Overall		**Boys**		**Girls**	
	W1	**W2**	**W1**	**W2**	**W1**	**W2**
NMBI$_1$						
Overall	**0.004112** ***(0.000338)***	0.004039 *(0.000333)*	0.003516 *(0.000439)*	0.002487 *(0.000302)*	0.004739 *(0.000515)*	0.005670 *(0.000602)*
Ed=1	0.006721 *(0.000911)*	0.007690 *(0.000962)*	0.005837 *(0.001291)*	0.004377 *(0.000885)*	0.007516 *(0.001280)*	0.010669 *(0.001623)*
Ed=2	0.003163 *(0.000409)*	0.002663 *(0.000369)*	0.002712 *(0.000495)*	0.002035 *(0.000414)*	0.003650 *(0.000659)*	0.003340 *(0.000623)*
Ed=3	0.003867 *(0.000661)*	0.002898 *(0.000500)*	0.003889 *(0.001007)*	0.002024 *(0.000457)*	0.003841 *(0.000816)*	0.003934 *(0.000945)*
Ed=4	0.001943 *(0.000486)*	0.001861 *(0.000370)*	0.001342 *(0.000397)*	0.001025 *(0.000287)*	0.002637 *(0.000939)*	0.002827 *(0.000724)*
NMBI$_2$						
Overall	**0.000456** ***(0.000056)***	0.000457 *(0.000054)*	0.000407 *(0.000087)*	0.000244 *(0.000044)*	0.000508 *(0.000070)*	0.000681 *(0.000100)*
Ed=1	0.000818 *(0.000168)*	0.000913 *(0.000159)*	0.000821 *(0.000298)*	0.000470 *(0.000125)*	0.000816 *(0.000174)*	0.001312 *(0.000277)*
Ed=2	0.000325 *(0.000059)*	0.000287 *(0.000056)*	0.000255 *(0.000065)*	0.000192 *(0.000068)*	0.000400 *(0.000100)*	0.000391 *(0.000091)*
Ed=3	0.000377 *(0.000072)*	0.000316 *(0.000086)*	0.000366 *(0.000101)*	0.000170 *(0.000052)*	0.000390 *(0.000103)*	0.000489 *(0.000177)*
Ed=4	0.000197 *(0.000055)*	0.000179 *(0.000047)*	0.000140 *(0.000051)*	0.000084 *(0.000032)*	0.000263 *(0.000103)*	0.000288 *(0.000094)*

Table A2: Intertemporal Obesity Measures by Gender and Maternal Education

	Overall			**Boys**			**Girls**		
	γ=0	**γ=1**	**γ=2**	**γ=0**	**γ=1**	**γ=2**	**γ=0**	**γ=1**	**γ=2**
$NMBI_0$									
Overall	0.085026	0.085026	0.085026	0.07033723	0.07033723	0.07033723	0.10046606	0.10046606	0.10046606
Ed=1	0.134598	0.134598	0.134598	0.11113367	0.11113367	0.11113367	0.15568891	0.15568891	0.15568891
Ed=2	0.073389	0.073389	0.073389	0.06488176	0.06488176	0.06488176	0.08258388	0.08258388	0.08258388
Ed=3	0.071206	0.071206	0.071206	0.06353587	0.06353587	0.06353587	0.08029265	0.08029265	0.08029265
Ed=4	0.038652	0.038652	0.038652	0.02674931	0.02674931	0.02674931	0.05239556	0.05239556	0.05239556
$NMBI_1$									
Overall	0.057885	0.004075	0.000457	0.04496063	0.00300154	0.00032532	0.07147098	0.00520438	0.00059452
Ed=1	0.093169	0.007206	0.000866	0.06775333	0.00510701	0.00064528	0.11601382	0.00909206	0.00106406
Ed=2	0.047997	0.00291281	0.00030603	0.04171948	0.00237381	0.00022328	0.05478328	0.00349541	0.00039548
Ed=3	0.04965152	0.00338281	0.00034638	0.04401632	0.0029566	0.00026769	0.0563273	0.00388773	0.0004396
Ed=4	0.02682596	0.00190205	0.00018787	0.01826398	0.00118355	0.00011193	0.03671179	0.00273164	0.00027555

	Overall			**Boys**			**Girls**		
	γ=0	**γ=1**	**γ=2**	**γ=0**	**γ=1**	**γ=2**	**γ=0**	**γ=1**	**γ=2**
$NMBI_2$									
Overall	0.044315	0.000357	9.21E-06	0.03227232	0.00024543	0.00000716	0.05697343	0.0004738	0.00001136
Ed=1	0.07245431	0.00069947	0.0000208	0.04606316	0.00047656	0.00001914	0.09617629	0.00089983	0.00002229
Ed=2	0.03530178	0.00023321	0.00000542	0.03013834	0.00017756	0.00000361	0.04088298	0.00029336	0.00000738
Ed=3	0.03887424	0.00024523	0.00000476	0.03425654	0.00020056	0.00000247	0.04434462	0.00029816	0.00000747
Ed=4	0.02091283	0.0001447	0.00000184	0.01402132	0.00008216	0.00000104	0.0288699	0.00021691	0.00000275