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Abstract: This paper examines mobility and changes in Body Mass Index (BMI) for a sample of Irish children across three waves of the longitudinal Growing Up in Ireland dataset. Particular attention is paid to transitions across the key BMI thresholds of overweight and obesity. Analysis is carried out by gender and by maternal education. In general, the degree of mobility appears to be relatively limited although it is greater than for the mothers of the children over the same time period. There is relatively little variation by gender and maternal education apart from some indication of less mobility out of obesity for girls.

Keywords: Obesity; mobility; transitions

JEL Codes: I12, I14, I39.

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BMI Mobility and Obesity Transitions Among Children in Ireland

1. Introduction

There has been much concern in recent years about rates of obesity and overweight among children and young adults, 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 *Safe*food and the Department of Health, and a special action group on obesity (SAGO) has been formed. International concern is reflected in the recent report from *The Lancet* (Swinburne et al, 2019). There is also evidence that, in some countries at least, rates may have plateaued (Keane et al, 2014, Abarca-Gomez et al, 2017).

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).* As GUI follows the same children over time, not only are we able to provide a snapshot of obesity at three different points in time for this cohort (at 9, 13 and 17 years of age), since it is the same children in these cohorts, we are also able to examine transitions into and out of obesity (and overweight), as defined by Body Mass Index (BMI). In analysing mobility and transitions between the different BMI categories we borrow from the economics literature on inequality, poverty and income mobility. For example, in poverty analysis, research in these areas has moved on from just analysing snapshots at a given point in time and attention is now paid to examining movements of people in and out of poverty analysing the same cohort (see for example Jenkins and van Kerm, 2006, Grimm, 2007). In the same way, we can examine movements in and out of obesity and overweight for the GUI cohort. Thus we can examine the extent to which

[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 three waves of data which we will be analysing include children aged 9, 13 and 17, the latter age being more accurately described as young adults.

obesity/overweight at this age can be regarded as a chronic condition which persists, or whether there is a degree of "churning" in the sense that children move in and out of states of overweight/obesity and we can also investigate how such churning differs according to observable characteristics such as gender and maternal education. This has both welfare and policy implications: it seems reasonable to suggest that society may prefer a situation where children move in and out of obesity compared to one where the same children are permanently obese. From a policy perspective it is also important to know the extent to which children are mobile across BMI categories, since a situation with very low mobility between categories is presumably more challenging in terms of moving children out of 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. 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 three cross-sections and do not exploit its panel nature. In section 4 we take account of the panel nature of the data and examine the degree of mobility present, particularly investigating if there is a pattern observable by gender or maternal education. Section 5 provides discussion and concluding comments.

2. The Measurement of Obesity in Children and Adolescents

The most common measure of obesity used 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".

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 were they available.

There is, however, one 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 differ by age or gender, 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 obesity/overweight 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 9 year olds, it seems appropriate to take the cut-off for age 9.5. Similarly for waves 2 and 3 of our data (who are mostly 13 and 17 year olds respectively) we use the cut-offs for ages 13.5 and 17.5. For the very small numbers of children who were aged 8 or 10 in wave 1 we use thresholds of (8.5, 10), (12.5, 14) and (16.5, 18) respectively for waves 1-3 and these cutoffs are presented 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 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 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. A more recent update provided by Jennings (2018) which built upon the Keane et al study confirmed these trends.

These findings are consistent with results from a number of other developed countries. Abarca-Gomez et al (2017) finds that the rising trends in childhood and adolescent obesity have plateaued in many countries and this echoes earlier work by Olds et al (2011) who presented evidence from nine, mostly high-income, 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.

Our study builds upon this work. As well as examining obesity and overweight at three snapshot points in time (2007-2008, 2011-2012 and 2015-2016), we also look at trajectories over time for the same children. We now discuss our data and present our first results using the snapshot approach.

3. Data

Our data comes from the first three waves of the Growing Up in Ireland 9 year old 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 a 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 from wave 1 of 8136. These children were then re-surveyed at ages 13 and 17 for the second and third waves. Since we wish to follow trajectories of BMI over the three waves, we choose to use a balanced panel i.e. only those observations who appear in all waves. That reduces the sample size to 5757. When we then once again drop observations where valid height and weight observations are not available in waves 2 and 3 the final sample reduces to 5487 (2702 boys and 2785 girls).

In making these adjustments the issue of attrition arises. Attrition in surveys such as GUI is rarely random and this is confirmed in Murphy et al (2018) who show that attrition tends to be higher for those with lower maternal education and also a lower score or non-completion of the Drumcondra Reasoning Test taken at age 13. Correspondingly the data was re-weighted so that the sampling weight in the balanced panel which we analyse is the product of the original sampling weight for wave 1 and the attrition weights which took account of subsequent non-random attrition.

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 grows older) a simple comparison of BMI can be misleading. Consequently we analyse *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, the mean values for BMI normalized to thresholds for overweight and obesity for waves 1-3. The results show very little change between waves 1 and 2 but there are signs that obesity picks up somewhat in wave 3. The increase is slightly more pronounced amongst males rather than females but the level of obesity remains higher for the latter. Overweight rates remain the same or even fall slightly. This is consistent with a story between waves 2 and 3 whereby there are transitions up through the weight categories but since it is not possible to transition into a higher weight category than obesity, the fraction who are obese increases. We examine these transitions in more detail in section 4.

In tables 3a-3c we present these results (for both genders) by education level of the principal carer (in nearly all cases the mother). We break down the sample into four education categories: (1) completion of lower secondary schooling (2) completion of secondary schooling (3) obtaining a post-secondary school diploma or cert and (4) completion of third level education. We choose to present these results by maternal education level in wave 1. While there is some change in maternal education levels between waves 1 and 3, it is relatively minimal and by fixing on wave 1 maternal level we ensure that it is the same sample of observations in each category for each wave. Taking males and females together, as table 3a shows there is a clear socioeconomic gradient, particularly for obesity. The nature of the gradient changes slightly in wave 2 with obesity for the lowest level of maternal education rising while obesity rates for other education levels are unchanged or else fall slightly. In wave 3 the gradient between the lowest level of education and subsequent education levels is not quite so steep but this reflects higher rates of increase in obesity rates amongst intermediate levels of education. Obesity for those with the highest level of maternal education stays pretty much unchanged over the three waves and at a low level of just over 2%.

Tables 3b and 3c present these results by gender. There are some differences discernible by gender. The socioeconomic gradient for obesity amongst males hardly exists in wave 1. It emerges in wave 2 as obesity among males whose maternal education is lowest shows a rise, while it falls in other educational categories. By wave 3 the classic gradient is present, owing to further increases in obesity amongst those with lowest maternal education and increases too amongst those with intermediate levels of maternal education. For those with the highest level of maternal education there are very slight rises, but only from a very low base.

Turning now to females, the socioeconomic gradient in obesity is clear from wave 1. It becomes even sharper in wave 2 as obesity rises amongst those with lowest maternal education but stays constant or falls for other levels of maternal education. By wave 3, the gradient is back to close to what it was in wave 1, albeit with a higher overall level of obesity for all groups apart from those with the highest level of maternal education. By wave 3 obesity for females with the lowest level of maternal education is about five times as great as for those with the highest. We hope to investigate the socioeconomic gradient in greater depth in future work but for a more detailed analysis of the gradient for waves 1 and 2, see Madden (2017).

To summarise before we turn to analyse mobility explicitly: obesity showed little change between waves 1 and 2, apart from increases for those with the lowest levels of maternal education. Wave 3 saw a continued rise for those with the lowest maternal education and it was accompanied by increases for those with intermediate levels of maternal education. By wave 3 a clear socioeconomic gradient was evident for both genders. Overweight rates showed much less change and also showed little evidence of a socioeconomic gradient. We now turn to analyse the transitions which underly these developments.

4. Mobility

This section of the paper explicitly examines mobility in (normalized) BMI. There are a number of different approaches we can take: we can look at absolute mobility (the extent of changes in BMI) or relative mobility (effectively looking at changes in rank of BMI but independent of the size or sign of those changes). We can also choose to concentrate on mobility in specific directions, upward or downward.

In addition to choosing between different types of mobility we may also wish to distinguish between mobility in different parts of the BMI distribution. A move between, say, the 40th and 50th percentiles may have little consequence in terms of health outcomes, since BMI at both percentiles is below the key obesity/overweight thresholds. That may not be the case for a move between the 80th and 90th percentiles. Thus we will look at mobility in the overall distribution of BMI but we will also look at mobility across key thresholds, those associated with overweight and obesity.

Finally, in terms of how precisely we analyse mobilty there are a number of approaches. We will start off with mainly graphical analysis, as this is often the easiest way to capture the broad sense of what is going on and this analysis can be supplemented by regression analysis. We also employ transition and mobility matrices as these provide information on transitions across quintiles and/or key thresholds. Graphs and/or matrices are very useful in giving a sense of developments but they may not work so well when comparisons need to be made, for example between mobility by gender, or by maternal education or indeed in terms of transitions between waves 1 and 2 and then between waves 2 and 3. Hence we also calculate specific mobility indices, in some cases explicitly derived from the transition and mobility matrices, and these indices have the advantage that they can provide a clear answer when making such comparisons. The disadvantage of course, and this applies to their use in areas such as inequality and poverty also, is that different specific indices may give different answers to any given question. We will look at mobility in general and also at specific parts of the distribution and we will also make comparisons for different subgroups (defined by gender and maternal education). For the most part of the analysis we will focus on mobility between waves 1 and 3. At the end of this section however we will review whether mobility differed during the sub-periods from wave 1 to wave 2 and from wave 2 to wave 3.

Graphical and Regression Based Analysis

The primary graphical approaches we will employ are *Mobility Curves* which were introduced by Aaberge and Mogstad (2014) to examine cross-country differences in *intra*-generational mobility in income across countries. They have since been used to examine *inter*-generational mobility income by Bratberg et al (2017) and it is their formulations which we use. The Bratberg et al curves were also employed by Chetty et al (2014) in their influential work on income mobility in the USA. To our knowledge, they have not been used before to analyse mobility across BMI but they are a useful graphical tool to provide an insight into such mobility. In addition, we also use the recently developed TIM curves introduced by Creedy and Gemmell (2019) and they provide a useful alternative graphical representation of mobility.

The first such curve we examine is the rank mobility curve. This captures positional mobility and can show how such mobility changes across the distribution of BMI. In what follows we will discuss mobility in the context of changes between waves 1 and wave 3. Suppose the fractional BMI rank for observation i in period t is denoted by p_{ti}. Then the rank mobility curve, employing the notation of Bratberg et al is given by

$$RM^{*}(p) = [p_{3i} - p_{1i} | p_{1i} = p], p = 1, \dots, 100 \ .$$

Thus this curve plots out the change in fractional rank between wave 1 and wave 3, using wave 1 as the counterfactual with no change. An alternative specification is

$$RM(p) = [p_{3i} | p_{1i} = p], p = 1, \dots, 100$$

which simply plots the fractional rank in wave 3, given the counterfactual of no mobility i.e. rank stays as it was in wave 1. A further alternative is to plot the absolute value of rank change against original rank i.e.

$$RM^{**}(p) = [|p_{3i} - p_{1i}| | p_{1i}], p = 1, \dots, 100 \ .$$

A further possibility is to plot the change in normalized BMI (both actual and absolute) against rank. Thus we have

$$BMI_{mob} = [BMI_{3i} - BMI_{1i} | p_{1i}], p = 1, \dots, 100$$

$$BMI_{absmob} = [|BMI_{3i} - BMI_{1i}| | p_{1i}], p = 1, \dots, 100$$

These curves can all be plotted by gender and level of education if desired.

In figure 1 we present the RM* curve, showing the plot of change in rank between waves 1 and 3 against rank in wave 1, while in figure 2 we show the RM curve with rank in wave 3 plotted against rank in wave 1. We show the scatter of points where the data is organized into 50 “bins” with each bin taking the value of the average of the observations for that bin. We also present the best linear fit for each relationship. The RM* plot is clearly downward sloping, while the RM curve is clearly upward sloping and in both cases the linear specification gives a good approximation to the relationship. The curves show that while there is some mobility, in the sense that rank in wave 1 is not a perfect predictor of rank in wave 3, mobility is relatively limited. By and large those observations that are highly ranked in wave 1 will also be highly ranked in wave 3.

Figures 3 and 4 show the BMI_{mob} and BMI_{absmob} curves respectively. It is important to remember that in this instance it is the change in normalized BMI which is on the vertical axis and not the change in rank. Again in figure 3 we see a clear negative relationship suggesting a compression of the distribution, in the sense that those who are ranked lower tend to have greater increases in normalized BMI, while the higher ranked observations show reductions in normalized BMI.

In figure 4 we see how the absolute change in normalized BMI varies with rank in wave 1. The relationship is probably best described as U-shaped. Hence we have included a quadratic fit and it appears to be the better approximation indicating high absolute mobility at both low and high ranks.

Figures 5a and 5b reproduce figures 3 and 4, except this time by maternal education.[2] In terms of the change in BMI by ranking, the linear specification still seems to hold well, with the possible exception of the two higher levels of education (3 and 4), where there is a hint of smaller increases at low ranks and bigger decreases at high ranks. In terms of the absolute change in BMI, the quadratic specification seems to work well for all levels of education.

Before proceeding to regression-based analysis, there is one further graphical device which is of interest. Recently Creedy and Gemmell introduced the "Three Is of Mobility" (TIM) curve, drawing inspiration from the "Three Is of Poverty" (TIP) curves of Jenkins and Lambert (Creedy and Gemmell, 2019, Jenkins and Lambert, 1997). These curves arrange observations in increasing order of wave 1 normalised BMI and then plot $\frac{1}{n}\sum_{i=1}^{k}(BMI_{3,i} - BMI_{1,i})$ against $h = \frac{k}{n}$ for $k = 1,..,n$. It thus plots the cumulative normalised BMI change per capita against the corresponding proportion of individuals. This plot is shown for the complete sample in figure 6. Average change was around 0.015 per cent and the straight line shows what the TIM curve would have been had normalised BMI increased by the same amount for all observations. That portion of the curve which is upward sloping is the part where growth is higher than average. The portion where the curve is downward sloping is where growth is below average.

[2] In these figures rather than having 50 bins in total, we have 25 bins per education level, hence 100 in total. 50 bins per education level would lead to an unduly cluttered graph. Each bin thus refers to a particular interval for that specific education level.

What we see is that growth increases up to about the 70th percentile and then declines, which is consistent with figure 3. Inequality of mobility within the sample is captured by the curvature, since the flat "equal TIM" curve reflects the situation where growth is the same for all.

Summarising so far, it seems to fair to say that the graphical analysis indicates that while some mobility is present, it is relatively limited. Highly ranked observations in wave 1 tend also to be highly ranked in wave 3. It is also the case that, visually at least, it is difficult to discern any major differences by gender or level of maternal education.

We now turn to regression-based analysis, starting off with simple rank-rank regressions as suggested by Acciari et al (2019) in their recent analysis of intergenerational income mobility in Italy. A simple regression of the form $p_{3i} = \alpha + \beta p_{1i} + \varepsilon_i$ gives the rank-rank slope measuring the correlation between a child's rank in wave 3 and their rank in wave 1. Acciari et al also suggest a simple index of mobility at the top of the distribution. Simply run the above regression for the top 10% and also for the bottom 90% and take the ratio of the slopes i.e. top mobility (TMR)=$\frac{\beta^{90-99}}{\beta^{0-89}}$. The higher is this ratio, then the greater is persistence in BMI at the top of the distribution. Results for transitions between waves 1 and 3 are presented in table 4a. Overall persistence as represented by the β coefficient for the total sample is around 0.63 with no real difference by gender. Persistence in the top 10% of the distribution is greater (and hence mobility is less) than elsewhere with a ratio of $\frac{\beta^{90-99}}{\beta^{0-89}}$ of 1.8. The results for top mobility by gender however show considerably more relative persistence at the top for females with a TMR coefficient of 3.04. The coefficient for males is calculated at 0.299 but the coefficient on the rank regression for the top decile was not statistically significant so little can be read into this.

Persistence results by maternal education are quite subtle. The results for overall persistence show little enough variation, though with some hint that it may be lower for the highest level of education. However, the relative gap between persistence at the top and elsewhere in the distribution appears to be more pronounced at higher levels of education.

Finally, in tables 4d-4f we show the results from quantile and interquartile regressions of log normalized BMI in wave 3 on log normalized BMI in wave 1. The results show the coefficients evaluated at the 50th and 90th percentiles and the difference between the two coefficients . A positive interquartile coefficient thus indicates relative greater persistence (and hence less mobility) at the 90th compared to the 50th percentile. Table 4d shows that persistence at higher quantiles is greater for the sample as a whole and that this is more the case for females and for higher education levels. Tables 4e and 4f reproduce the same analysis for mobility between waves 1 and 2 and between 2 and 3. The results in table 4d are thus consistent with the results from table 4a.

To summarise the results so far: we see that there clearly is some mobility in BMI over the three waves. In general mobility acts to compress normalized BMI with increases generally observed for lower ranked observations and decreases observed for higher ranked observations. To the extent that the graphical analysis shows differences by gender or maternal education there seems to be little enough differentiation across the whole distribution but there is some hindication of less mobility for females at higher levels of BMI. We now see if these results are replicated by analysis using transition and mobility matrices.

Transition and Mobility Matrices

We now turn to look at transition matrices. Before examining the matrices in detail, we first present some visual representations of them. Figure 6 simply shows the total number of moves, regardless of direction, between BMI categories (normal, overweight and obese) by fraction of the sample over the three waves. Thus if someone moves from normal to overweight between waves 1 and 2, and then again moves into the obese category in wave 3 this counts as 2 moves. Similarly someone who was in the normal category between waves 1 and 2 but then moved from normal to obese between waves 2 and 3 would also count as two moves. We see that over 70% of the sample do not move category at all. 21% make one move over the three waves while about 8% make two moves.

Figure 7 show what Van Kerm (2011) labels transition colour probability plots. There are five rows in each plot and each row of the plot shows what fraction of the period 1 quantile goes to the other quantiles. If we had five bars each of a different colour that represents a situation of zero mobility, with each observation staying in the same quintile. Where each bar has different colours, that shows the different quantiles which observations move towards. Colours rage from blue to red, with blue representing the lower quantiles. A high degree of mobility would be characterised by a lot of red in the top rows and a lot of blue in the bottom rows. The plots indicate that mobility is present for both genders and all levels of maternal education, but perhaps the main difference which is visually discernible is by gender, where we see less mobility overall for males (essentially fewer colours overall), but also less mobility from the top quintile for females (more red in the lowest row), and this is consistent with the results from the regression analysis.

We now turn to the numbers underlying these plots. To avoid information overload in the main tables we present summary statistics while in the appendix tables we present the actual matrices upon which the summary statistics are based. Thus in tables A1-A7 we look at a sequence of transition matrices of normalised BMI by quintile. For example in table A1, the top left entry in the matrix is 0.52. This reveals that of the population who were originally in the bottom quintile of normalised BMI, 52% stayed in this quintile. 25% moved up the next highest quintile, while 3% moved all the way up to the highest quintile. A lack of mobility is reflected in high values along the main diagonal, indicating that most people stayed in the same quintile. Thus a summary measure of mobility which has been suggested by Shorrocks (1978) is $\frac{m-Tr(M)}{m-1}$ where *m* refers to the dimensionality of the transition matrix (5, in this case) and *Tr(M)* is the trace of the transition matrix, *M*. This provides an index whose lower bound is clearly zero (since the proportion along the main diagonal would be unity for each quintile) and whose upper bound is $\frac{m}{m-1}$, since in this case the entry for each element along the main diagonal is zero. Calculation of this measure for the transition matrices in table 5a show very little variation with values ranging between 0.72 and 0.78. There is some indication that mobility may be lower for lower levels of maternal education but this difference is only barely statistically significant. Thus table 5a suggests that mobility across the overall distribution of BMI between waves 1 and 3 shows little variation by gender or maternal education.

While these indicators of mobility in BMI are of interest, given the focus on obesity in this paper, we may be more concerned with transitions above and below the key overweight/obesity thresholds, rather than between quantiles. Thus a *mobility matrix* which examines movements across these thresholds may be more relevant than the transition matrices in tables A1-A7. Hence in table A8-A15 we show mobility matrices across the two thresholds for overweight and obesity and in tables 5a-5c we calculate the Shorrocks index for these matrices.

The data in tables A8-A15 are “row proportions” by BMI category. Category 1 refers to the “normal” BMI range, category 2 is overweight and category 3 is obese. Thus if we look at the first row of table A8, which gives this information for the sample as a whole, we see that of those who were non-overweight/obese in wave 1, 86% were still remained in that category in wave 3, 12% had moved into overweight and 2% become obese. The second row tells us that of those who were overweight in wave 1, 44% were still overweight in wave 3, 40% had moved down to non-overweight/obese, while 17% became obese.

Note that the figures in tables A8-A14 represent proportions. Thus while 17% of those who were overweight in wave 1 moved on to become obese in wave 3, this only represents a flow of less than 4% of the total sample (since just under 20% of the sample in wave 1 were overweight). Thus when interpreting these figures, while proportional mobility may appear relatively "high", the absolute numbers making the transition, particularly in and out of obesity may not be so high.

Nevertheless, it is still interesting to see if any pattern is observable by gender or maternal education. A comparison of tables A9 and A10 immediately shows one critical difference by gender. We see from table A9 that of those males who were obese in wave 1, only 33% remain obese in wave 3. Thus the transition rate out of obesity is quite high for males with two-thirds of them making the change. Contrast this with table A10 for females, where of those who were obese in wave 1, 55% remain obese in wave 3. There is thus considerably less mobility out of obesity for females compared with males. Transition rates *into* obesity show little difference by gender although those for males are marginally higher.

This difference is also reflected when looking at the Shorrocks indices in table 5. For mobility across the whole of the BMI distribution we see that the index for females is 0.76, while that for males is 0.74. However, when we look at mobility into and out of overweight and obesity we see that females show much less mobility with an index of 0.56, compared with a male index of 0.71. As we have seen from tables A9 and A10 this is driven by lower mobility out of obesity. Thus while females exhibit marginally more mobility across the whole of the distribution, for mobility at the top of the distribution across the critical obesity thresholds mobility is less for females and this is entirely consistent with the results from the regression analysis where persistence at the top of the distribution is higher for females than males.

Table 5 also hints at an increase in mobility for higher levels of maternal education with the Shorrocks index rising from a value of 0.62 for those whose mothers have not completed secondary education to a value of 0.65 for those whose mothers have completed third level. This "gradient" of mobility by education is considerably less than that observed by gender.

A criticism which has been made of the Shorrocks index is that it is sensitive only to differences between transition indices which arise from those on the main diagonal. Bartholomew's average jump index is equal to the number of boundaries crossed by an individual averaged across all individuals and thus closely related to figure 5. The final two columns of table 5 shows this index for both the quintile transition matrix and the mobility matrix across BMI thresholds. What is important here is not the comparison between these two columns - since there five quintiles but only three BMI categories there are clearly a greater number of boundaries which can be crossed in the former compared to the latter case. What is relevant here is the comparison by gender and maternal education. Once again we see relatively little difference across these dimensions when looking at the transition matrix but considerably less mobility for females when looking at mobility across BMI thresholds. Mobility across BMI thresholds does not differ greatly by maternal education.

In our discussion so far we have stressed that we are not indifferent to *where* in the overall distribution of BMI mobility is observed, hence our analysis of mobility at the top of the BMI distribution. Nor are we indifferent to the direction of mobility. Apart from the relatively small number of cases where BMI reflects underweight, in general we have a weak preference for downward rather than upward mobility. We employ the term "weak" preference as we are indifferent between upwards or downwards movements in BMI as long as the key overweight and obesity thresholds are not crossed. Where such thresholds are crossed however, from a health policy perspective then presumably there is more concern over upward mobility i.e. movements into overweight or obese categories.

As an initial indicator of upward mobility Fields (2000) suggests applying stochastic dominance to changes in BMI (in his application it was applied to income changes). This is particularly useful in examining upward mobility by gender or education. The sample is arranged in increasing order of BMI change, from negative to positive. Dominance of one distribution over another (e.g. females compared to males) is then observed if the percentage below any given change amount is smaller for females than for males, or if the BMI change cut-off for each given percentage grouping is higher in one distribution than another. This can be inspected by comparing the cumulative distribution functions (CDFs) of BMI changes by gender.

Figures 8a-8c show the CDF for BMI change by gender and by maternal education. In figure 8a we show the CDF for all changes, both positive and negative. Careful inspection shows that stochastic dominance does not apply, as the CDFs cross, around about zero. For decreases in BMI for the most part the curve for females lies above that for males i.e. for any given decrease in BMI the fraction of females with greater decreases is larger than males. However, when we look at positive BMI changes, the CDF for females lies below that for males. Thus for any given increase in BMI, say of 0.2, the fraction of females whose BMI change was smaller than this is less than the fraction of males whose BMI change was smaller. We can see this more clearly when we look at figure 8b where we look just at BMI increases. The curves thus indicate that females in general show larger increases in BMI than males.

Figure 9 also illustrates this as it replicates the BMI mobility curve, this time by gender. Note that when we examine the curves for high values of the fractional ranks, in general bins for males show greater decreases than for females. This reflects greater mobility out of the higher BMI categories for males than females. Thus overall, what figures 8a-8b and figure 9 show is that for the sample that experienced decreases in BMI, in general, females experienced greater decreases. However they also experienced greater increases, which is a public policy concern. In addition for those with high BMI in wave 1, there was less mobility out of that category for females.

Finally, in figure 8c we show the CDF for increases only by maternal education. Again, we do not strictly observe stochastic dominance as the curves cross for certain regions of changes. However, for a substantial range of increases (from about 0.05 to about 0.4) we see that the CDF for the lowest level of maternal education is distinctly below the CDFs for other levels of education. This shows that those with the lowest level of maternal education in general experienced greater increases in BMI.

Another way of looking at mobility at the top of the distribution is provided in table 6, where again we borrow an approach which has been used in the income distribution literature (see Jenderny, 2016). The table shows the fraction of each quintile that does *not* move down to a lower quintile i.e. what we could regard as a measure of persistence. Thus looking at the first three columns, clearly for those in quintile 1 none of them move down a quintile, since they are already in the lowest quintile. For those in quintile 2, about 75% do not move down to the next quintile, though this fraction is slightly lower for females at 0.727. Turning to the quintile 5 again we see some difference by gender. Of the total sample about 0.58 of the highest quintile stay in that quintile, but the figure is about 0.62 for females and about 0.56 for males.

The final three columns show persistence *within* the top quintile and in this table each row quintile is actually a "quintile of a quintile". Hence quintile 5 for the last three columns actually represents the top 4% by wave 1 BMI. This gives an idea of persistence/mobility right at the top of the distribution and again we see quite a difference by gender. Only about 0.23 of males who were in that top quintile of a quintile in wave 1 are still there in wave 3. However, for females the fraction is twice as high, at 0.46.

Our results so far have all discussed mobility between waves 1 and 3 i.e. between when children were 9 to when they were 17. However, given that we have three waves of GUI it is possible to examine whether mobility differs according to the stage of adolescence. Thus we can examine mobility between waves 1 and 2 (when children go from aged 9 to aged 13) and between waves 2 and 3 (when children go from aged 13 to age 17). This is potentially important from a policy perspective, since if we observe very low mobility, say between waves 2 and 3, then it implies that measures to address mobility might be better focussed at a younger age when it appears that mobility is more fluid. We do not present the graphical analysis as it is difficult to perceive differences from wave to wave merely by eye-balling the graphs. Instead we concentrate on tables 4-6 and the indices which summarise mobility.

Tables 4a-4c provide the rank regressions for all the transitions and also the measure of mobility at the top of the distribution. Table 4a shows that the overall rank regression coefficient for mobility over the whole period is about 0.63 and tables 4b and 4c show that overall mobility varies very little by wave as the regression coefficients from waves 1 to 2 and waves 2 to 3 are practically identical. However, in looking at overall mobility we see that mobility was relatively greater for females between waves 1 and 2, but relatively greater for males between waves 2 and 3. Looking at mobility at the top of the distribution relative to the rest of the distribution, again it is less for females than males. Care must be taken in looking at the TMR index for wave by wave transitions. Recall that a value of the index above unity indicates less mobility at the top relative to elsewhere in the distribution. While the TMR for females falls from 2.67 to 1.83 (in terms of the wave to wave transitions), since *overall* mobility for females fell over time, top level mobility may rise relative to mobility elsewhere but still fall in an absolute sense and this is borne out when we look at another measure of mobility/persistence in table 6.

Turning now to how tables 4a-4c differ by maternal education, recall that for the total period overall mobility seemed to increase at higher levels of education but within that pattern mobility at the top of the distribution seemed to decline as maternal education increased. As figures 4b and 4c indicate, that pattern for overall mobility seems to be less pronounced when looking at mobility on a wave by wave basis. For mobility at the top, the lower mobility for higher levels of education is still discernible between waves 1 and 2, between waves 2 and 3, mobility at the top declines as we go from education level 2 to 3, but then increases again when we go to education level 4. It is worth bearing in mind that for top mobility at least the sample sizes upon which β^{90-99} is based are quite small and hence confidence intervals can be wide.

In terms of the interquartile regressions in tables 4d-4f, we see that the phenomenon of less mobility at the top (especially for females) is mainly manifest in regressions between waves 1 and 3. There is greater persistence across the whole of the distribution between waves 1 and 2. Between waves 2 and 3 persistence falls but by a greater degree at the median compared to the 90th percentile. There is no difference in terms of the interquartile coefficient by gender, but overall persistence is higher for females.

We now turn to the mobility indices in tables 5a and 5b. For mobility over the whole of the distributions and for the whole sample, there is little difference in terms of the two wave to wave transitions. Looking at mobility across the key BMI thresholds, the gender difference whereby there is less mobility for females is also apparent in the wave by wave transitions. When looking at these transitions by maternal education, the transition from wave 1 to wave 2 seems to clearly indicate less mobility for the highest level of education, but this is reversed when we examine the wave 2-wave 3 transitions.

In terms of the Bartholomew jump index, for the transition matrix which covers jumps across all of the distribution by quintile, there seems to be more mobility in the transition between waves 2 and 3, for males and those with maternal education level 1. When we look at jumps across the key BMI thresholds, then the biggest difference observed is for maternal education level 4, where mobility increases markedly for wave 2-wave 3 transition compared to the wave 1-wave 2 transition (0.415 compared to 0.327). In particular, there are more people transitioning from obesity to normal weight and thus jumping across two categories in the wave 2-wave 3 transition.

Finally we turn to tables 6a to 6c where we examine persistence at the very top of the BMI distribution. Recall that owing to very small cell sizes we do not present figures by maternal education, but we do observe differences by gender with greater top persistence for females.

This can again be seen for both of the individual transitions but the relatively higher persistence for females appears to be greater for the wave 2 to wave 3 transition.

To summarise: looking at the total sample, overall mobility does not seem to differ that much when examining transitions between waves 1 and 2 and between waves 2 and 3. Bearing in mind the complications of comparing absolute and relative regression coefficients in tables 4a-4f, the gender difference whereby there is less mobility at the top of the distributions for females is also generally apparent for both transitions. This pattern is also evident when looking at the Shorrocks indices in tables 5a-5c and the top quintile persistence figures in tables 6a-6c. Overall mobility is pretty much the same for both sets of transitions, but there is evidence of a clear gender gap when looking at mobility at the top of the distribution with lower mobility for females and some indication that the lack of mobility for females at the top of the distribution may be slightly more pronounced when looking at the wave 2 to wave 3 transition. Mobility at the higher end of the distribution also seems to increase for the highest level of maternal education in the wave 2-wave 3 transition compared to wave1-wave 2.

One final point which is worth mentioning is how the various measures and indices of mobility for the study children compare with those of their principal carers. While it is interesting to see how mobility amongst the study children differs by gender and by maternal education, there is also a sense that these measurements are in a vacuum and it is useful to have another comparison group. In appendix B we replicate the relevant tables for the birth mothers in GUI and we observe in all cases that mobility for the mothers is lower. Thus while the coefficient on the rank regressions is in the region of 0.63 for the children, table B1 shows it is around 0.77 for the mothers. Similarly table B2 shows that the coefficients for the quantile regressions are generally higher than for the children, although relative persistence does not differ too much between the 90th and 50th percentile. Similarly, the Shorrocks mobility index is around 0.75 and 0.62 for the transition and mobility indices respectively for the children, but table B3 shows that the corresponding figures for the mothers are 0.61 and 0.48. Perhaps the only set of indices where the numbers are alike is table B4 where we examine persistence. In this case persistence at the very top percentiles is very similar for both study children and mothers.

5. Conclusions

In this paper we have examined BMI mobility across a representative sample of Irish adolescents. We have seen that, relative to a parallel sample of adults, mobility amongst adolescents is considerably higher. We have also examined mobility towards the top of the

BMI distribution, where health concerns are most relevant. Again we see that mobility is higher than amongst adults, but also that there seems to be a gender difference. Mobility at the top of the distribution appears to be lower (and hence persistence higher) for girls than for boys. We also examined whether mobility differed by maternal education and found relatively little variation, certainly less variation than by gender. Finally, we looked at mobility across different stages of adolescence, what we labelled early and later adolescence and found that by and large there was not too much difference with some tentative evidence that the lack of mobility at the top of the distribution for girls was slightly more pronounced for the transition between waves 2 and 3.

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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
16.5	24.19	29.14	24.54	29.56
17.5	24.73	29.7	24.85	29.84
18.0	25.0	30.0	25.0	30.0

Table 2: Normalised BMI by gender, waves 1-3 (standard errors in italics).

	Overall			Male			Female		
	W1	**W2**	**W3**	**W1**	**W2**	**W3**	**W1**	**W2**	**W3**
BMIOB	0.762 *0.002*	0.748 *0.002*	0.778 *0.003*	0.756 *0.003*	0.742 *0.003*	0.772 *0.003*	0.768 *0.004*	0.755 *0.004*	0.785 *0.004*
BMIOV	0.917 *0.003*	0.917 *0.003*	0.935 *0.003*	0.909 *0.004*	0.908 *0.004*	0.927 *0.004*	0.926 *0.004*	0.926 *0.004*	0.943 *0.005*
Obesity Rate	0.055 *0.004*	0.054 *0.004*	0.072 *0.005*	0.043 *0.005*	0.041 *0.005*	0.064 *0.007*	0.067 *0.007*	0.068 *0.007*	0.081 *0.008*
Overweight Rate (not incl. obese)	0.195 *0.007*	0.200 *0.008*	0.198 *0.007*	0.173 *0.010*	0.192 *0.010*	0.181 *0.010*	0.218 *0.011*	0.208 *0.011*	0.216 *0.011*

Table 3a: Normalised BMI, Obesity, Overweight by education of principal carer, waves 1-3 (standard errors)

	Wave 1	Wave 2	Wave 3
Lower Secondary			
BMI Norm Ob	0.781 *0.006*	0.773 *0.006*	0.803 *0.007*
BMI Norm Ov	0.940 *0.007*	0.948 *0.008*	0.964 *0.008*
Obesity %	0.087 *0.01*	0.107 *0.01*	0.117 *0.01*
Overweight %	0.219 *0.017*	0.218 *0.017*	0.220 *0.017*
Complete Secondary			
BMI Norm Ob	0.761 *0.004*	0.745 *0.004*	0.775 *0.004*
BMI Norm Ov	0.914 *0.004*	0.913 *0.004*	0.930 *0.004*
Obesity %	0.050 *0.006*	0.040 *0.005*	0.065 *0.007*
Overweight %	0.197 *0.012*	0.217 *0.012*	0.207 *0.012*
Diploma/Cert			
BMI Norm Ob	0.755 *0.004*	0.736 *0.004*	0.767 *0.004*
BMI Norm Ov	0.909 *0.005*	0.902 *0.005*	0.921 *0.005*
Obesity %	0.044 *0.008*	0.033 *0.005*	0.058 *0.009*
Overweight %	0.186 *0.014*	0.174 *0.013*	0.170 *0.013*
Third Level			
BMI Norm Ob	0.739 *0.004*	0.724 *0.004*	0.755 *0.003*
BMI Norm Ov	0.889 *0.005*	0.887 *0.005*	0.907 *0.004*
Obesity %	0.022 *0.005*	0.023 *0.005*	0.025 *0.004*
Overweight %	0.157 *0.014*	0.156 *0.015*	0.163 *0.014*

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Table 3b: Normalised BMI, Obesity, Overweight by education of principal carer, waves 1-3 (standard errors) – Males only

	Wave 1	Wave 2	Wave 3
Lower Secondary			
BMI Norm Ob	0.759 *0.008*	0.750 *0.008*	*0.775* *0.008*
BMI Norm Ov	0.912 *0.009*	0.917 *0.010*	0.931 *0.010*
Obesity %	0.055 *0.012*	0.070 *0.015*	0.087 *0.018*
Overweight %	0.164 *0.021*	0.192 *0.023*	0.183 *0.023*
Complete Secondary			
BMI Norm Ob	0.764 *0.005*	0.748 *0.005*	0.777 *0.005*
BMI Norm Ov	0.919 *0.057*	0.915 *0.006*	0.933 *0.006*
Obesity %	0.045 *0.008*	0.036 *0.007*	0.071 *0.010*
Overweight %	0.202 *0.017*	0.227 *0.018*	0.194 *0.017*
Diploma/Cert			
BMI Norm Ob	0.755 *0.007*	0.737 *0.005*	0.768 *0.006*
BMI Norm Ov	0.908 *0.008*	0.902 *0.006*	0.922 *0.007*
Obesity %	0.049 *0.014*	0.030 *0.017*	0.055 *0.013*
Overweight %	0.160 *0.018*	0.151 *0.018*	0.160 *0.018*
Third Level			
BMI Norm Ob	0.737 *0.004*	0.724 *0.005*	0.758 *0.005*
BMI Norm Ov	0.886 *0.005*	0.886 *0.006*	0.910 *0.005*
Obesity %	0.015 *0.004*	0.019 *0.005*	0.021 *0.005*
Overweight %	0.137 *0.017*	0.157 *0.020*	0.171 *0.020*

Table 3c: Normalised BMI, Obesity, Overweight by education of principal carer, waves 1-3 (standard errors) – Females only

	Wave 1	Wave 2	Wave 3
Lower Secondary			
BMI Norm Ob	0.802 *0.008*	0.796 *0.009*	0.829 *0.010*
BMI Norm Ov	0.967 *0.010*	0.976 *0.011*	0.995 *0.012*
Obesity %	0.116 *0.019*	0.141 *0.021*	0.148 *0.021*
Overweight %	0.270 *0.026*	0.241 *0.025*	0.259 *0.025*
Complete Secondary			
BMI Norm Ob	0.757 *0.005*	0.743 *0.005*	0.772 *0.005*
BMI Norm Ov	0.913 *0.006*	0.911 *0.006*	0.927 *0.006*
Obesity %	0.055 *0.010*	0.040 *0.007*	0.058 *0.009*
Overweight %	0.191 *0.016*	0.206 *0.017*	0.221 *0.017*
Diploma/Cert			
BMI Norm Ob	0.754 *0.006*	0.735 *0.006*	0.766 *0.006*
BMI Norm Ov	0.909 *0.007*	0.902 *0.007*	0.920 *0.008*
Obesity %	0.037 *0.007*	0.036 *0.008*	0.061 *0.012*
Overweight %	0.220 *0.021*	0.203 *0.020*	0.182 *0.020*
Third Level			
BMI Norm Ob	0.741 *0.007*	0.724 *0.006*	0.752 *0.005*
BMI Norm Ov	0.894 *0.009*	0.888 *0.007*	0.903 *0.006*
Obesity %	0.031 *0.010*	0.028 *0.006*	0.029 *0.007*
Overweight %	0.180 *0.024*	0.155 *0.022*	0.154 *0.021*

Table 4a: Rank-rank regressions, wave 1 to wave 3

	Total	Male	Female	Educ=1	Educ=2	Educ=3	Educ=4
Dependent variable: fractional rank in wave 3							
Rank, Wave 1	0.629***	0.629***	0.628***	0.628***	0.655***	0.604***	0.558***
	(0.014)	(0.020)	(0.019)	(0.032)	(0.020)	(0.025)	(0.027)
Constant	0.192***	0.192***	0.193***	0.208***	0.174***	0.191***	0.221***
	(0.008)	(0.012)	(0.012)	(0.018)	(0.013)	(0.013)	(0.015)
TMR	1.805	0.299	3.046	0.546	2.175	3.246	3.001
N	5487	2702	2785	784	1697	1423	1583

Table 4b: Rank-rank regressions, wave 1 to wave 2

	Total	Male	Female	Educ=1	Educ=2	Educ=3	Educ=4
Dependent variable: fractional rank in wave 2							
Rank, Wave 1	0.746***	0.776***	0.719***	0.749***	0.751***	0.722***	0.737***
	(0.011)	(0.015)	(0.017)	(0.025)	(0.018)	(0.025)	(0.023)
Constant	0.135***	0.117***	0.151***	0.147***	0.130***	0.140***	0.130***
	(0.007)	(0.010)	(0.010)	(0.017)	(0.012)	(0.014)	(0.014)
TMR	1.950	1.160	2.670	1.950	1.414	2.878	2.466
N	5487	2702	2785	784	1697	1423	1583

Table 4c: Rank-rank regressions, wave 2 to wave 3

	Total	Male	Female	Educ=1	Educ=2	Educ=3	Educ=4
Dependent variable: fractional rank in wave 3							
Rank, Wave 2	0.736***	0.707***	0.764***	0.738***	0.752***	0.736***	0.682***
	(0.012)	(0.018)	(0.015)	(0.028)	(0.018)	(0.022)	(0.021)
Constant	0.134***	0.149***	0.118***	0.140***	0.123***	0.128***	0.158***
	(0.007)	(0.012)	(0.009)	(0.019)	(0.011)	(0.013)	(0.011)
TMR	1.932	1.713	1.834	1.725	1.892	2.824	1.034
N	5487	2702	2785	784	1697	1423	1583

***=p≤0.01, **=0.01p≤0.05, *=0.05<p≤0.1

Table 4d: Interquartile range regressions (0.9-0.5), wave 1 to wave 3

	Total	Male	Female	Educ=1	Educ=2	Educ=3	Educ=4
Dependent variable: Log normalised BMI, wave 3							
Log BMI, Wave 1, q50	0.678*** (0.012)	0.646*** (0.018)	0.698*** (0.017)	0.745*** (0.031)	0.715*** (0.022)	0.669*** (0.023)	0.590*** (0.023)
Log BMI, Wave 1, q90	0.771*** (0.023)	0.698*** (0.034)	0.824*** (0.031)	0.808*** (0.059)	0.704*** (0.044)	0.785*** (0.039)	0.725*** (0.042)
Log BMI, Wave 1, q90-q50	0.093*** (0.026)	0.053** (0.027)	0.126*** (0.026)	0.063 (0.050)	-0.011 (0.032)	0.116*** (0.031)	0.135*** (0.047)
N	5487	2702	2785	784	1697	1423	1583

Table 4e: Interquartile range regressions (0.9-0.5), wave 1 to wave 2

	Total	Male	Female	Educ=1	Educ=2	Educ=3	Educ=4
Dependent variable: Log normalised BMI, wave 2							
Log BMI, Wave 1, q50	0.875*** (0.010)	0.881*** (0.014)	0.868*** (0.015)	0.881*** (0.031)	0.878*** (0.019)	0.870*** (0.021)	0.864*** (0.019)
Log BMI, Wave 1, q90	0.852*** (0.018)	0.847*** (0.026)	0.851*** (0.027)	0.841*** (0.067)	0.807*** (0.038)	0.863*** (0.029)	0.842*** (0.034)
Log BMI, Wave 1, q90-q50	-0.023 (0.016)	-0.033 (0.025)	-0.018 (0.025)	-0.040 (0.052)	-0.071** (0.028)	-0.007 (0.035)	-0.022 (0.035)
N	5487	2702	2785	784	1697	1423	1583

***=p≤0.01, **=0.01p≤0.05, *=0.05<p≤0.1

Table 4f: Interquartile range regressions (0.9-0.5), wave 2 to wave 3

	Total	**Male**	**Female**	**Educ=1**	**Educ=2**	**Educ=3**	**Educ=4**
Dependent variable: Log normalised BMI, wave 3							
Log BMI, Wave 2 q50	0.744*** (0.010)	0.706*** (0.015)	0.766*** (0.013)	0.804*** (0.028)	0.771*** (0.018)	0.732*** (0.019)	0.679*** (0.018)
Log BMI, Wave 2 q90	0.797*** (0.017)	0.756*** (0.023)	0.823*** (0.022)	0.811*** (0.046)	0.797*** (0.029)	0.790*** (0.034)	0.764*** (0.030)
Log BMI, Wave 2, q90-q50	0.053*** (0.015)	0.050** (0.021)	0.057*** (0.021)	0.007 (0.053)	0.027 (0.026)	0.058* (0.033)	0.086** (0.034)
N	5487	2702	2785	784	1697	1423	1583

***=p≤0.01, **=0.01p≤0.05, *=0.05<p≤0.1

Table 5a: Mobility indices, wave 1 to wave 3

	Shorrocks Transition	Shorrocks Mobility	Bartholomew Jump Index (T)	Bartholomew Jump Index (M)
Total Sample	0.75	0.62	0.88	0.48
Males	0.74	0.71	0.86	0.57
Females	0.76	0.56	0.91	0.42
Educ level 1	0.72	0.62	0.90	0.49
Educ level 2	0.76	0.62	0.88	0.48
Educ level 3	0.77	0.64	0.87	0.52
Educ level 4	0.78	0.65	0.90	0.49

Table 5b: Mobility indices, wave 1 to wave 2

	Shorrocks Transition	Shorrocks Mobility	Bartholomew Jump Index (T)	Bartholomew Jump Index (M)
Total Sample	0.664	0.518	0.706	0.369
Males	0.643	0.587	0.675	0.417
Females	0.688	0.470	0.739	0.337
Educ level 1	0.672	0.518	0.734	0.380
Educ level 2	0.655	0.517	0.695	0.366
Educ level 3	0.684	0.599	0.735	0.413
Educ level 4	0.677	0.474	0.690	0.327

Table 5c: Mobility indices, wave 2 to wave 3

	Shorrocks Transition	Shorrocks Mobility	Bartholomew Jump Index (T)	Bartholomew Jump Index (M)
Total Sample	0.672	0.498	0.731	0.371
Males	0.672	0.577	0.741	0.427
Females	0.677	0.441	0.726	0.329
Educ level 1	0.708	0.508	0.808	0.382
Educ level 2	0.667	0.475	0.716	0.351
Educ level 3	0.658	0.509	0.710	0.371
Educ level 4	0.663	0.554	0.695	0.415

Table 6a: Persistence: fraction that do not move to lower quintile, wave 1 to wave 3

	All Quintiles			Top Quintile		
Quintile	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**
1	1.00	1.00	1.00	0.427	0.426	0.538
2	0.747	0.747	0.727	0.355	0.321	0.347
3	0.620	0.620	0.600	0.380	0.380	0.406
4	0.554	0.514	0.569	0.388	0.355	0.374
5	0.582	0.558	0.620	0.360	0.234	0.468

Table 6b: Persistence: fraction that do not move to lower quintile, wave 1 to wave 2

	All Quintiles			Top Quintile		
Quintile	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**
1	1.00	1.00	1.00	0.4356	0.4977	0.506
2	0.7318	0.792	0.6992	0.444623	0.411801	0.446484
3	0.6281	0.6449	0.6158	0.442351	0.462212	0.415814
4	0.6144	0.6033	0.6252	0.412837	0.471272	0.340347
5	0.6778	0.6647	0.6896	0.475488	0.379353	0.488125

Table 6c: Persistence: fraction that do not move to lower quintile, wave 2 to wave 3

	All Quintiles			Top Quintile		
Quintile	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**
1	1.00	1.00	1.00	0.4785	0.4687	0.5223
2	0.7603	0.7644	0.7441	0.461016	0.400834	0.479301
3	0.6476	0.6546	0.615	0.421575	0.404814	0.399489
4	0.6213	0.5976	0.6321	0.427204	0.393917	0.506447
5	0.652	0.64	0.6869	0.561488	0.388859	0.58946

Figure 1: Change in rank mobility curve – complete sample

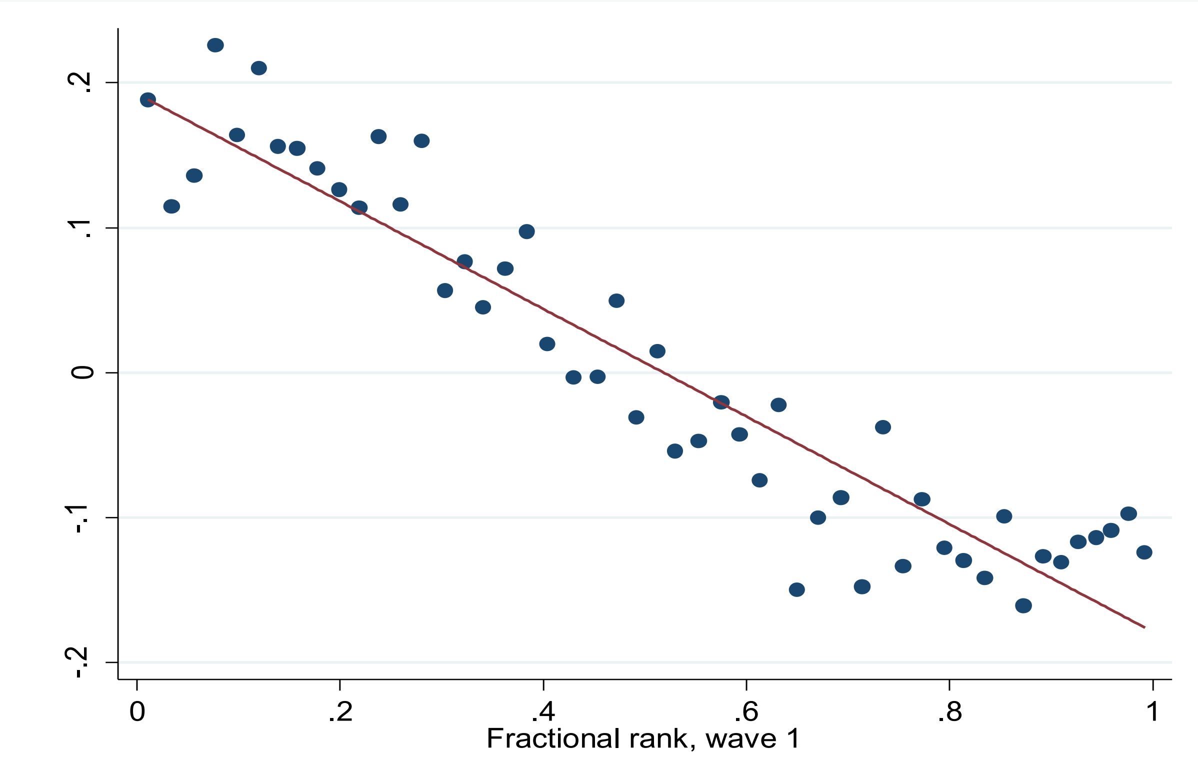


Figure 2: Rank mobility curve – complete sample

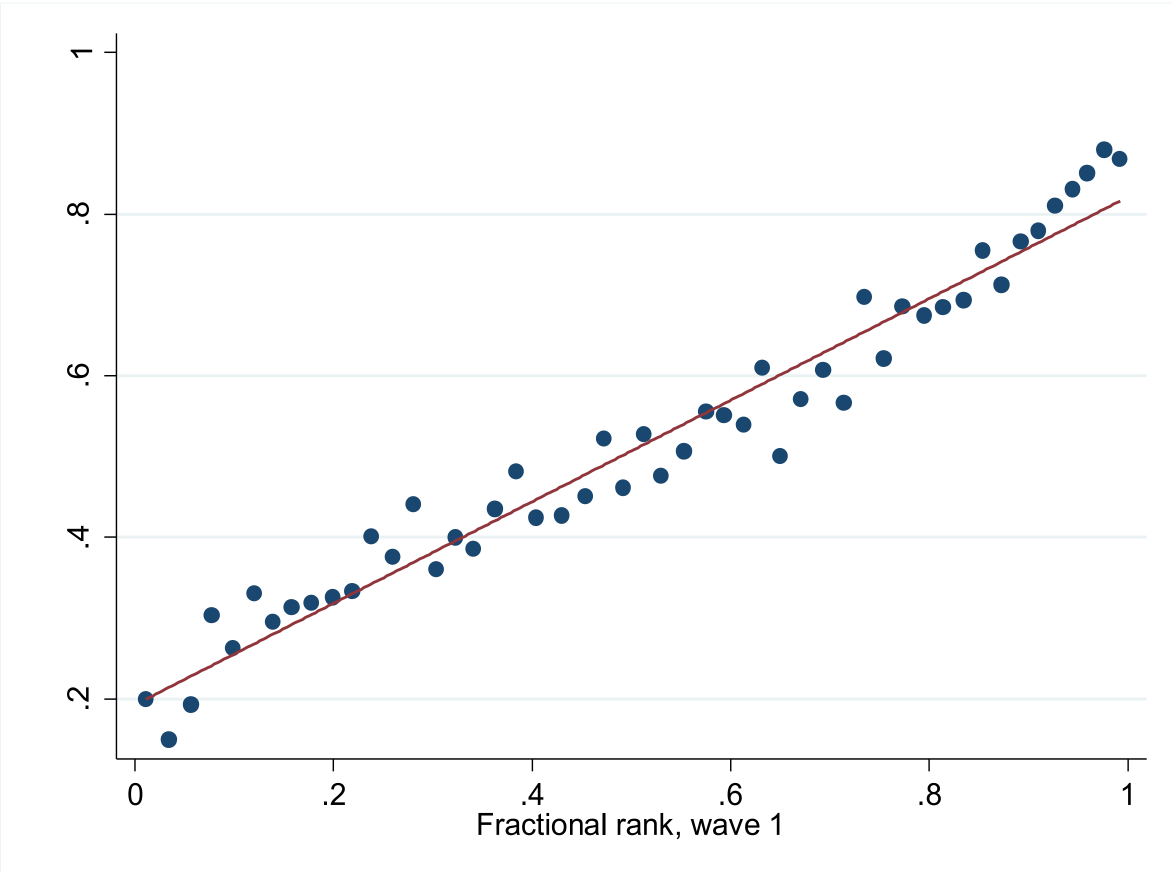


Figure 3: BMI Mobility curve

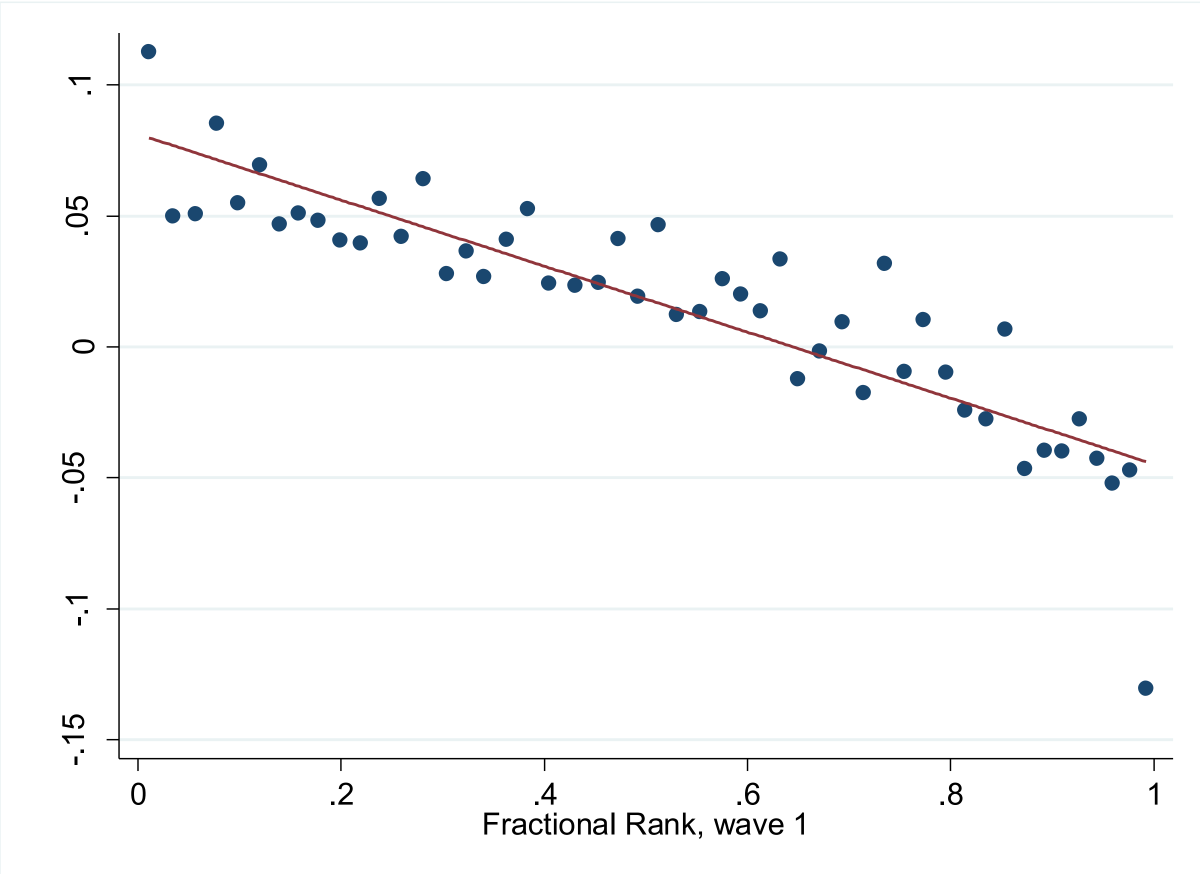


Figure 4: BMI Absolute Mobility Curve

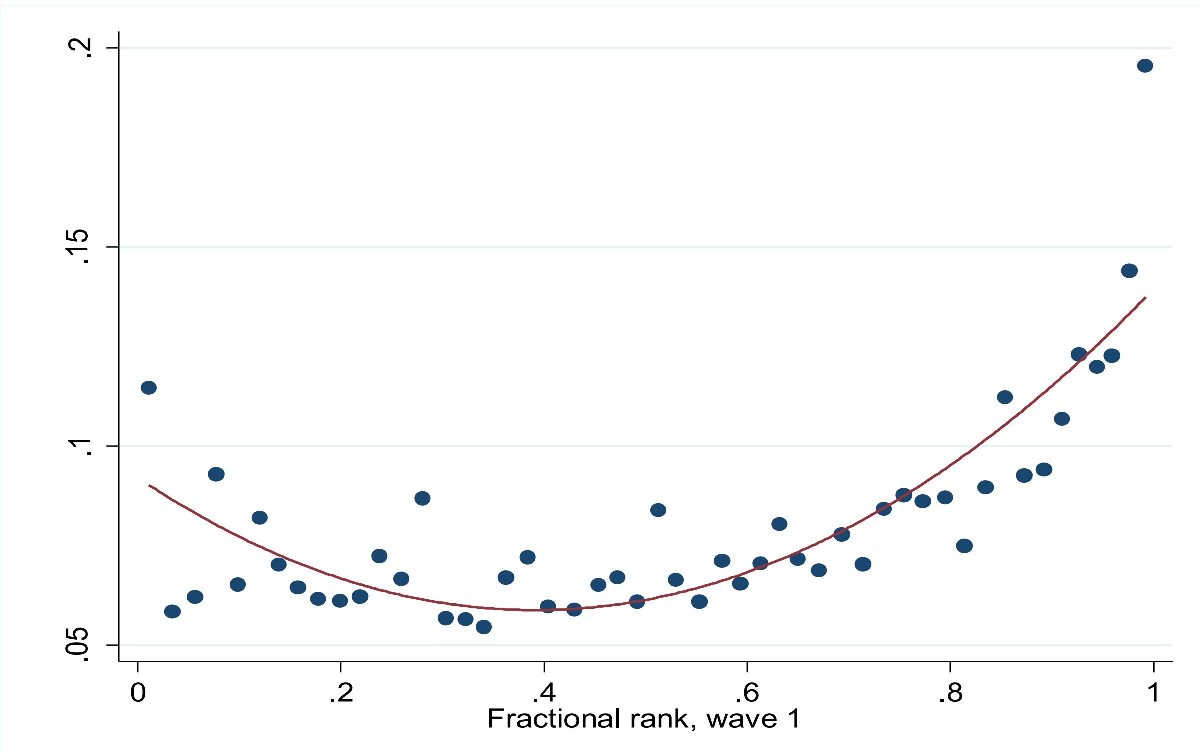


Figure 5a: BMI Mobility curve by education

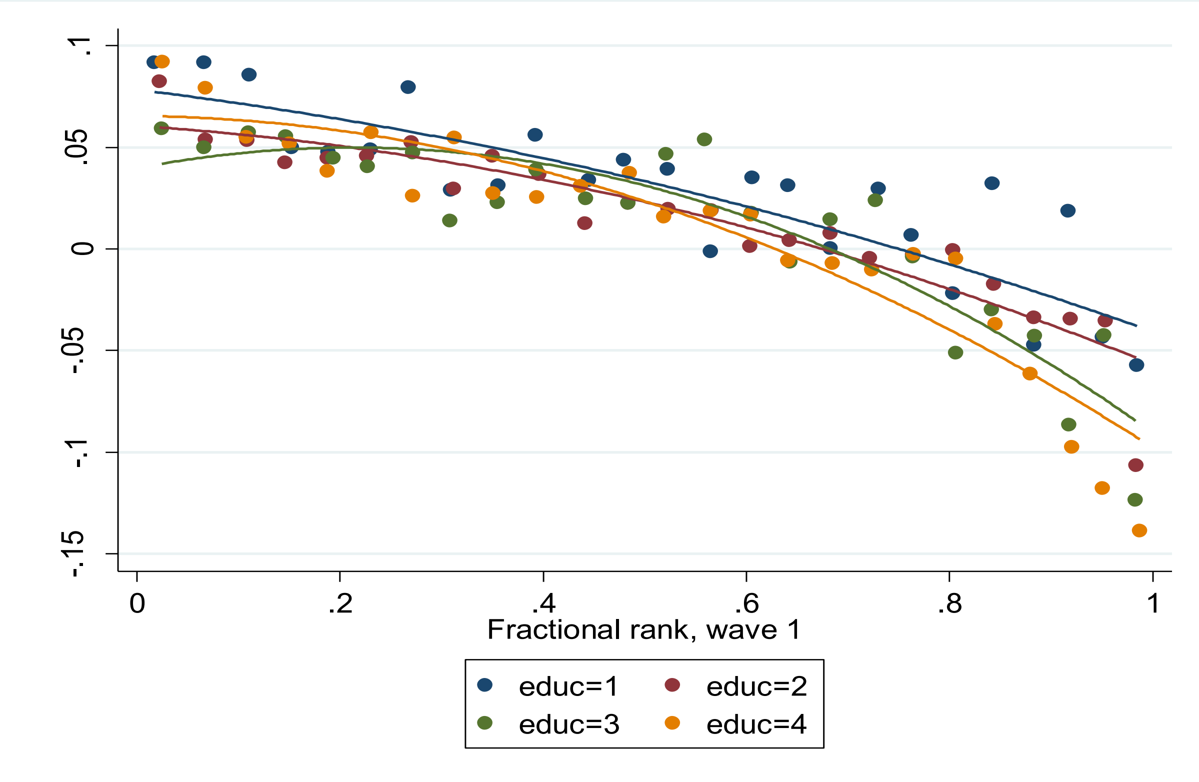


Figure 5b: BMI Absolute Mobility Curve, by education

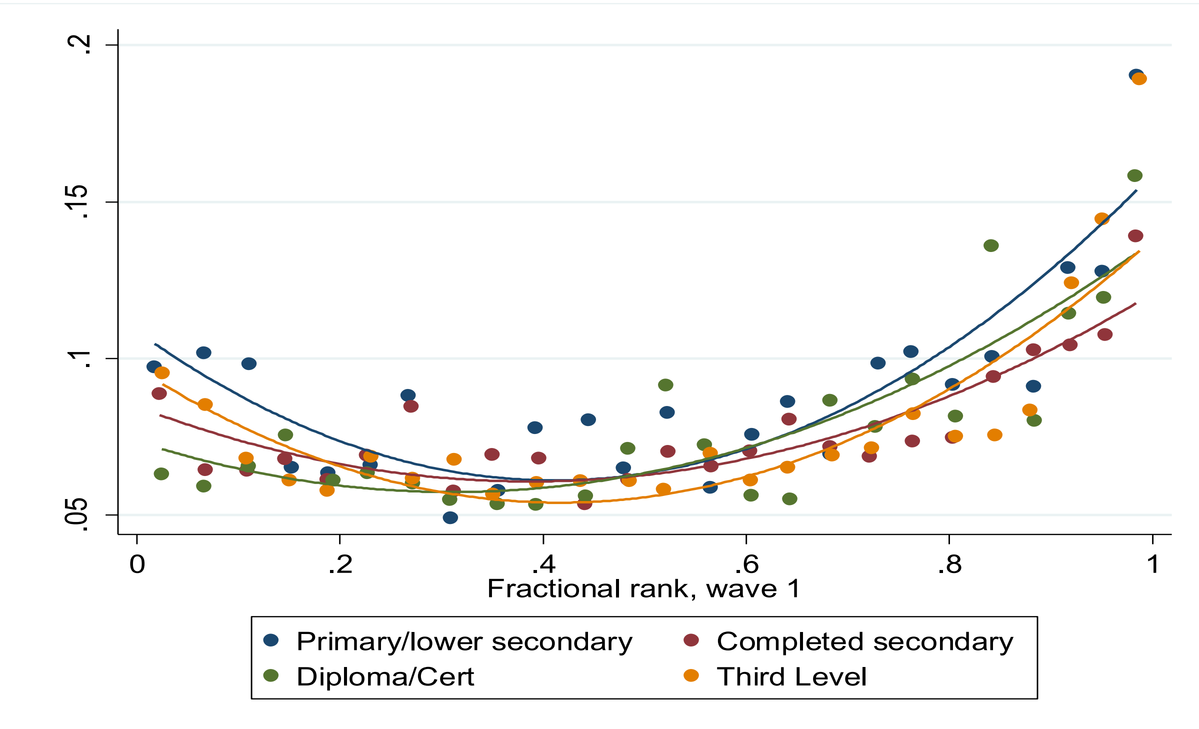


Figure 5: TIM Curve, complete sample

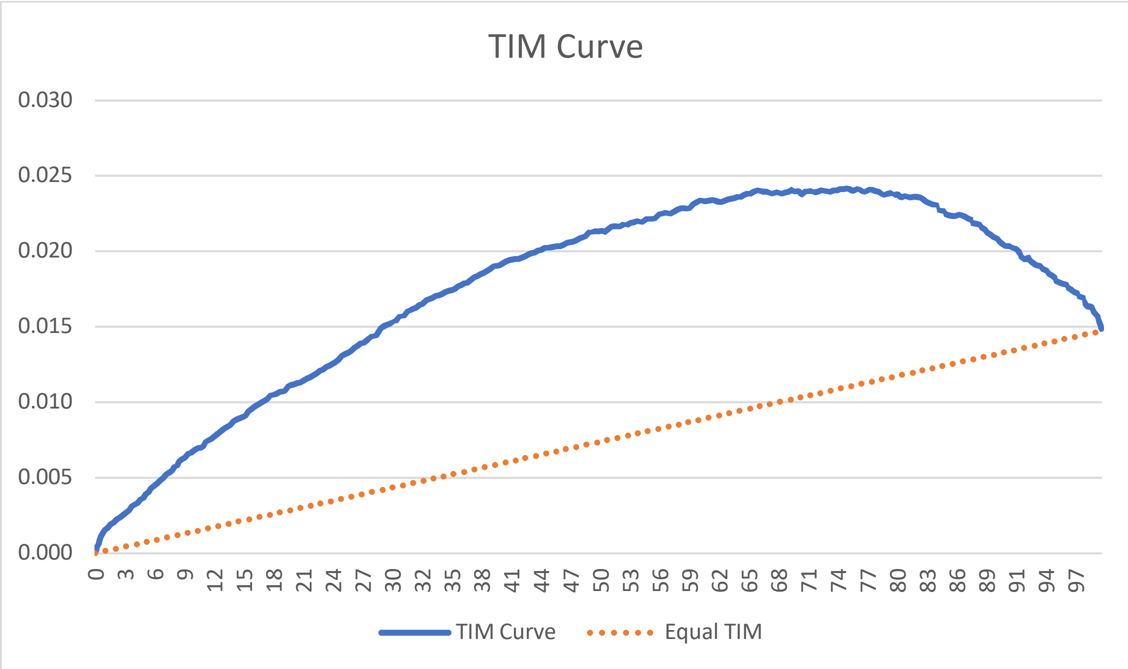


Figure 6: Total number of moves between BMI categories

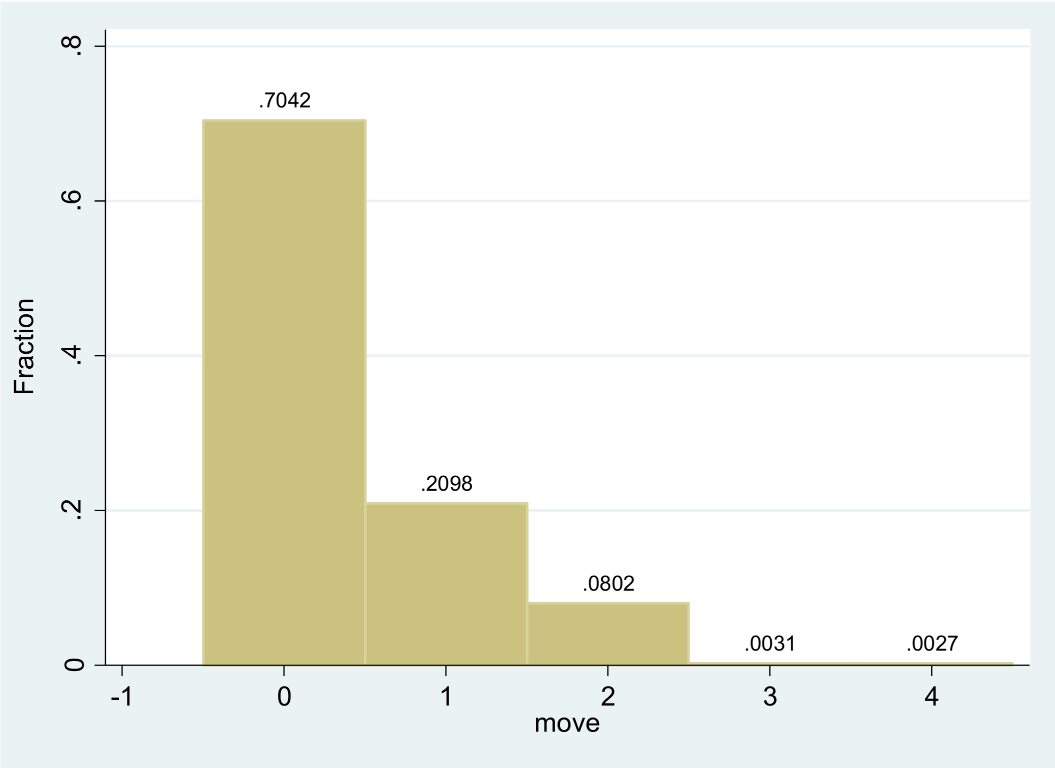
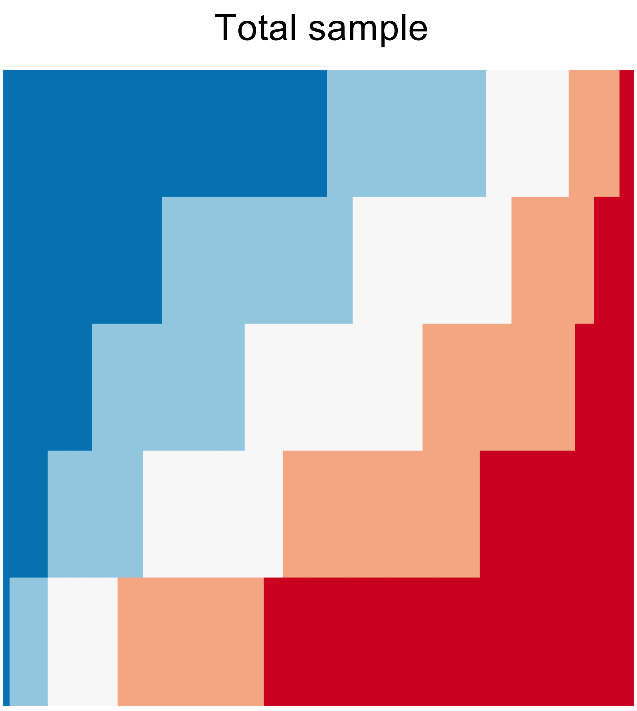
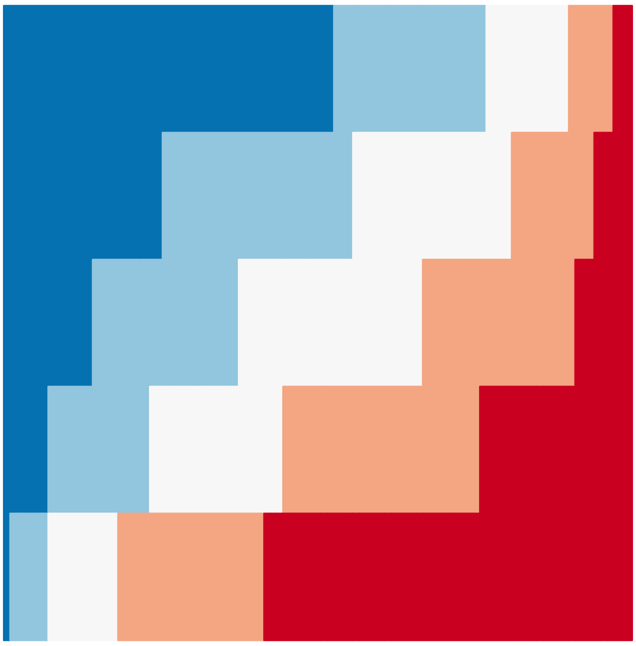


Figure 7: Transition Probability Colour Plots

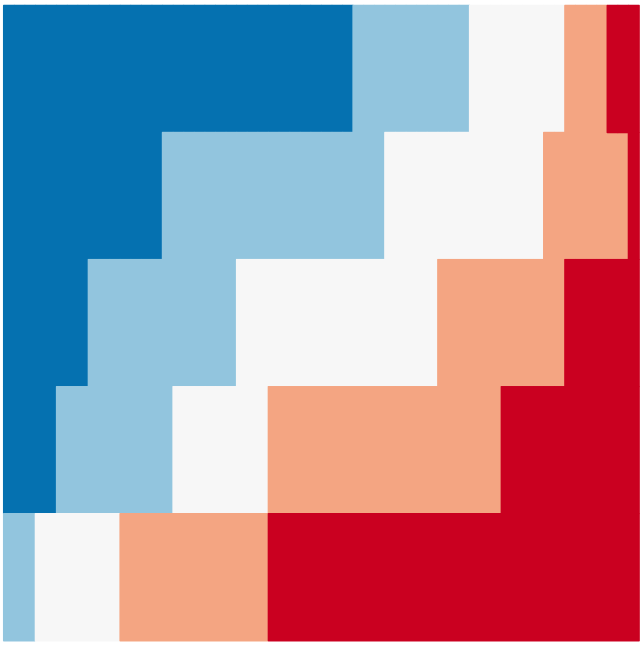


Males only

Females only

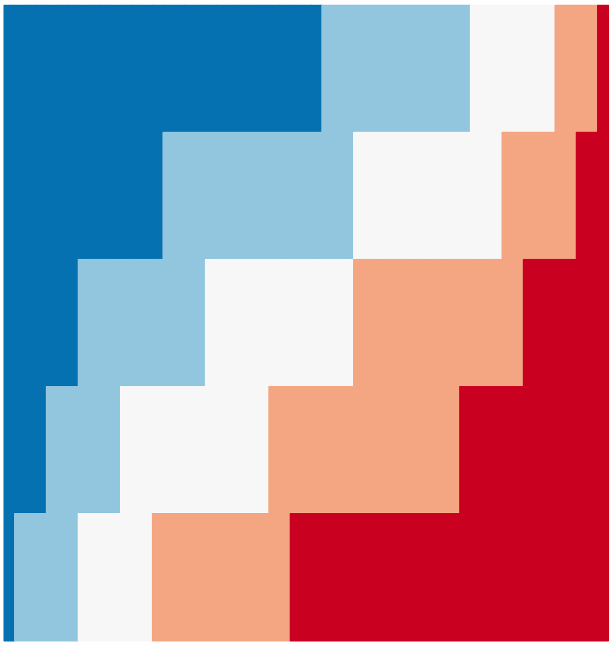


Maternal education 1



Maternal education 2

Maternal education 3



Maternal education 4

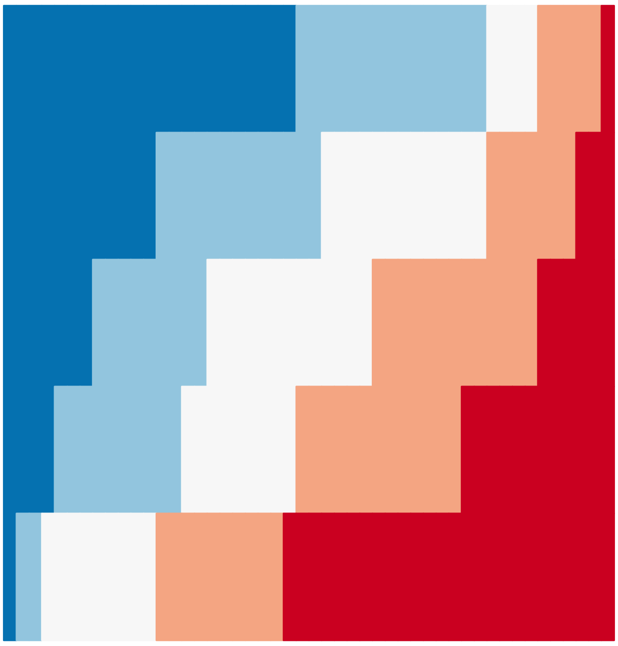


Figure 8a: Upward mobility dominance by gender

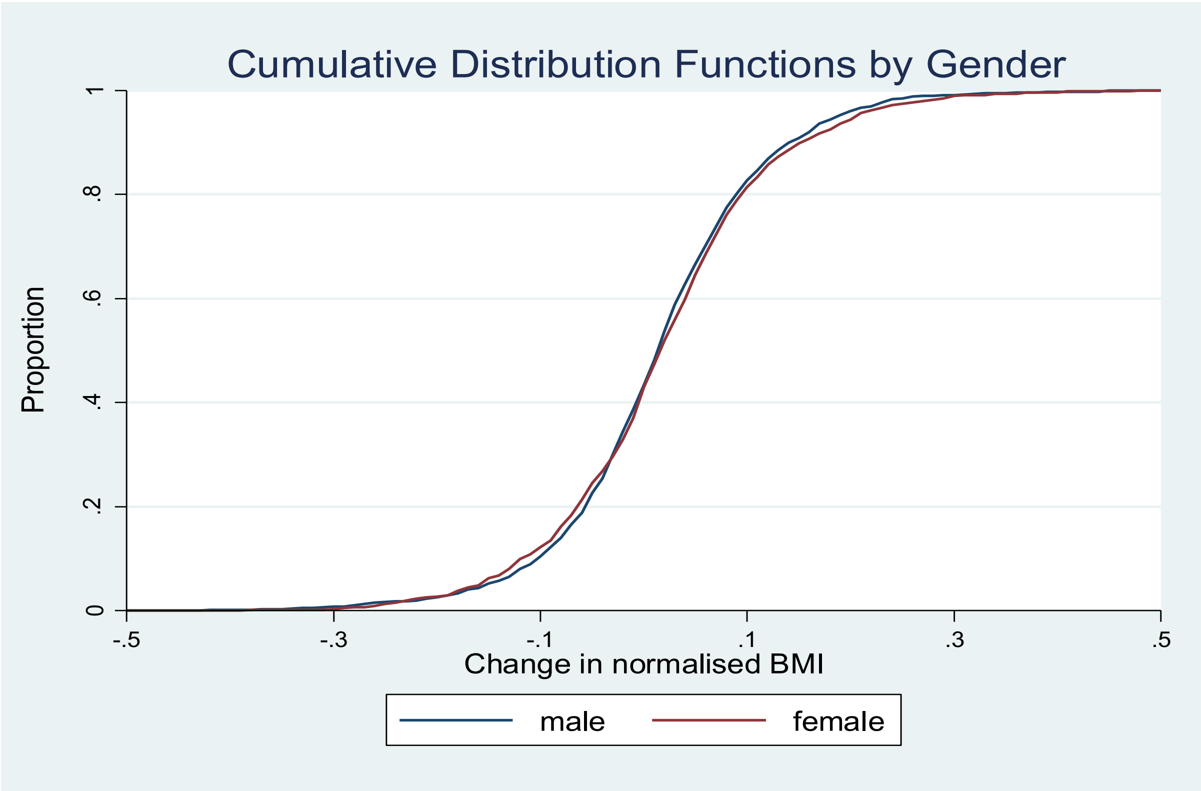


Figure 8b: Upward mobility dominance by gender, positive BMI changes only

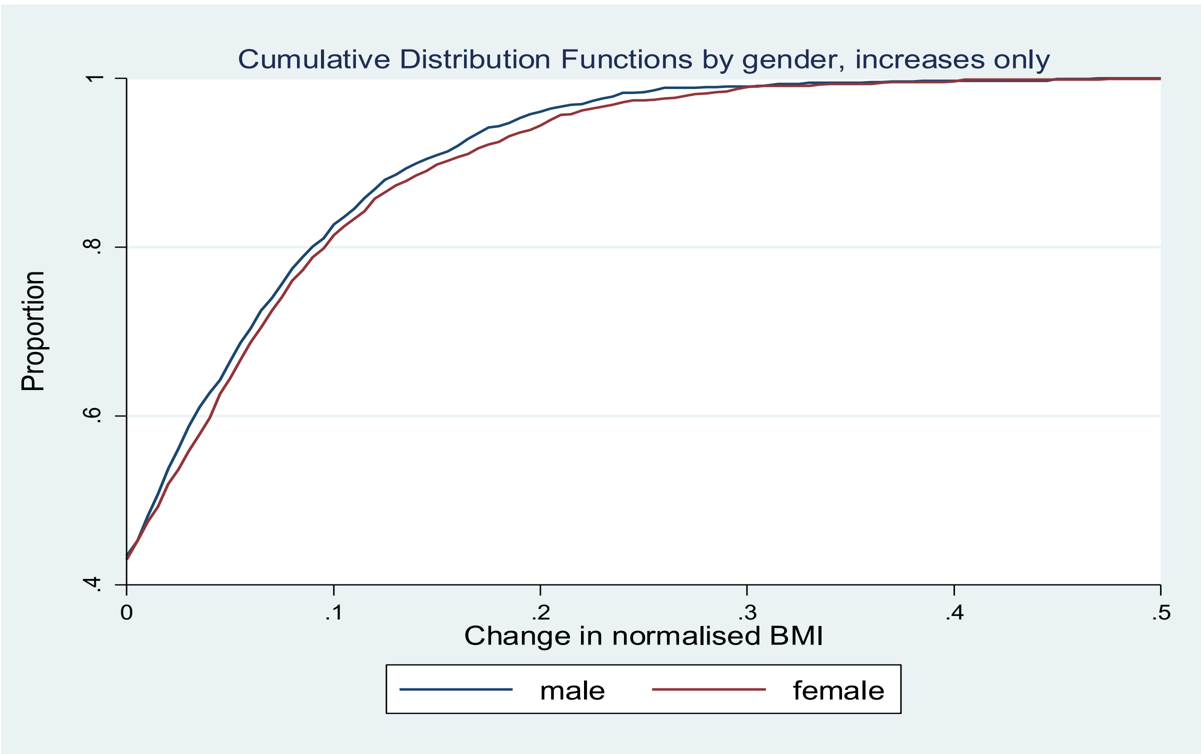


Figure 8c: Upward mobility dominance by maternal education, positive BMI changes only

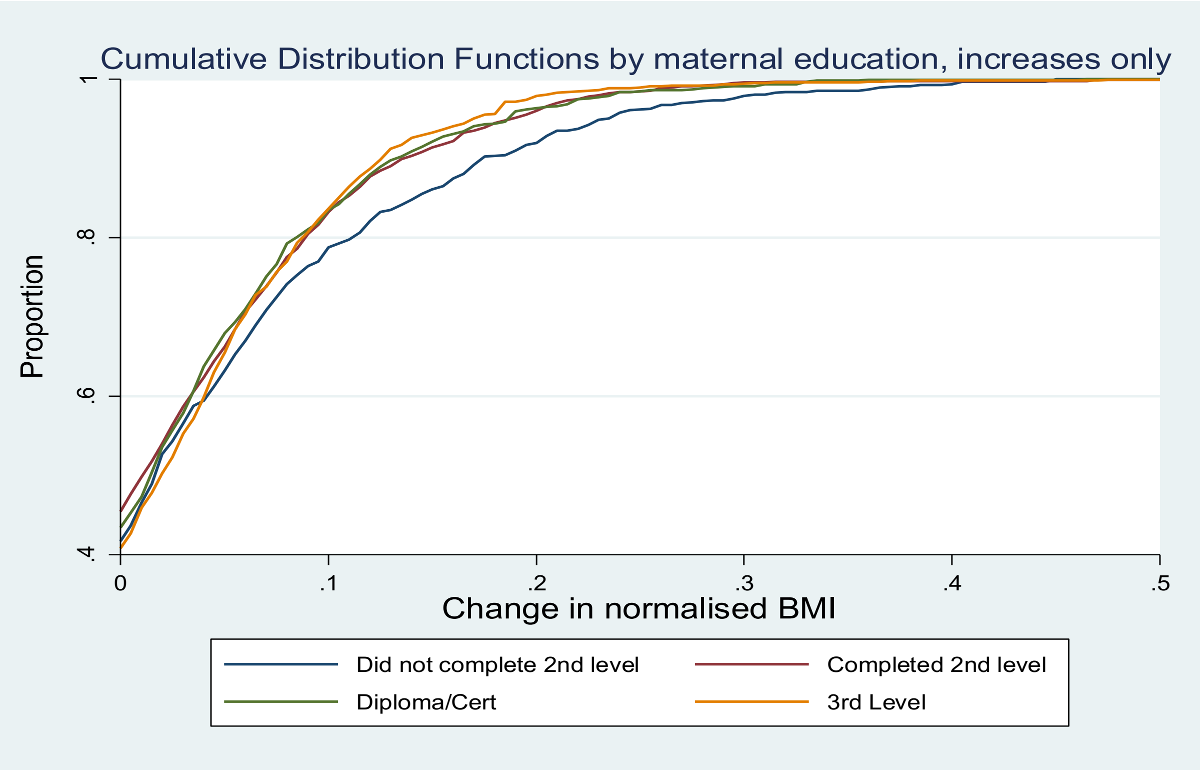
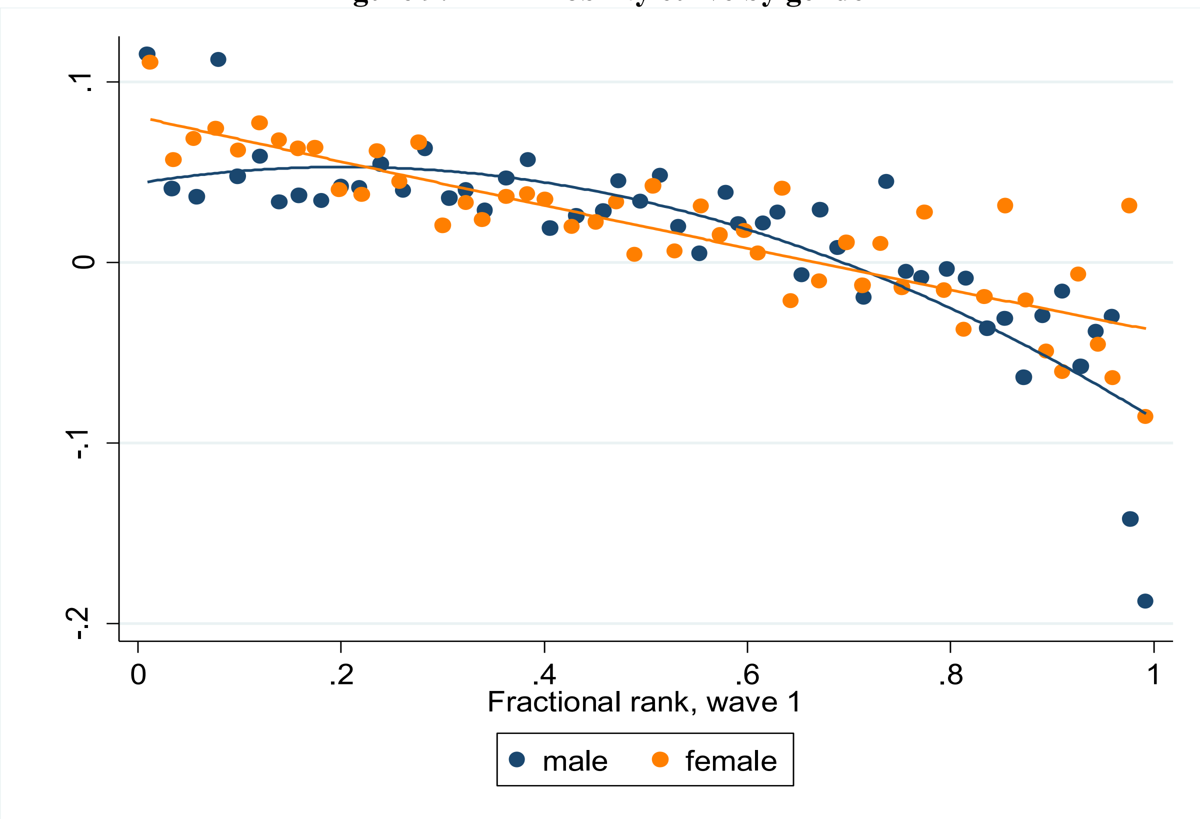


Figure 9: BMI mobility curve by gender



Appendix A

Table A1: Transition matrix by quintile, complete sample

	1	2	3	4	5
1	0.52	0.25	0.13	0.08	0.03
2	0.25	0.30	0.25	0.13	0.06
3	0.15	0.24	0.28	0.24	0.10
4	0.07	0.15	0.22	0.32	0.23
5	0.01	0.06	0.12	0.23	0.58

Table A2: Transition matrix by quintile, males

	1	2	3	4	5
1	0.57	0.22	0.14	0.07	0.02
2	0.25	0.29	0.26	0.14	0.06
3	0.11	0.23	0.30	0.25	0.11
4	0.06	0.12	0.25	0.35	0.21
5	0.01	0.06	0.14	0.26	0.53

Table A3: Transition matrix by quintile, females

	1	2	3	4	5
1	0.47	0.28	0.12	0.09	0.03
2	0.25	0.32	0.24	0.12	0.06
3	0.19	0.25	0.25	0.23	0.09
4	0.08	0.18	0.19	0.29	0.26
5	0.01	0.05	0.10	0.20	0.63

Table A4: Transition matrix by quintile, maternal education level 1

	1	2	3	4	5
1	0.55	0.18	0.13	0.08	0.06
2	0.23	0.31	0.24	0.15	0.07
3	0.14	0.23	0.30	0.20	0.13
4	0.09	0.18	0.13	0.32	0.27
5	0.01	0.05	0.09	0.19	0.65

Table A5: Transition matrix by quintile, maternal education level 2

	1	2	3	4	5
1	0.52	0.25	0.14	0.07	0.02
2	0.29	0.27	0.24	0.11	0.08
3	0.18	0.27	0.25	0.20	0.09
4	0.07	0.12	0.25	0.31	0.25
5	0.01	0.06	0.09	0.22	0.61

Table A6: Transition matrix by quintile, maternal education level 3

	1	2	3	4	5
1	0.52	0.26	0.15	0.06	0.01
2	0.26	0.35	0.23	0.13	0.03
3	0.11	0.23	0.25	0.30	0.10
4	0.07	0.13	0.27	0.32	0.21
5	0.02	0.08	0.10	0.30	0.49

Table A7: Transition matrix by quintile, maternal education level 4

	1	2	3	4	5
1	0.46	0.33	0.10	0.10	0.01
2	0.20	0.32	0.31	0.15	0.02
3	0.11	0.20	0.34	0.29	0.06
4	0.05	0.19	0.26	0.34	0.16
5	0.02	0.03	0.26	0.27	0.41

Table A8: Mobility matrix by BMI category, total sample

	1	2	3
1	0.86	0.12	0.02
2	0.40	0.44	0.17
3	0.19	0.35	0.46

Table A9: Mobility matrix by BMI category, males

	1	2	3
1	0.86	0.12	0.02
2	0.43	0.39	0.18
3	0.27	0.40	0.33

Table A10: Mobility matrix by BMI category, females

	1	2	3
1	0.86	0.13	0.01
2	0.37	0.47	0.16
3	0.13	0.32	0.55

Table A11: Mobility matrix by BMI category, maternal education level 1

	1	2	3
1	0.83	0.14	0.03
2	0.32	0.44	0.24
3	0.18	0.34	0.48

Table A12: Mobility matrix by BMI category, maternal education level 2

	1	2	3
1	0.86	0.13	0.01
2	0.38	0.45	0.17
3	0.17	0.38	0.45

Table A13: Mobility matrix by BMI category, maternal education level 3

	1	2	3
1	0.87	0.11	0.02
2	0.51	0.39	0.10
3	0.25	0.28	0.47

Table A14: Mobility matrix by BMI category, maternal education level 4

	1	2	3
1	0.89	0.10	0.01
2	0.48	0.45	0.07
3	0.20	0.43	0.37

Appendix B: Mobility Amongst Principal Carers

In this section of the paper we replicate the analysis for the principal carers of the adolescents in the main part of the paper. We do this for two reasons: first of all, the issue is of interest in its own right and secondly it also gives us results with which to compare the results for the adolescents.

The data source is as in the main part of the paper, the GUI survey except that now our focus of analysis is the principal carer of the study child. In almost all cases this is the birth mother and we drop those observations where it is not. Unlike the case with adolescents we do not have to concern ourselves with different BMI thresholds by age and gender. We use the standard thresholds of 25 for overweight and 30 for obesity.

Table B1: Rank-rank regressions

	Total	**Educ=1**	**Educ=2**	**Educ=3**	**Educ=4**
Dependent variable: fractional rank in wave 3					
Rank, Wave 1	0.771 (0.009)	0.765 (0.024)	0.765 (0.016)	0.796 (0.017)	0.758 (0.016)
Constant	0.097 (0.005)	0.106 (0.014)	0.094 (0.008)	0.094 (0.009)	0.095 (0.008)
TMR	3.321	1.207	7.286	1.580	7.196
N	4909	627	1535	1272	1418

Table B2: Quantile regressions

	Total	Educ=1	Educ=2	Educ=3	Educ=4
Dependent variable: log BMI in wave 3					
Log BMI Wave 1, q=50	0.908*** (0.010)	0.898*** (0.028)	0.912*** (0.019)	0.912*** (0.018)	0.901*** (0.018)
Log BMI, Wave 1, q=90	0.859*** (0.017)	0.824*** (0.063)	0.868*** (0.030)	0.815*** (0.034)	0.873*** (0.032)
Log BMI, Wave 1, q90-q50	-0.048*** (0.018)	-0.074 (0.053)	-0.044** (0.022)	-0.098*** (0.027)	-0.028 (0.035)
N	4909	627	1535	1272	1418

Table B3: Mobility indices

	Shorrocks Transition	Shorrocks Mobility	Bartholomew Jump Index (T)	Bartholomew Jump Index (M)
Total Sample	0.61	0.480	0.64	0.350
Educ level 1	0.629	0.474	0.676	0.345
Educ level 2	0.618	0.498	0.653	0.364
Educ level 3	0.581	0.471	0.584	0.342
Educ level 4	0.621	0.493	0.642	0.362

Table B4: Persistence: fraction that do not move to lower quintile

Quintile	All Quintiles	Top Quintile
1	100	0.4323
2	0.5928	0.346488
3	0.563	0.409968
4	0.6152	0.340625
5	0.6664	0.373048

Table B5: Transition matrix by quintile, complete sample

	1	2	3	4	5
1	0.75	0.16	0.05	0.03	0.01
2	0.4	0.35	0.16	0.08	0.01
3	0.13	0.31	0.34	0.19	0.05
4	0.06	0.1	0.23	0.46	0.16
5	0.01	0.03	0.04	0.25	0.67

Table B6: Transition matrix by quintile, maternal education level 1

	1	2	3	4	5
1	0.65	0.22	0.07	0.04	0.01
2	0.44	0.28	0.19	0.09	0
3	0.11	0.28	0.35	0.18	0.09
4	0.09	0.14	0.2	0.46	0.11
5	0.01	0	0.02	0.22	0.75

Table B7: Transition matrix by quintile, maternal education level 2

	1	2	3	4	5
1	0.79	0.14	0.04	0.03	0
2	0.34	0.39	0.17	0.1	0
3	0.16	0.33	0.28	0.19	0.05
4	0.04	0.08	0.26	0.44	0.18
5	0.02	0.04	0.07	0.24	0.63

Table B8: Transition matrix by quintile, maternal education level 3

	1	2	3	4	5
1	0.74	0.16	0.06	0.02	0.02
2	0.48	0.31	0.12	0.07	0.02
3	0.1	0.28	0.4	0.21	0.02
4	0.03	0.07	0.18	0.53	0.2
5	0	0.03	0.02	0.25	0.7

Table B9: Transition matrix by quintile, maternal education level 4

	1	2	3	4	5
1	0.74	0.16	0.06	0.02	0.02
2	0.48	0.31	0.12	0.07	0.02
3	0.1	0.28	0.4	0.21	0.02
4	0.03	0.07	0.18	0.53	0.2
5	0	0.03	0.02	0.25	0.7

Table B10: Mobility matrix by BMI category, total sample

	1	2	3
1	0.64	0.29	0.07
2	0.12	0.56	0.33
3	0.02	0.13	0.85

Table B11: Mobility matrix by BMI category, maternal education level 1

	1	2	3
1	0.6	0.32	0.08
2	0.11	0.56	0.33
3	0.01	0.11	0.89

Table B12: Mobility matrix by BMI category, maternal education level 2

	1	2	3
1	0.64	0.3	0.06
2	0.14	0.54	0.33
3	0.03	0.14	0.83

Table B13: Mobility matrix by BMI category, maternal education level 3

	1	2	3
1	0.63	0.3	0.07
2	0.1	0.54	0.36
3	0.01	0.11	0.88

Table B14: Mobility matrix by BMI category, maternal education level 4

	1	2	3
1	0.68	0.24	0.08
2	0.1	0.61	0.29
3	0.02	0.25	0.73

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