AN INVESTIGATION INTO THE RELATIONSHIP BETWEEN PRODUCTIVITY, EARNINGS AND AGE IN THE EARLY YEARS OF A WORKING LIFE

Report Prepared for the Low Pay Commission

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EXECUTIVE SUMMARY

A: The National Minimum Wage and Age-Earnings Profiles of Young Workers

- The first element of this report examines empirical age-earnings profiles of young workers before and after the introduction of the National Minimum Wage (NMW) using individual data from the Annual Survey of Hours and Earnings (ASHE).
- While there has been average real wage growth for all workers over 1990-2009, for younger workers aged 28 or under, there has been comparatively very little growth in their average real hourly wages over this period.
- We investigate the rate of growth of real hourly wages by cohort of birth, comparing the empirical age-earnings profiles of workers who were young (aged under 22) before the advent of the youth and development rates with those that have received the age-specific NMWs. There is little evidence of any change in the slope of the age-earnings profiles between the younger worker (aged 16-21) and young adult (age 22-28) cohorts. Real earnings growth for younger workers does not appear to have been affected by the introduction of the youth and development rates.
- A simple before-after regression analysis which allows for the age-earnings profiles to differ pre- and post- NMW confirms that the rate of growth of earnings by age has been unchanged by the introduction of the NMW. This conclusion is robust to the inclusion of a number of controls for gender, part-time status, hours, occupation and region.
- When attention is focussed only on low-paying sectors and low skill occupations, a similar finding is evident. While the average rate of growth of earnings by age is rather lower amongst these workers than in the population as a whole as would be expected, there is once again no evidence that the introduction of the NMW has affected the age-earnings profile of these workers who are more likely to be paid at or close to the NMW.

B: Sectoral Productivity and Wage Equations

- The second half of the report uses data from the Annual Business Inquiry (ABI) and ASHE to construct a panel of industries over the period 1996-2007 to estimate productivity and wage equations at the sector level.

- The results in our preferred specification (Table B6) suggest that the age-productivity profile and the age-earnings profile both rise with age, reaching a plateau once workers are aged in their forties, with some suggestion that the productivity profile may slope downwards slightly for workers in their fifties.
- The youngest workers (aged 16-21) therefore have lower wages than all other age groups, and also lower productivity. Furthermore, their negative productivity gap relative to older workers is larger than their negative wage gap relative to older workers, suggesting that young workers are overpaid for their productivity contribution, relative to older workers.
- Given the previous point, it might have been feared that introducing a NMW that could potentially benefit younger workers more than older workers, if the NMW has a larger effect on the former's wages, could have exacerbated this situation of overpayment for younger workers.
- There is, however, no evidence for such an effect of the NMW. Breaking the sample into pre- (1996-1998) and post-NMW (1999-2007) periods, and estimating the equations separately for both periods, reveals that the age-earnings profile is unchanged by the introduction of the NMW – the wage relativities across age groups remain the same. The introduction of the NMW has not increased the wages of younger workers more than for older workers, and so has not narrowed the wage gaps between age groups. This suggests that the relativities in the various age-specific NMW rates have been set at about the right level.
- This result is unaffected if the sample is restricted to low-paying sectors, and also if we measure the impact of the NMW by the proportion of workers earning at or near the NMW, rather than simply a before-and-after analysis of its introduction.
- Furthermore, the productivity equation results suggest that productivity differences between 16-21 year old workers and older workers have actually narrowed in the post-NMW period. While this cannot be said with certainty to be a causal effect, one possible explanation is that the NMW has acted as an efficiency wage, motivating effort, more for younger workers than for older workers.

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AN INVESTIGATION INTO THE RELATIONSHIP BETWEEN PRODUCTIVITY, EARNINGS AND AGE IN THE EARLY YEARS OF A WORKING LIFE

Introduction

This research project has two main elements. In the first part, using data from the New Earnings Survey (NES) and Annual Survey of Hours and Earnings (ASHE), we analyse empirical age-earnings profiles. We compare the slopes of the profiles for young people aged 16 to 21 years before and after the introduction of the National Minimum Wage (NMW), and contrast these with the gradients of the age-earnings profiles of those aged 22 and over (and hence eligible for the adult NMW rate). Standard quadratic in age (or experience) profiles are known to understate early earnings growth (and to overstate the decline for older workers). Hence we restrict the analysis to focus just on younger workers and young adults aged 28 years or under, and use more flexible parametric and semi-parametric specifications. Our focus in this part of the project is on any differences and changes in the relative slopes of these age-earnings profiles for younger workers aged 16 to 21 years following the introduction of the NMW. Attention is also focussed on low paying sectors and low skill occupations which employ a high share of young people and in which the minimum wage is likely to be particularly relevant for pay setting.

Under strong assumptions regarding product and labour markets, the estimated relationship between age and earnings can be used to infer the age-productivity relationship. However, for these younger workers with little labour market experience, and in a labour market in which a minimum wage is binding, these assumptions are certainly too strong. Hence the second part of this project examines the relationship between age, wages and productivity more explicitly. In particular, productivity and wage equations are estimated at the 3 digit industry level using Annual Business Inquiry (ABI) data. In addition to standard industry controls, the right hand side variables include measures of the proportion of each industry’s workforce who fall within particular age bands. Of interest is the gap between wages and productivity for different age groups, revealing whether workers at each age are under- or over-paid relative to their productivity. In addition, undertaking this analysis using data from before and after the introduction of the NMW reveals whether the wage-productivity gap for young workers has been affected by the introduction of the NMW.

SECTION A: The NMW and age-earnings profiles of young workers

A.1 Introduction

This first element of the project uses NES and ASHE data to estimate empirical age-earnings profiles. Following Murphy and Welch (1990) for the US, and Robinson (2003) for the UK, the standard quadratic functional form for the relationship between wages and age or experience as utilised widely in the literature since Mincer's (1974) pioneering work has been known to underestimate the rate of growth of earnings in the early years of work, and hence would be particularly inappropriate in this case. We examine the slope of the age-earnings relationships for younger workers (16-21 year olds) as compared to young adults (aged 22-28), in order to see whether the average growth rate in earnings with age has changed significantly since the introduction of the NMW rates.

Any absolute and relative changes in the growth of earnings in the early years of a working life brought about because of the introduction of the two youth minima and the adult NMW rate may be obscured in any aggregated analysis. Hence we also repeat the analysis for a select group of low pay sectors and low skill occupations in which there are disproportionately more young people, and for which the minimum wage is particularly relevant.

A.2 Data and preliminary results

The primary data used in this section of the report is the ASHE and its predecessor, the NES. This is a random 1% sample of all workers with NI numbers, and is widely regarded as the primary source of information on pay, especially low pay. Our measure of earnings is hourly wages unaffected by absence (variable *hexo* in ASHE), deflated by the April RPI index to give real hourly wages in 2005 prices. Figure A1 shows the empirical age-earnings profiles for all workers aged 16 to 60 years of age over the period 1990 to 2009, split into 5 year averages.[1] These exhibit the anticipated 'inverted U-shape' in age. As can be seen, real wages grew in each semi-decade over this period on average, although the growth is clearly very uneven.

[1] The lines are a smoothly drawn plot through the median real hourly pay for workers at each age.

In particular, for younger workers (aged 16-21) and young adults (aged 22-28), there was very little real wage growth evident over the two decades. Figure A2 illustrates this more clearly by focusing on these workers only. The empirical age-earnings profiles for workers aged 21 or less are almost coincident across the four semi-decades from 1990 to 2009, while for workers aged 22 to 28 years old, real wages have only marginally increased. To confirm this pattern of real wage growth, Table A1 presents the growth in mean and median hourly earnings between 1990-94 and 2005-09. As shown in the top panel of the table, while mean real wages for all workers aged 16-60 grew by around one quarter over this period, for younger workers aged 16-21, they grew by less than one tenth. A similar pattern is apparent in the growth of median real wages as shown in the bottom panel of the table.

Of course, the aggregated figures disguise considerable heterogeneity. Figures A3 and A4 present the same information as in Figures A1 and A2 separately for men and women. While average wages are lower for women than for men, amongst younger workers, the patterns of earnings by age are very similar for men and women. For younger workers and young adults, there was very little real earnings growth between 1990-94 and 2005-09, especially for men. Table A1 confirms this visual impression, with younger workers aged 16-21 achieving very little real wage growth across the two decades in particular. While there was a modest increase in real hourly earnings for young adult women aged 22-28, this is still only half the growth in real pay experienced by women aged 29 or over. The rate of growth of earnings for young adult men aged 22-28 was even lower than for men aged 16-21.

One difficulty in interpreting the empirical age-earnings profiles presented above is that they combine workers from very different birth cohorts who attain any given age in quite different years. That is, they conflate age and cohort effects. For example, the real hourly earnings of 25 year old workers are being averaged from workers who reach the age of 25 at any time within our NES/ASHE sample of 1990 to 2009 and hence include individuals who were born between 1965 (and so were age 25 in 1990) and 1984 (so were age 25 in 2009), almost two decades later. In order to distinguish between age and cohort effects in the empirical age-earnings profiles presented above, Figure A5 presents the median (top diagram) and mean (bottom diagram) real wage profiles over time for younger workers for five selected birth cohorts. Each set of cohort members were all born in the same year as indicated in the legend to the figures, and given the sampling methodology for ASHE, effectively these are the same workers being observed over time (although new workers can join the cohort as they complete their education and enter the labour force for the first time).

Thus the first line represents the empirical age-earnings profile for individuals born in 1970, and so they were aged 20 in 1990 as indicated on the line itself. By the time that the NMW was introduced in April 1999, they were 29 years old and so would have been eligible for the adult (22+) NMW rate. Even in comparable real (2005 prices) terms, the £3.60 adult rate that was introduced in April 1999 was considerably lower (worth approximately £4.20 in 2005 prices) than the median of £9.13 per hour or mean £10.58 per hour (2005 prices) these individuals were earning on average, and thus it is perhaps unsurprising that there is no indication of any impact on their average wages.

The second line represents individuals born in 1975 and hence they were aged 16 in 1991 when they first joined the labour market. Again, these individuals would have been eligible for the adult rate NMW when it was introduced in April 1999 at which time they were aged 24 years. Their median and mean pay were again well in excess of the adult rate that was introduced at the time and there is no apparent change in the earnings profiles. The third cohort was born in 1980 and so joined the labour market aged 16 in 1996. They were age 19 in April 1999 and so would have been covered by the NMW development rate for 18-21 year olds of £3.00 per hour, and then in 2002 when they were aged 22 would have become eligible for the adult NMW rate. There is no apparent evidence of a shift in their earnings profile at either age. The fourth cohort was born in 1985 and so first entered the labour market in 2001 at age 16. At that time, there was no 16-17 year old NMW rate since this was not introduced until October 2004, and hence their pay was unregulated until they reached age 18 in 2003 when they became eligible for the 18-21 development rate, and then the full adult rate when they reached 22 in 2007. Their median and mean pay was apparently unaffected by these eligibility criteria. Finally, the last cohort illustrated in Figure A5 was born in 1990 and hence entered the labour market in 2006 aged 16. This group will have been eligible for the 16-17 year old rate which in

October 2006 was £3.30 in nominal terms (or approximately £3.22 in 2005 prices). At age 18 in 2008 they would have become eligible for the 18-21 development rate which in October that year was set at £4.77 (approximately £4.23 in 2005 terms). While their median and mean pay were relatively closer to this (at £5.20 and £5.62 respectively) than for older workers and the adult rates, their earnings profiles do not exhibit any noticeable change in slope.

The central hypothesis to be examined in this section of the report is whether the NMW has impacted upon the rate of earnings growth in the early years of a working life. Figure A5 allows us to informally examine that hypothesis by comparing the relative slopes of the cohort-specific age-earnings profiles. We examine whether the cohorts that have been eligible for the NMW[2] have differential earnings growth in the early years, as evidenced by any differences in the slope of their age-earnings profiles when compared to earlier cohorts which were not covered by the NMW when they were young. At first glance it would appear that the cohort-year profiles are approximately parallel in the early years of individuals' working lives suggesting there has been little if any change in the rate of growth of earnings according to whether cohorts have been eligible/covered by the provisions of the NMW.

This tentative conclusion is further supported by Figure A6 which plots the empirical cohort-age profiles, once again for median (top diagram) and mean (bottom diagram) real hourly earnings. The labelling on the cohort earnings profiles is now by their year of birth ('70' for those born in 1970, '75' for those born in 1975 etc). Clearly, not only has there been comparatively little real earnings growth for younger workers and young adults as suggested in the empirical age-earnings profiles presented earlier, but the rate of growth of earnings does not appear to differ systematically across different cohorts. Moreover, neither the NMW development rate for 18-21 year olds, nor the NMW adult rate for those aged 22 and over would appear to impinge on the rate of earnings growth for those cohorts that were affected by their introduction and subsequent upratings, at least as far as median and mean real hourly wages are concerned.

[2] At the teen rate for 16-17 year olds, development rate for 18-21 year olds, or adult rate for those aged 22 or over

Thus, from an initial 'eye-balling' of the data, there would appear to be no impact on the growth of average real hourly earnings for younger workers aged 16-21 relative to that of young adults aged 22-28 years as a consequence of the introduction and subsequent upratings of the NMW The next sub-section presents a more formal assessment of any changes in the earnings profiles which also takes account of other factors which can impact on the rate of growth of earnings over time and between individuals. Sectors and occupational groups likely to be particularly affected are also considered separately.

A.3 Regression Results

In this sub-section, we estimate regression based models to investigate any changes in the age-earnings profiles for young people which occur as a result of the NMW. Our basic approach is to estimate a piece-wise linear spline in age[3] which allows for a change in slope in the continuous relationship between earnings and age at age 22 when individuals become eligible for the adult NMW rate, while also additionally allowing for an intercept shift at age 22. This approach facilitates simple comparisons of the growth in earnings across age. We combine this approach with a before-and-after methodology to compare the age-earnings profile that existed prior to the introduction of the NMW with that which existed after 1999. In order to focus attention on the impact of the introduction of the NMW, and to minimise any additional influences on earnings growth, we restrict the sample to 1996 to 2001, and thus have a 'window' of 3 years of data prior to the introduction of the NMW (1996, 1997, and 1998) and 3 years of data afterwards (1999, 2000, and 2001). This also has the advantage that our analysis is not compromised by the additional inclusion of the 16-17 year old NMW rate from October 2004. However, we investigate the sensitivity of our findings to changes in the width of this window which will thereby also incorporate any impact of the introduction of the teen-rate[4]. Once again we focus on younger workers and young adults only (i.e. workers aged from 16 to 28), since age-earnings

[3] The assumption of linearity seems justified from the graphical analysis presented in the previous sub-section.

[4] Of course, subsequent upratings to the NMW are also subsumed in the 'after' window, but given that the relativities between the development and adult rates are approximately constant, this should not adversely impact on any findings.

profiles for adults aged 30 or older have very different trajectories as seen in Figures A1-A4 above.

Our basic empirical model is therefore as follows:

$$\begin{aligned} w_{it} = {} & \beta_0 + \beta_1 \mathrm{I}(22+) + \beta_2 A(16-21) + \beta_3 A(22+) \\ & + \beta_4 NMW + \beta_5 NMW \times \mathrm{I}(22+) + \beta_6 NMW \times A(16-21) + \beta_7 NMW \times A(22+) \\ & + \varepsilon_{it} \end{aligned} \qquad (1)$$

where w_{it} is hourly real wage for individual *i* in year *t*; $\mathrm{I}(22+)$ is a dummy variable indicating individuals aged 22+, $A(16-21)$ and $A(22+)$ are the linear spline variables which provide a piecewise linear function between wages and age with a node (or knot) at age 22 (see Stewart and Wallis, 1981, for example); NMW is a dummy for years after 1999 and the introduction of the NMW, and this latter variable is interacted with all of the previous variables in order to allow the piece-wise linear function to differ in both segments (16-21 and 22+) after the introduction of the NMW. The dummy variable $\mathrm{I}(22+)$ captures any shift in wages that occurs at age 22, and its interaction with *NMW* provides for this shift in wages to differ after the introduction of the NMW.

Table A2, column 1, reports the estimates for this basic specification. The data are pooled over all individuals who are between 16 and 28 years of age at some year in the period 1996 to 2001. Interpretation of the estimates is as follows. The coefficients on the two spline terms $A(16-21)$ and $A(22+)$ indicate that, prior to the introduction of the NMW, the average rate of growth of earnings is 46p per hour per year for 16-21 year olds and 47p per hour per year for 22-28 year olds. A formal test reveals that these are not statistically different (p=0.543). Individuals also experience an average increase (jump) in their wage of 45p per hour (in real terms) when they reach the age of 22 as revealed by the coefficient on the age dummy $\mathrm{I}(22+)$. After the introduction of the NMW, the slopes of the profiles for both 16-21 year olds and 22-28 year olds are virtually unchanged, both absolutely and relative to each other as shown by the insignificant coefficients on both of the interaction terms with the linear spline. They are both very slightly steeper by 4p per hour per year for 16-21 year olds and 1p per hour per year for 22-28 year olds, but neither of these changes is statistically significant. Moreover, the growth rates are still insignificantly different from each other (p=0.479). There is, however, a slightly larger upward shift in the profile at age 22 which is now (45+16=) 61p. However, this is not statistically significantly different at conventional levels from the 45p per hour jump prior to the introduction of the NMW.

To illustrate these findings more clearly, Figure A7 graphically presents the estimated profiles. The four segments shown are the linear age-earnings profiles for individuals 16-21 and 22-28, pre- and post- the introduction of the NMW in April 1999, with data for 3 years prior to and 3 years after the 1999 introduction used to estimate the profiles. On the left hand side of the figure, it can be seen that while real wages for 16-21 year olds increased slightly between 1996-98 and 1999-2001, the growth rate of earnings by age is almost identical. Similarly, the right hand side of the figure shows the age-earnings profiles for 22-28 year olds and once again, the growth rate in earnings by age is unchanged post-NMW. The jump in earnings at age 22 is visibly greater between the two upper segments corresponding to the period post-1999 than between the two lower segments although, as reported above, this difference is not statistically significant for younger workers (aged 16-21) or young adults (aged 22-28).

Thus we conclude that there is no evidence in the raw data that the age-earnings profiles for younger workers (16-21) as compared to young adults (22-28) has been affected by the introduction of the NMW in 1999. Indeed, there is no evidence to suggest that the growth in average earnings by age has changed between the period immediately before 1999 and that immediately after for either younger workers, or for young adults.

The remainder of the analysis in this sub-section explores the sensitivity of this finding. First, the same results hold whether the data window is expanded to encompass more years of data before and after the introduction of the NMW in 1999, or contracted to focus on just 1998 (before) and 1999 (after). For example, expanding the window to 5 years before (1994-98) and 5 years after (1999-2003) still produces no significant differences in the slopes of the profiles either between younger workers (aged 16-21) and young adults (22-28), or over time for each separate age group, and no significant increase in the ‘jump’ in wages at age 22.

Similarly, focussing on just 1998 and 1999 produces the same result of no difference in slopes between the age groups or over time, nor any change in the jump in wages at age 22. These results are presented in Table A5, columns 1 and 2 respectively.

Secondly, the regression results presented in Table A2 column 1 essentially estimate the mean wage profiles in each age segment. Quantile regression techniques (Koenker and Bassett, 1982) can be used to estimate the profiles corresponding to the median wage profiles which may be more representative of the 'average' worker. The results are reported in Table A2, column 2 and are qualitatively identical to those obtained previously. While the rates of growth of median earnings are lower than for mean earnings – 41p per hour per year of age as compared to 46p per hour per year of age for 16-21 year olds, and 39p per hour per year as compared to 47p per hour per year for 22-28 year olds – these rates of growth are not statistically different from each other either before the introduction of the NMW (p=0.198) or after (p=0.396). The jump in median hourly real pay at age 22 is estimated to be 29p per hour before the introduction of the NMW, and increased by 18p to 47p after the introduction of the NMW, and this increase is statistically significant at conventional levels.

Thirdly, given the repeated sampling (panel) nature of the ASHE, the pooled observations used to estimate the age-earnings profiles in Table A2, column 1, actually include repeated observations on the same individuals. Consequently, the standard errors should really be adjusted (clustered) to take account of the fact that these are not strictly all independent observations. The robust (cluster) standard errors for some of the coefficients are smaller than in column 1 and the interaction terms $NMW \times \mathrm{I}(22+)$ and $NMW \times A(16-21)$ are now both statistically significant at the 5% level. Thus the jump in wages at age 22 is now significantly greater by 16p per hour, and the rate of growth of earnings is 4p per hour per year of age greater for 16-21 year olds than before the introduction of the NMW. However, more importantly for our analysis, the rate of growth of earnings still does not differ significantly between the two age groups, neither before (p=0.369) nor after (p=0.370) the introduction of the NMW.

Fourth, it is possible to take account of a number of other influences on earnings growth to better reflect the heterogeneity of the individuals under consideration. Thus we augment the basic specification in equation 1 to include a vector of additional regressors, *Z*, so that our empirical model becomes:

$$\begin{aligned} w_{it} = {} & \beta_0 + \beta_1 \mathrm{I}(22+) + \beta_2 A(16-21) + \beta_3 A(22+) \\ & + \beta_4 NMW + \beta_5 NMW \times \mathrm{I}(22+) + \beta_6 NMW \times A(16-21) + \beta_7 NMW \times A(22+) \\ & + \beta_z' Z + \varepsilon_{it} \end{aligned} \qquad (2)$$

Unfortunately the other individual characteristics included in the ASHE data are rather limited, and perhaps most importantly, do not include educational qualifications. However, we do have gender, part-time status and weekly basic hours of work, which are all likely to be important influences on real hourly pay. Table A2 column 3 includes these three additional variables in the basic specification and all are statistically significantly different from zero at the 1% level and have their anticipated signs, such that both women and part time workers earn less per hour than men and full time workers respectively[5]. Workers who have longer basic hours also tend to earn less per hour on average, having controlled for gender and part time status. Our central conclusions, however, are completely unaffected by the inclusion of these additional variables. We can also include occupation indicators to reflect, in part, likely differences in educational attainment since there is a clear correspondence between occupation and education. And finally, we can take account of pay differences between individuals that may arise from living in particular regions which tend to have higher hourly pay. Table A2, column 4 includes these additional dummy variables. As can be clearly seen, the results are qualitatively the same as in the previous specifications.

An alternative approach to including a range of characteristics and other variables to capture other influences on real hourly pay is to exploit the repeated observation nature of the ASHE and to treat the data explicitly as a panel rather than simply

[5] The large negative coefficient on part-time status is apparently due to its strong (negative) correlation with hours of work. When excluding *basic hours* from column 3, the coefficient on *part time* is –1.36 (i.e. part time workers earn on average £1.36 less per hour than their full-time counterparts, *ceteris paribus*) which seems a more reasonable estimate. Similarly, when omitting *part time* from column 3, the coefficient on *basic hours* is then positive and statistically significant, indicating that those working more hours (i.e. full time cf part time workers) earn more per hour, consistent with the result that part time workers earn less per hour.

pooling the data. We estimated both fixed effects and random effects versions of our basic specification[6] and obtained qualitatively similar results to our least squares estimates presented above in both cases. In particular, there were no significant differences in the earnings growth rates before or after the introduction of the NMW for 16-21 vs 22-28 year olds, and the rates of growth in earnings by age for the two age groups are not significantly different from each other.

One potential criticism with the above analysis is that by analysing all workers, any impact on those likely to be paid at or close to the NMW is likely to be obscured. We therefore repeated all of the analysis presented in Table A2, first for the so-called 'low pay sectors', and second for lower skilled occupation groups.

We use as our definition of low pay sectors those defined by the Low Pay Commission in its annual report in 2007 (Annex 5). These low paying sectors are: retail; hospitality; social care; textiles and clothing; cleaning; hairdressing; security; agriculture; leisure, travel and sport; and food processing, and contain disproportionate numbers of workers who will be paid minimum wages.

The results of this analysis are reported in Table A3. Column 1 reports the results for the basic specification, and this is illustrated in Figure A8. The first point to note is that for workers in these sectors, there is no evidence for a jump in real hourly pay at age 22 prior to the introduction of the NMW, and the age-earnings profile follows an almost constant gradient from age 16 to age 28. The second point is that the rate of growth of earnings by age for workers in these sectors is significantly lower than for young workers (aged 16-21) and young adults (aged 22-28) averaged across all sectors as presented above. For workers in low pay sectors, real hourly pay increases by approximately 27-30p per hour per year of age, as compared to the 46-47p per hour per year of age seen previously. However, consistent with the previous findings for all sectors, after the introduction of the NMW, the rate of growth of pay in low pay sectors is almost unchanged for both younger workers (aged 16-21) and young adults (aged 22-28) as compared to before the NMW. There is a small (19p per hour) (but statistically insignificant) jump in pay at age 22 in the period after the

[6] A Hausman test decisively rejects the random effects specification in favour of the fixed effects model.

NMW was introduced. In addition, there is a slight 'levelling out' of the profile with a marginally steeper profile before the age of 22 and a shallower profile thereafter, as compared to the period before the NMW. However, none of these differences is statistically significant. Similar findings are apparent when expanding the observation period to 1994-2003, or contracting it to examine just 1998 and 1999 as shown in Table A5, columns 3 and 4 respectively.

Column 2 of Table A3 presents the median (quantile) age-earnings profiles for workers in low pay sectors only. Here there is some evidence that the slope of the age-earnings profile is marginally steeper (4-5p per hour per year of age) for younger workers aged 16-21 than for young adults aged 22-28 prior to the advent of the NMW, and this difference is maintained post-1999 This is consistent with the 'levelling out' of the profiles of average (mean) earnings amongst these workers in column 1. In column 3, we take account of other influences on pay such as gender and part time status. Once again the profiles are unchanged with the introduction of the NMW, and this is confirmed in column 4. The slightly steeper profile for 16-21 year olds after the introduction of the NMW is evident here too – in the post-1999 period, younger workers aged 16-21 in low pay sectors receive, on average, around 6p more per hour per year of age than those aged 22-28.[7]

Second, we also repeat the analysis for low skill occupations, defined on the basis of SOC90 to be in Major Groups 6 to 9[8]. These include: personal and protective service occupations (including catering, hairdressing, childcare etc); sales (including retail, checkout operators); plant and machine operatives; and other occupations (including shelf fillers, and cleaners). The results of this analysis are presented in Table A4. The basic specification presented in column 1 is illustrated in Figure A9. In this case, the age earnings profiles are piecewise linear both before and after the introduction of the NMW. However, there is some evidence to suggest that the profile is more concave after 1999 and this is confirmed when testing the slopes of the profiles. There is no difference prior to 1999 in the rate of growth of earnings between 16-21

[7] Similar results as found previously for the fixed and random effects specifications for all workers were also found for those in these low pay sectors.

[8] NES/ASHE uses SOC90 for 1991 to 2001, and SOC2000 for 2002-2009 and hence we have to use SOC90 for our definitions of low pay occupations.

year olds and 22-28 year olds. However, after 1999, the rate of growth of earnings is 9p per hour per year of age greater for the younger workers group than for the young adults group. Similar findings are apparent when the analysis is undertaken over the longer period 1994 to 2001 (Table A5, column 5) and the shorter period 1998-99 (Table A5, column 6). As shown in Table A4, column 2, at the medians, this slightly steeper profile for the younger workers is also evident prior to the introduction of the NMW, but does not change after 1999. Once we include the additional regressors as in Table A4, columns 3 and 4, a similar pattern is evident, with a constant gradient in earnings by age from 16 to 28 years prior to the NMW, but a steeper gradient for younger workers (aged 16-21) followed by a shallower gradient for young adults (aged 22-28) after its introduction. For example, for column 4 in Table A4, the real hourly wage grows on average at 7p per hour per year of age faster for 16-21 year olds than for 22-28 year olds working in these low skill occupations. This may be a consequence of upward pressure on wages at age 22 as a consequence of the adult NMW, and is a similar finding to that reported above for low paying sectors.

All of these investigations into the robustness of our findings tend to confirm the initial result that there is no substantive or significant difference between the average rate of growth of earnings for younger workers (aged 16-21) as compared to young adults (aged 22-28). This conclusion does not differ after the introduction of the NMW since its introduction has not significantly affected the average rate of growth of earnings for either 16-21 year olds or for 22-28 year olds. However, there is some tentative evidence to suggest that in low pay sectors and/or low skill occupations, after 1999 the rate of growth of earnings of 16-21 year olds is slightly higher than in the period immediately before the introduction of the NMW, while the rate of growth of earnings of 22-28 year olds is slightly lower. One possible explanation is that the minimum wage is driving up wages at a faster rate for younger workers, with the consequence that their rate of growth of earnings after age 22 is then less than it otherwise would have been.[9] However, recall from the earlier graphical analysis that real earnings for younger workers (aged 16-21) and young adults (aged 22-28) have hardly increased

[9] We have also repeated the analysis in this subsection for the introduction of the teen rate for 16-17 year olds in 2004. No significant impact on earnings growth can be identified relative to 18-21 year olds or young adults aged 22-28.

at all in the last two decades. Hence we conclude that the NMW has had no impact on the growth rate of earnings for younger workers relative to young adults.

In the second part of the report, we examine whether there is evidence of any impact on the age-productivity relationship of the introduction and subsequent upratings of the NMW.

SECTION B: Sectoral Productivity and Wage Equations

B.1 Introduction

This second half of the report examines the relationship between age on the one hand, and productivity and wages on the other, through the estimation of sectoral productivity and wage equations. The aim of this analysis is to derive age-productivity and age-earnings profiles, and determine to what extent they differ from each other. In other words, the results will reveal the relative wage differences between workers in the different age groups, and then show whether productivity differs across the age groups to the same extent. A positive (negative) gap between a productivity coefficient and a wage coefficient for a particular age group will reveal the extent to which workers in that age group are underpaid (overpaid) for their productivity contribution, relative to workers in the reference age group. In all analyses, the youngest workers (aged 16-21) will form the reference category, so that the relative position of young workers compared to workers in all other age groups can be determined.

In a competitive labour market, wages should be equal to the marginal productivity contribution of the worker, so that any average productivity differences between age groups should be reflected in average wage differences. If the results show that productivity differences across age groups do not equal wage differences, then such evidence would suggest imperfections in the labour market.

Further analysis will consider the impact of the introduction of the National Minimum Wage (NMW) in 1999 on the estimated productivity and wage equations. The aim is to examine whether the NMW has either created or widened any productivity-wage gaps, i.e. whether the NMW has created or widened any labour market distortions. As before, young workers are of particular interest here. It might be hypothesised that the introduction of the NMW reduced wage differentials, and therefore flattened the age-earnings profile, if younger workers were initially lower paid and so benefitted more from the NMW. Unless relative productivity changes to a similar extent, this would then create a gap between the relative wage and productivity (or widen an existing gap). Thus, the results will reveal whether the NMW has caused young workers to be overpaid for their productivity contribution, relative to older age groups.

B.2 Literature Review

The paper most similar to the analysis presented here, in that it is based on UK data at the sector level, is Dearden *et al*. (2006). The aim of the Dearden *et al.* paper was to examine the relationships between training, productivity and wages, but they do include the age structure of the workforce in each sector amongst the control variables in their productivity and wage equations, and so their results are of interest here. Their data source for sector level variables is the Annual Census of Production (the forerunner to the Annual Business Inquiry data used in this report). This provides data for manufacturing only. Dearden *et al*. study the period from 1983-1996. The source of their training data is the Labour Force Survey, which also provides information on other worker characteristics including age. These characteristics are aggregated to the sector level.

Dearden *et al.* use the panel element of their data set to estimate random and fixed effects models. Looking at the results on their age variables, they find that younger workers, aged 16-24, are significantly less productive than prime-aged workers in the 35-44 year old age group, who form the reference category. In the wage equations, lower wages are evidenced in sectors with a higher proportion of older workers, aged 55-64. In addition, lower wages are also associated with the youngest age group (16-24 year olds) in the random effects specifications only. Dearden *et al.* also estimate GMM equations, as done in this report, but they do not report the coefficients on their age variables in this specification.

There is a small number of other, non-UK, papers in the literature that also estimate productivity and wage equations with age included amongst the regressors. In most cases these are performed at the firm level, rather than the sector level as here, due to the availability of matched firm-worker data sets in a number of countries. These studies can be classified into two groups, according to whether they use cross-sectional or panel data sets.

An example of a cross-sectional study is Hellerstein *et al*. (1999). Their data source is the Worker Establishment Characteristics Database (WECD) in the US. This provides information on almost 200,000 workers in 16,144 plants, observed in 1990. Their results show both higher productivity and higher wages for prime-aged and older workers, relative to young workers, though the differences are not precisely measured. Wages appear to rise in line with productivity over workers' lifetimes, consistent with Human Capital Theory.

Another cross-sectional study is that by Lallemand and Rycx (2009). This paper uses two cross-sections of matched workers and firms, from 1995 and 2003 in Belgium. In both years they find that productivity is higher in firms that employ a higher proportion of young or prime-aged workers, relative to workers aged 50 or over. Lallemand and Rycx do not estimate wage equations.

A number of papers use panels of firms to estimate productivity and wage equations. The advantage of panel data is that it can be used to control for unobserved heterogeneity via firm level fixed effects, and can potentially correct for endogeneity of regressors, as explained in more detail in the following methodology section. Examples include Crepon *et al.* (2002) and Ilmakunnas and Maliranta (2007). The former using French data for the period 1994-97 and the latter using Finnish data for the period 1988-98, both papers find that the productivity-age relationship is an inverted U-shape, whilst wages rise continually with age. These results therefore suggest that the higher wages of older workers are not justified by higher productivity that comes with experience, but rather are compatible with the incentive mechanism theories of Lazear (1979). Dostie (2006), using Canadian data from 1999-2003 finds inverted U-shaped age profiles for both productivity and wages, though there is some evidence that the productivity profile falls more steeply with age than the wage profile. Gobel and Zwick (2009) only estimate productivity equations, but their results are interesting in that they compare the effects of using different estimation methodologies, similar to this report. They use German data for the period 1997-2005. When they use OLS, they find the inverted U-shaped age-productivity profile, observed by a number of papers above. When the relationship is estimated by fixed effects, however, the profile essentially becomes flat, suggesting that some of the inverted U-shaped relationship observed in the OLS results is due to omitted firmspecific heterogeneity. When the authors use GMM estimation, the results suggest if anything a rising age-productivity relationship, at least up to age 55.

The paper most similar to ours, in that it uses OLS, fixed effects and GMM to estimate both productivity and wage equations, is that by van Ours and Stoeldraijer (2010). The difference is that, as with the papers reviewed in the previous paragraph, they use firm level data, rather than data at the sectoral level as used here. In particular, they use matched firm-worker data from the Netherlands for the period 2000-2005. Their OLS results reveal the usual inverted U-shaped age-productivity profile, while the wage profile initially rises and is then essentially flat. When fixed effects are used, in both equations almost all the age coefficients become statistically insignificant, suggesting flat profiles, with some evidence of an insignificant decline in productivity amongst workers aged over 50. The authors' GMM results reveal a rising age-productivity profile up to age 57, consistent with the results of Gobel and Zwick (2009) above. The wage profile also rises with age, also up to around age 57. In terms of the gap between productivity and wage profiles, van Ours and Stoeldraijer (2010) find no statistically significant effects, with the exception of a positive productivity-wage gap amongst the youngest workers (aged below 25).

In a developing country context, Jones (2001) considers a panel of firms in Ghana. She uses an experience variable rather than an age variable, but finds similar results in terms of an inverted-U shaped experience-productivity and experience-wage profiles.

In summary, the previous literature has not found a consistent set of results, which is not surprising given the range of countries, time periods and estimation methodologies used. If there is any pattern in the results, many papers seem to find an inverted U-shaped age-productivity profile in OLS specifications, while wages tend to rise with age, thus leading to an increasing gap between wages and productivity amongst older workers. However, when statistical techniques are used that allow for firm level unobserved heterogeneity, and/or for endogeneity, some of these results are overturned, with age-productivity profiles apparently flatter or positively sloped up to much higher ages. These results will be contrasted with our own findings, when the latter are considered below.

B.3 Methodology

In common with most of the papers reviewed above, we estimate productivity and wage equations, in our case estimated at the sector (industry) level. The starting point for deriving the estimating model is to assume a Cobb-Douglas production function:

$$Y = AL^{\alpha}K^{\beta}$$

where *Y* is output, *L* is labour input and *K* is capital input. Characteristics of workers can be entered into the model via *L*, thus defining labour input not simply in terms of the number of workers[10], but in terms of the labour quality input, where quality is measured by the characteristics of workers available. We are primarily interested in age, but also include gender and qualifications. Dividing through by *L*, and taking logs to linearise, produces an estimating equation:

$$\log y_{it} = \gamma_0 + \gamma_1 \log k_{it} + \sum_z \gamma_{2z} a_{zit} + u_{it} \quad (3)$$

where *y* is a measure of productivity (*Y*/*L*) and *k* is capital stock per head (*K*/*L*). The set of a_z variables are *z* workforce characteristics, expressed as a proportion of the sector's workforce. Of particular interest is the proportion of each sector's workforce who fall into each age category (here defined as aged 16-21, 22-29, 30-39, 40-49, 50-59), though we also control for the proportion of the sector's workforce who are female, the proportion who work part-time, and the proportion working in the private sector, as well as the average qualification level in the sector. All of these variables are observed for each sector, *i*, for each year, *t*, in our data set. Finally, u_{it} is a random disturbance term.

An equivalent wage equation is:

[10] Total labour input would be more accurately measured by the number of worker hours, rather than simply the number of workers. This will however not be pursued here, though we do control for the proportion of employees working part-time in each industry in each year, and at one point estimate an equation using 'full-time equivalent' employment as a robustness check.

$$\log w_{it} = \delta_0 + \delta_1 \log k_{it} + \sum_z \delta_{2z} a_{zit} + \varepsilon_{it} \qquad (4)$$

where *w* is the wage rate in sector *i* in year *t*. Comparison of the γ and δ coefficients will reveal whether the workforce characteristics have a larger effect on productivity or wages.

The disturbance terms in equations 3 and 4, u_{it} and ε_{it}, are likely to contain an unobserved heterogeneity term, whereby unobserved characteristics of industry *i* influence that industry's productivity and/or wages. To the extent that this unobserved heterogeneity is correlated with the explanatory variables, then its presence would bias the estimated coefficients. Industry fixed effects will therefore be included in equations 3 and 4 to allow for unobserved heterogeneity.

A further source of potential bias is endogeneity of the explanatory variables. For example the age structure of their workforce could be chosen by firms in response to productivity differentials, or alternatively, the age structure of the workforce and productivity levels could both be determined by, for example, a negative productivity shock that might lead firms to lay off younger workers. To allow for the potential endogeneity of the age structure, as well as the other explanatory variables, and in the absence of other variables to act as instruments, equations 3 and 4 were estimated by the Generalised Method of Moments (GMM) (see Arellano and Bond 1991). In particular, 'system GMM' is used, whereby a system of equations in levels and first differences is estimated. Lagged values of the explanatory variables are used as instruments for the endogenous right-hand side variables in the difference equation, while in the levels equation, the endogenous variables are instrumented by their lagged first differences. This 'system GMM' has been shown to produce more efficient results than standard 'difference GMM'. [11]

B.4 Data

Due to a lack of individual productivity data, the relationship between worker characteristics and productivity cannot be estimated at the individual worker level, as wage equations so frequently are. In order to obtain productivity data, a higher level

[11] See Blundell and Bond (1998).

of aggregation is therefore needed. In the absence of good matched firm-worker data sets in the UK, as used by a number of papers summarised in the earlier section, the unit of observation in this analysis was chosen to be sectors (industries). All data used therefore had to be aggregated to this level.

A range of data sources were used to estimate the sectoral productivity and wage equations. The basis for the constructed data set is the Annual Business Inquiry (ABI). The ABI is a sample survey of all UK businesses. The sample is stratified by sector and employment level, so that within sectors, all large businesses are surveyed, while the proportion of smaller businesses surveyed declines with business size. Obtained data are then grossed up to the full population of businesses. This sample design ensures the best possible estimate of the population variables for the smallest sample size. In all, around 65,000 businesses are surveyed per year. The ABI provides information, at a sector level, on gross value added, total employment (at the point in time of the survey and averaged across the previous year), total employment costs and total net capital expenditure, in addition to other variables that we do not make use of. ABI data are available from 1995-2007.

Information on the characteristics of the workers in each sector was obtained from the Annual Survey of Hours and Earnings (ASHE). This survey involves a 1% sample of employees, asking their employers for information about a limited number of characteristics of the workers and their jobs. ASHE data were used to provide information about the number of each sector's workforce who fall into each age category, the number female, the number working part-time and the number working in the private sector. This information could then be mapped into the ABI data set by sector (SIC) code.

We are also interested in the qualifications held by the workforce in each sector, as an important indicator of worker quality. Unfortunately, ASHE respondents do not report their qualifications. However, an occupation (SOC) code is provided for each worker, and when combined with that worker's age, gives a reasonable indication of a worker's qualification.[12] We therefore matched into the ASHE dataset the average qualification level of workers in every occupation-age group cell, with occupation measured using SOC90 at the 3 digit level until the year 2000, and by SOC2000 at the 4 digit level thereafter.[13] This provided an 'expected' qualification level for every worker in ASHE. These data were then averaged within sectors to produce an average qualification level in each sector, which could then be matched in to the ABI dataset. The resulting variable is on a scale from 0 to 7, with higher numbers representing higher levels of education.

ASHE data were also used to calculate the average wage in each sector, to be used as the dependent variable in the sectoral wage equation. We used wage information from those ASHE respondents whose pay is unaffected by absence. The wage rates obtained were deflated by the retail price index in order to obtain a real wage series, as indeed was done for any other variable measured in monetary terms (for example, gross value added).

One issue with the ABI data is that employment data are not available until 1998. Given that we are interested in the pre-NMW period before 1999, this would have produced only one year of pre-NMW data. We therefore also used ASHE data to provide an estimate of the total number of workers employed in each sector. Since ASHE is a random 1% sample of the working age population, then the number of ASHE respondents in each sector, multiplied by 100, was taken as an indicator of the total number of employees in the sector. An alternative source of employment data is the Quarterly Labour Force Survey, and these were used as a robustness check on the estimate provided by ASHE. QLFS data were merged from the four quarters in each year to produce annual data sets, using only the first wave respondents to avoid duplication of individuals in the obtained data sets. The number of respondents reporting their main job to be in each sector was measured, then

[12] It is necessary to take account of individuals' age as well as occupation, due to the increasing qualifications levels required to gain access to many occupations. As an example, nursing in the UK is now a graduate profession for new entrants, but historically has not been so. A young person working as a nurse would be expected, on average, to hold a degree, while an older nurse would be expected to hold a professional vocational qualification.

[13] We are extremely grateful to Peter Dolton and Gerry Makepeace for supplying the data on average education levels by occupation and age group.

grossed up to produce a population estimate using the QLFS weights provided. This information could then also be matched into the ABI data set by sector (SIC) code.

We therefore had multiple sources of employment data, namely ASHE, QLFS and from 1998 onwards, the ABI. The estimated numbers produced were similar in many sectors, though were very different in some, as might be expected given the different economic agents responding to the surveys and different sampling methods of the surveys. Examples of sectors where the QLFS produced a significantly lower estimate of the number of workers include hotels, bars, restaurants, 'letting own property' and business consultants. These are all sectors in which individuals can work for a small number of hours, whilst pursuing other jobs or economic activities. Given the QLFS data are recording respondents' main jobs only, this therefore explains the estimated lower number of employees in such sectors in the QLFS. On the other hand, the QLFS reports significantly more individuals working in sectors such as agriculture, and 'taxis'. In such sectors where casual labour or self-employed workers are likely to be present, a survey of firms is likely to understate the number of workers. A final difference is found in the education sectors. The two employer-reported surveys, ABI and ASHE, report many times more workers in primary education than in secondary education. This is because the ONS tend to categorise firms by largest group of workers, so for local authorities, all teachers are often classified as being in Primary School Education.

The outcome of the above process is a sectoral level data set, containing information on the sectors and the average characteristics of the workers in those sectors. The dimensions of the data set, in terms of number of sectors and number of years, were determined by the lowest common denominator across the 3 datasets used to provide the source information (ABI, QLFS and ASHE). ABI data are available for the years 1995-2007, so this set the absolute limits in the time dimension, In fact 1995 data were dropped, due to the ASHE data set using a different classification to define sectors in 1995 (SIC80) compared to subsequent years (SIC92), so that the sectors could not be defined consistently for 1995. Our final data set was therefore for the years 1996-2007.[14]

In terms of sectors, they had to be small enough to give us a sufficiently large number of sectors with which to perform the statistical analysis, but also large enough to contain sufficient numbers of respondents in ASHE with which to estimate the age distribution of workers within that sector. Our starting point was SIC codes at the 3 digit level. In some cases, the 3 digit industry was sufficiently large to be disaggregated further, so a handful of our sectors are classified at the 4 digit level (typically a collection of a few 4 digit classes within the same 3 digit group). In other cases, the 3 digit industry proved to be too small to provide sufficient ASHE respondents with which to estimate the age distribution. In these circumstances we aggregated the 3 digit industries up in order to use the 2 digit industry instead.

As well as limitations caused by the number of respondents in ASHE, sometimes the limitation was caused by the ABI. A number of sectors are simply not included in the ABI, and so could not be used in our data set. In particular, firms in Section J of the SIC (Financial Intermediation), Section L (Public admin and defence, social security), Section P (Private household staff) and Section Q (Extra territorial) are not surveyed as part of the ABI.

Finally, if the QLFS employment measure was used, then this caused further limitations to the sector definitions. In particular, in the QLFS Construction (SIC 45) Wholesale Trade (SIC 51) and Retail Trade (SIC 52) are not disaggregated below the 2 digit level. So while these large sectors could have provided a number of 3 digit and even 4 digit industries to the sectoral data set, we were restricted to using them at the 2 digit level when using the QLFS, due to the classification in that data set. These sectors are obviously therefore considerably larger than the other sectors in the data set.

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[14] During this period the sector classification changed with the introduction of SIC03. However, the changes were minor and mostly occurred at the 4-digit level, and so did not prevent a consistent definition of our sectors.

The end result was a sector level data set containing 121 sectors if ASHE was used to provide employment data, and 94 sectors if the QLFS was used. These sectors are listed in Appendix A and Appendix B respectively. Since ASHE provided more sectors, particularly in National Minimum Wage-relevant areas such as retail trade, these data are used for most analyses below, though the results are checked for robustness using the QLFS employment data and sectors. Finally, for the vast majority of sectors, we have data for all 12 years in the data set. For a small number, occasional years are missing, in most cases due to missing information in the ABI for that year. The data set is therefore not quite a balanced panel.

Table B1 reports mean values for all of the variables used in the analysis, in total and separately for the pre-NMW and post-NMW periods. Comparing the means of the variables across the two periods, we can see that gross value added and wages both increased, in real terms, over the period. Looking at the explanatory variables, we observe an increase in the average age of sectors' workforces, as the proportion of younger (older) workers falls (rises). There is also a small increase in the proportion of workers working part-time, an increase in the proportion belonging to the private sector, and an increase in the average qualification level of workers. All of these changes are consistent with prior expectations. There is a small fall in the average amount of net capital expenditure per capita, in real terms. Finally, the 'spike' variable measures the proportion of each sector's workforce earning within a 5% range of the NMW rate.[15] The average percentage of workers across sectors earning at the spike is quite small at 3.25%, but ranges from 0 to 30%.

B.5 Results

(i) OLS Results

Table B2 contains the results from our basic OLS specification, for both the productivity equation and the wage equation. Looking first at the productivity equation, the results reveal large coefficients on the age variables. For example, the first coefficient in the productivity equation reveals that if there is a 1 percentage point

[15] For each worker, their wage is compared to the appropriate minimum wage rate for their age, when determining whether they earn at the NMW spike.

rise in the proportion of workers aged 22-29 in a sector, then productivity will rise by 4%, relative to a similar sized change in the proportion in the reference category of workers aged 16-21. The size of this effect seems implausibly large for a mere 1 percentage point change in the proportion aged 22-29. Similarly, a 1 percentage point increase in the proportion of a sector's workforce aged 30-39 is associated with a 2.84% rise in productivity, relative to the reference category. The productivity difference between workers aged 40-49 and workers aged 16-21 is estimated to be a statistically insignificant 0.26%, while the final age coefficient is negative, suggesting that an increase in the proportion of 50-59 year old workers is associated with a fall in sectoral productivity of 1.06%, relative to 16-21 year olds.

Taking the four age coefficients as a group suggests an inverted U-shaped age-productivity profile, with productivity rising with age until the workers reach their 30s, then falling thereafter, and at a faster rate once workers are aged over 40. The inverted U-shaped age-productivity relationship in the OLS results is consistent with the findings of most other studies, which were summarised in the literature review above.

The wage equation results show a similar inverted U-shaped age-earnings profile. A 1 percentage point increase in the proportion of 22-29 year olds is associated with 0.3% higher average wages in a sector, relative to a similar sized increase in the proportion of 16-21 year olds. A 1 percentage point increase in the proportion of 30-39 year olds or 40-49 year olds is associated with an average wage increase of 1.48% and 1.14% respectively. However, an increase in the proportion of 50-59 year old workers is associated with no higher wages than for 16-21 year olds, therefore producing the inverted U-shape to the age-earnings profile. This is in contrast to a number, though not all, of the papers reviewed above, which observed continuously upward-sloping age-earnings profiles. The UK study by Dearden *et al*. (2006) found similar lower wages in sectors with higher numbers of older workers.

In terms of the productivity-wage gap, the relative size of the productivity and wage coefficients reveal that the inverted U-shaped age-earnings profile is flatter than inverted U-shaped age-productivity profile. The end column investigates whether there is a significant difference between the age coefficients in the productivity and the wage equations, and finds that there are such differences. Hence, a rise in the proportion of workers in their twenties or in their thirties, relative to workers aged 16-21, is associated with a significantly larger productivity gain than wage increase. Such prime-aged workers therefore appear under-paid relative to their productivity, compared to 16-21 year olds. In contrast, workers aged in their forties and fifties achieve a negative productivity-wage gap relative to all younger age groups. For these older workers, their lower productivity does not justify their wages.

In summary, then, the key message as far as young workers are concerned is that they appear to be overpaid relative to their productivity when compared to prime-aged workers aged in their twenties and thirties, but underpaid relative to their productivity when compared to older workers aged in their forties and fifties. It therefore seems as though there are some departures from the competitive market prediction that wages will equate with productivity. One theory consistent with the results for older workers is the incentive theory of Lazear (1979), whereby older workers earn more than their productivity, as an incentive to younger workers to progress their careers.

Briefly considering the other coefficients in Table B2, they show that sectors that employ a higher proportion of female workers have lower wages, but also lower productivity, with the productivity effect being significantly larger. A similar pattern of results is observed for part-time workers (lower productivity and lower wages, with the former effect significantly larger). Sectors with a higher proportion of private sector workers, on the other hand, pay slightly, though significantly, higher wages, but also enjoy significantly higher productivity. Finally, as expected, average sectoral wages rise with the qualification level of the workforce, though somewhat surprisingly productivity is observed to be lower in those sectors employing better educated workers, on average. Recall, however, the potential biases in the OLS specification, discussed above. It could be that a sector that has experienced a negative productivity shock responds by laying-off its less skilled workers, thus increasing the proportion of well-qualified workers in the sector. This surprising coefficient on the qualifications variable, together with the implausibly large coefficients on the age variables, leads us to suggest that the biases in the OLS equation appear to be having serious consequences on the estimated coefficients. We therefore do not want to put too much emphasis on the OLS results, and the Fixed Effects results that follow will be our preferred specification. Before leaving the OLS specification, however, we will briefly consider the impact of the NMW in that framework.

Table B3 looks at the impact of the introduction of the NMW in 1999 on the estimated productivity and wage equations, by dividing the sample into pre and post-1999 sub-samples and estimating the equations separately. Looking first at the middle columns, we can see some evidence of a flatter age-earnings profile in the post-NMW period, as shown by the smaller absolute size of the coefficients. However, if the wage gap between 16-21 year olds and older workers has contracted, the productivity coefficients suggest that the productivity gaps have similarly narrowed. The final columns show that the productivity-wage gaps of workers in their twenties and workers in their thirties, relative to 16-21 year old workers, are essentially unchanged. With respect to the older two age groups, the relative productivity-wage gaps become negative and statistically significant, suggesting that the position of these two age groups declines relative to the youngest workers. There is therefore no evidence in these results that the NMW has awarded the youngest workers pay awards that are unjustified by their relative productivity (i.e. there are no cases of significant positive changes in the 'gap' coefficients between the two periods).

Of course, many sectors were barely affected by the introduction of the NMW, since they already paid a higher wage to most workers. It could be, therefore, that any NMW effects are hidden in Table B3, and cannot be detected. The analysis of Table B3 was therefore repeated for only those sectors identified as low-pay sectors.[16] The results in Table B4 are a little erratic, due to the smaller number of observations when analysis is restricted to low-paying sectors only, as well as the continued biases inherent in OLS being present. The underlying message is unchanged, however. In only one case is there a positive change in the productivity-wage gap coefficient (suggesting that the productivity-wage position of workers in their thirties

[16] These are certain sub-sectors in retail, hospitality, social care, food processing, leisure, cleaning, agriculture, security, childcare, textiles and hairdressing. The definition of a low-paying sector that was used was the industry-based definition, using SIC03 codes, as described in Table A5.1 of the Low Pay Commission Report, 2007.

improved relative to the youngest workers), but even in this case the change is not statistically significant.

There are a number of issues with the results in Tables B3 and B4 as a test of the impact of the NMW. For example, the number of observations in the sub-sample equations is small, particularly in the pre-NMW period when only three years' worth of data are available, and also particularly when the sample is restricted to low-paying sectors only. In addition, by breaking the sample period into pre-1999 and post-1999 periods, the analysis can only do a before-and-after analysis of the introduction of the NMW, and not the continued effect of the NMW as its value is continually up-rated post-1999. An alternative method to investigate the effects of the NMW is to consider all sectors and all years, and measure the percentage of workers in each sector paid at, or close to, the NMW (taking into account the age of each worker and therefore the appropriate rate of the minimum wage for each). The resulting variable, which we call the NMW 'spike', can then be interacted with all of the explanatory variables in our estimated equations. In this way, we can investigate whether the productivity and wage differences between the age groups (or between the genders, the private/public sector etc) are smaller in those sectors where the NMW has more bite (as indicated by more workers being paid at the spike). The results are displayed in Table B5. It can be seen that a number of the interaction coefficients are statistically significant, suggesting that productivity and wage differences between workers of different characteristics do alter in size according to the bite of the NMW. In particular, the interaction coefficients on three of the four age-spike interaction terms in the wage equation are negative and statistically significant, suggesting that the age-earnings profile is flatter where more workers are paid at the minimum wage. Note, however, that the equivalent age-spike interaction coefficients in the productivity equation are also negative and in most cases larger in absolute size. The conclusion is therefore the same as that in the before-and-after analysis above; although the NMW is associated with lower wage differentials between age groups, it is also associated with smaller productivity differences, so that there is no evidence in the results that young workers have received pay rises through the NMW that are unjustified by their productivity.

Another point with the results in Table B5 is that it can be queried whether they are an appropriate test of the impact of the NMW. The results showed that the wage distribution is narrower across age groups in sectors where a higher proportion of workers are paid at the minimum wage. But it is not surprising that if more workers are paid at a single spike in one sector than in other sectors, that wage differentials are smaller in the former sector. The coefficients on the minimum wage spike interactions are therefore being determined by variation across sectors in characteristics determining the size of the spike, whereas it is the impact of changing minimum wage rates *over time* that we want to investigate. This can be done by looking at the effect of the minimum wage over time *within* sectors, i.e. in a sector Fixed Effects framework. This is one more reason for preferring the Fixed Effects results over the OLS results, and so it is to the Fixed Effects results that we now turn.

(ii) Fixed Effects Results

Table B6 shows the results from the base Fixed Effects specification, in which the coefficients are estimated based on within-sector variation in the explanatory variables over time. As described in the literature review, previous studies have found that the estimated age-productivity and age-earnings profiles often become flatter in Fixed Effects specifications.

The results in Table B6 show that our profiles also lose much of their slope, with much smaller estimated coefficients in both the productivity and wage equations. Indeed, one of the problems with the OLS results discussed above was the implausibly large estimated coefficients, particularly in the productivity equations. The coefficients in Table B6, on the other hand, are more appropriate in terms of their size. Thus, the largest productivity effect is now only a 1.42% effect, when the proportion of workers aged in their forties increases by 1 percentage point, relative to 16-21 year olds. The largest wage effect is a 0.47% rise in average wages, following a similar 1 percentage point rise in the proportion of 40-49 year olds. As well as the productivity and wage profiles losing some of their steepness, they also lose their downward-sloping parts at higher ages. Therefore the lower wages and productivity for older workers observed in Table B2 above seems to be due to unobserved characteristics of sectors with which age is correlated, rather than due to age itself.

The size of these coefficients in the Fixed Effects specification seems to be appropriate and accord with expectations. All coefficients are comparing individuals in various age bands above the age of 22, to individuals aged 16-21. Given the difference in experience and average education levels between adult and teenage workers, differences of such magnitudes seem entirely reasonable. Note that comparing the sizes of the coefficients on different age bands suggests much smaller differences between adult workers (aged 22 and above) in different age categories, than between adults and teenagers, as we would expect.

The results in Table B6 show that the lowest wages and productivity are observed for the youngest workers, as we would probably expect. Both profiles reach their maximum when individuals are aged in their forties, and plateau after that (the age-productivity profile showing a small, and statistically insignificant, decline when individuals reach their fifties). The productivity-wage gap coefficients are all positive, suggesting that the higher productivity of all older workers relative to 16-21 year olds more than justifies their higher wages, compared to those received by the youngest age group. It is therefore the youngest workers, aged 16-21, who appear overpaid relative to their productivity contribution. It should be noted, however, that the productivity-wage gap is only *significantly* larger in one case, when workers in their forties are compared to workers aged 16-21.

There are a couple of other interesting outcomes in the Fixed Effects results, when compared to the OLS results in Table B2. First, while Table B2 suggested that women's lower wages reflected lower productivity, once we control for unobserved heterogeneity of sectors, the Fixed Effects results reveal that an increase in the proportion of a sector's workforce who are female does not lower productivity, and in fact has absolutely no effect on that sector's productivity. Hence the earlier, OLS, result comparing across sectors was likely to be due to sorting effects of women into lower-productivity sectors. A 1 percentage point rise in the proportion of the workforce who are female is associated with 0.29% lower wages, however, suggesting that women are underpaid relative to their productivity. Another problem with the OLS results, that the Fixed Effects specification seems to correct, is that industries with a more qualified workforce were associated with lower productivity in the OLS results. This finding is overturned in the Fixed Effects specification, with a positive and statistically significant coefficient now obtained on the qualifications variable in the productivity equation. The size of the coefficient is smaller than the qualifications coefficient in the wage equation, though the difference is not statistically significant. The Fixed Effects specification therefore suggests that the higher wages of more qualified workers are justified in terms of higher productivity.

Table B7 reports the results from a number of robustness checks on the basic Fixed Effects specification, to check that our preferred results in Table B6 are robust to slight changes in the specification. Each panel in Table B7 represents a separate estimated equation, with only the age coefficients reported, for the sake of brevity.[17] One criticism of the results presented in Table B6 could be that when the productivity measure (gross value added per head) was derived, the denominator was a simple head count of workers, not taking account of full- or part-time status. A new ‘full-time equivalent’ measure of employment in each sector was therefore derived, treating a part-time worker as 0.5 of a full-time worker. This new measure of employment was then used to derive new productivity and net capital expenditure per head measures. The results in panel a.) of Table B7 show that the coefficients on the age variables are almost identical to those observed in Table B6.

Another issue with the earlier results is that they do not include a measure of the capital stock in each sector, as required in equations 3 and 4, but only net capital expenditure. We investigated how the results are affected by the exclusion of this variable. A large change in the results would suggest that capital is playing some role in the estimated relationships with age. On the other hand, if the results are little affected, this would suggest that the capital measure does not significantly influence the statistical relationship, and we can continue to use the net capital expenditure variable with no serious consequence. All of the papers reviewed above have found little effect of including capital on the other coefficients in their estimated relationships, and this is also the case here. The results in the second panel of Table B7, obtained when the capital measure is excluded from the estimated equation,

[17] The estimated equations continue to control for the same variables as the specification in Table B6.

show a pattern of coefficients that is qualitatively the same as that observed in Table B6.

The third panel of Table B7 shows that excluding the year dummies also has little effect on the estimated results.

The next two panels in Table B3 (panels d.) and e.)) split the sectors into manufacturing and service sectors, or more accurately into non-service and service sectors. Thus, looking at the list of sectors in Appendix A, non-services are sectors 1-39, and services are sectors 40-121. The productivity and wage equations were then estimated separately for the two groups of sectors. Table B7 shows that the results are quite different in the two groups. Amongst the service sectors, the results are quite similar to the overall results in Table B6, with the exception of a steeper decline in productivity amongst workers in their fifties. This similarity in results is to be expected, given that around two-thirds of our sectors are classified as services. Amongst the manufacturing/non-service sectors, however, the results are quite different. Productivity is now highest amongst the youngest and the oldest age groups, with the prime-aged group in their twenties and thirties associated with the lowest productivity. The age-productivity relationship is therefore U-shaped. It should be noted, however, that none of the estimated age coefficients are statistically significant, though this is mostly due to large standard errors, due in turn to fewer observations when the sample is restricted to non-service sectors. The wage equation displays a more similar pattern of coefficients to the service sector, though with much shallower slopes, all age coefficients again being statistically insignificant.

There is no obvious explanation for the difference in age-productivity profiles between the two sectors. Perhaps in manufacturing, productivity can be increased through youthful vigour or older experience, and these two contrasting forces produce the U-shaped age-productivity profile. Productivity falls as youth disappears, but beyond some point increases again as the effect of experience kicks in. In the service sector the former effect may be absent if there is no productivity-enhancing benefit of youthful energy, so that the age-productivity profile slopes in the opposite direction. This can only be speculation, however, with the aggregate data available to us here.

The final two panels in Table B7 use QLFS data to provide the estimates of sectoral employment used to derive the dependent variable in the productivity equation, rather than ASHE. The results in panel f.) show that the estimated coefficients in the wage equation are very robust to this change in employment data, so that the results are not driven by our choice of data set. The productivity equation results are, however, quite different, though mostly statistically significant. This is something of a puzzle. The OLS productivity results are almost identical using the ASHE and QLFS measures of employment (not reported) so it is only in the Fixed Effects that they diverge, suggesting that something within certain sectors, presumably large dominating sectors, is skewing the Fixed Effects productivity results. Given that when using the QLFS we were forced to merge large sectors such as construction, retail and wholesale due to a lack of disaggregation in the raw QLFS data, this is the likely cause, and is another reason for basing most results and discussion in this report on the ASHE results. Lastly, in column g.), use is made of the fact that the QLFS contains information recording the age at which respondents completed full-time education, so that a variable measuring potential work experience can be calculated as current age minus age left education. This information was then used to create relative ‘potential experience’ ratios within each sector, rather than relative age ratios as used above. The two sets of variables will differ to the extent that sectors’ workforces differ in their qualification levels and hence the age at which they left full-time education. When the experience variables are used, the results in panel g.) show that the wage equation results are qualitatively similar to those obtained with the age variables, albeit smaller in size, while the productivity coefficients are again erratic in the Fixed Effects specification with QLFS data.

In summary, Table B7 shows that our estimated results are robust to a range of changes, with the exception of restricting the sample to manufacturing/non-service sectors, or using the flawed QLFS sectoral data.

Table B8 considers Fixed Effects specifications before and after the introduction of the NMW in 1999. Looking first at the wage equations, the first thing to note is that in our preferred Fixed Effects specification, there is little evidence for a narrowing of the age-earnings differentials. Only the wage differential between those aged in their thirties and those aged 16-21 appears to contract, though even this change is not statistically significant. The introduction of the NMW has therefore had little effect on the age-earnings profiles of workers, consistent with the results in the first half of this report.

Turning to the productivity equations, there does appear to be a narrowing of the productivity differentials across age groups in the post-NMW period. In this respect at least, the Fixed Effects results remain consistent with the OLS results. Although none of the changes in the productivity coefficients across periods are statistically significant, this is due to the large standard errors, in turn due to the small sample sizes in the pre-NMW period. The changes in the sizes of the productivity coefficients are clearly economically significant, however.

Given that the age-earnings differentials are barely affected, while the age-productivity differentials are narrowed, we would expect the productivity-wage gaps to contract in size, and that is exactly what we observe in the final columns of Table B8. Again there are no statistically significant changes due to large standard errors, but clearly the productivity-wage gaps have all changed substantially in size, and in every case, the changes have been negative, with the gap coefficients becoming smaller positive, or turning negative in some cases. Recall that a possible worry about the NMW was that if it is received more by young workers, then it might reduce the wage differentials between age groups, while having no effect on productivity, thus harming the productivity-wage relationship against young people. The results presented here find no evidence for such an impact. Indeed, if anything, the opposite has been observed, with no changes in the wage differentials between age groups, but a narrowing of the productivity differentials between age groups (the latter, though large in size, being statistically insignificant, however). Thus, far from the NMW introducing a wedge between productivity and wages, it seems to be that productivity and wages are actually more closely aligned in the post-NMW period.

Table B9 repeats the Fixed Effects pre- and post-NMW analysis of Table B8, but for low-paying sectors only. The results are actually very similar. The coefficients in the wage equation are very similar across the two periods, being virtually identical in all cases except the age 30-39 coefficient, which sees a small, but highly statistically insignificant increase. Once again, therefore, we do not observe any effect of the introduction of the NMW on the age-earnings profile, even when we focus on low-paying sectors only. The results in the first two columns do show a narrowing of the productivity differentials between age groups, however, and so the outcome is smaller productivity-wage coefficients for most age groups relative to 16-21 year olds, as was observed for the full sample of sectors in Table B8.

Looking at the other coefficients in Tables B8 and B9, it is clear that there is some parameter instability in the estimated coefficients, particularly in the case of the productivity coefficients. For example, in both tables, the sign on the female and qualifications variables changes between the pre-NMW and post-NMW periods in the productivity equation. The descriptive statistics in Table B1 above did not reveal any large changes in these two explanatory variables between the two periods that might explain such parameter instability. The most likely explanation is therefore the small number of observations in the pre-NMW period, making the estimated coefficients in that period in particular potentially unreliable. We therefore turn to our second method of investigating the impact of the NMW.

Table B10 repeats the analysis of Table B4, where we introduce the variable measuring the proportion of a sector's workforce earning at or near the NMW rate (the 'spike') and interact this variable with the other explanatory variables, only now using the Fixed Effects specification. As explained when discussing Table B4, this method of investigating the impact of the NMW has the advantage of not having to split the sample into before and after periods, with resulting small sample sizes and high standard errors, as well as being able to investigate the impact of ongoing changes in the NMW and not just its introduction.

Looking first at the wage equation in the middle column, the coefficients on the age group variables show the now familiar pattern in the Fixed Effects results, of an initially rising age-earnings profile, which then plateaus as workers reach their forties. Turning to the age-spike interactions, however, their coefficients are all statistically insignificant, suggesting no change to the age-earnings profile as the bite of the NMW varies (including the period pre-1999 with no NMW at all). In addition, this statistical insignificance is certainly not caused simply by high standard errors as an outcome of multicollinearity amongst the interaction terms. The size of the interaction coefficients themselves is very small in all cases, and so the effects are economically insignificant as well. We can therefore say that these interaction coefficients are actually zero.

Turning to the productivity interaction coefficients, these are of an order of magnitude larger than the wage coefficients. Three of the four interaction coefficients are negative, one of which is statistically significantly negative. These coefficients therefore suggest, when there is an increase in the bite of the NMW within sectors over time, then the productivity differentials between age groups are smaller. This is particularly the case for the productivity differential between individuals aged 40-49 and individuals aged 16-21. When no workers earn at the NMW spike, then each 1 percentage point increase in the proportion of 40-49 year olds is associated with a 1.16% increase in sector productivity, relative to 16-21 year olds. However, if, within the same sector, the NMW begins to have bite, then this productivity differential is reduced down from 1.16%, by 0.15% per percentage point increase in the proportion of workers earning at the minimum wage.

The results of the ‘spike’ analysis are therefore consistent with the results of the ‘before-and-after’ analysis, when estimating the impact of the NMW on wage and productivity differentials by age. Both methods suggest that the introduction of the NMW, or its variation over time, have not affected the age-earnings profile at all, with wage differentials between age groups remaining unchanged. Productivity differentials between age groups, on the other hand have if anything narrowed after the introduction of the NMW or an increase in its bite.

Finally, before leaving the results section, Table B11 shows the results from the GMM estimation of the productivity and wage equations.[18] The resulting age-productivity equation is quite similar to that estimated by OLS (Table B2). The GMM age-earnings profile is essentially flat, but for a statistically significant fall for workers

[18] Tests for AR(2) autocorrelation in the first differenced equations reveal no evidence of such autocorrelation, as required. (z=0.18, p-value=0.857 in the productivity equation and z=-0.37, p-value=0.708 in the wage equation). The Hansen test of the identification restriction failed to reject the hypothesis that the lagged instruments used are exogenous.

aged in their fifties. The overall effect is higher productivity-wage gaps for all age groups except 50-59 years olds, relative to 16-21 year olds. None of the productivity-wage gaps are statistically significant however.

Unfortunately it was not possible to estimate the GMM equations before and after the introduction of the NMW, due to the fact that only 3 years of data pre-1999 were available, which meant that only one year could have been used in the pre-NMW GMM system, given the need for t-2 data to provide instruments for the first-differenced variables. Our final piece of analysis is therefore to include the NMW 'spike' interaction terms in a GMM setting. The results are reported in Table B12. These results are qualitatively similar to the equivalent Fixed Effects results in Table B10. Thus, all the 'age-spike' interaction coefficients are statistically insignificant in the wage equation in Table B12, and take very small values. In the productivity equation, three of the four interaction coefficients are negative, and all are of an order of magnitude larger than the equivalent wage interactions. None are statistically significant, however, due to large standard errors, though the coefficient on the interaction between the spike variable and the 20-29 year old age group is just statistically significant at the 10% level. The conclusion from the GMM analysis is therefore unchanged from that of the Fixed Effects analysis: there is no evidence that the changes in the minimum wage bite over time have reduced wage differentials across age groups, while productivity differentials across age groups have if anything narrowed.

Conclusions

The economic theory of a perfectly competitive labour market suggests that workers are paid their marginal products, and so there is a close correspondence between wages and productivity. If a minimum wage was then introduced into such a market, this could distort the relationship between wages and productivity. There could be a concern that such outcomes may be particularly apparent amongst younger workers aged 16-21, whose pay may have been more affected by the introduction of the National Minimum Wage (NMW), and who also may be less able to alter their productivity, since their young age means by definition that they have lower levels of work experience and formal qualifications than the average worker. This report therefore investigates the impact of the introduction of the NMW on such relationships. In particular we investigate first whether the introduction of the NMW did alter the slope of age-earnings profiles in the early part of the working life, and then second, whether the introduction of the NMW introduced any gaps, or widened existing gaps, between wages and productivity, and if so whether this occurred at any particular age.

The first half of the report reveals that the introduction of the NMW had an insignificant effect on the slope of the age-earnings profile in the early years of the working life, at least as measured by the median or mean hourly real wage. Thus there is no evidence that the rate of growth of earnings with age differs between younger workers aged 16-21 and young adults aged 22-28. Nor is there any evidence that this linear gradient has been impacted upon by the NMW, at least on average. This result is quite robust to specification. There is some tentative evidence that amongst low pay sectors and/or low skill occupations, the impact of the NMW has been to make the age-earnings profile more concave, with faster real earnings growth prior to age 22 and slower earnings growth thereafter, as compared to the period immediately before the introduction of the NMW. However, the changes in profile even for this subset of the population are quite small.

The second half of the report adds productivity to the analysis, which necessitates a move to a higher level of aggregation, namely the sectoral or industry level. By estimating productivity and wage equations that include relative age variables, we can derive estimated age-productivity and age-earnings profiles. Our preferred results are those estimated by Fixed Effects, which control for unobserved heterogeneity amongst sectors. These results suggest that the age-productivity profile and the age-earnings profile are both initially upward-sloping, reaching a plateau once workers are aged in their forties. There is some suggestion that the productivity profile may then slope downwards slightly for workers in their fifties. The implication is that the youngest workers (aged 16-21) therefore have the lowest wages and also the lowest productivity of all age groups. Furthermore, their productivity lags that of older workers more than their wage does, suggesting that young workers are overpaid for their productivity contribution, relative to older workers. For example, increasing the proportion of 40-49 year old workers in a sector by 1 percentage point is estimated to increase productivity by 1.4%, but wages by only 0.5%, relative to a similar increase in 16-21 year olds. Given this it might have been feared that the introduction of a NMW might have exacerbated this situation of overpayment for younger workers. This would have been the case if the NMW had a greater impact on the wages of younger workers than older workers, for example if the former were more likely to be originally low paid.

The empirical results presented in this report, however, find no evidence to support such a fear. When the sample is split into pre- and post-NMW periods, the estimated age-earnings profiles are very similar in both periods (also consistent with the results in the first half of this report). There is therefore no evidence that the wage differentials between age groups have changed in the post-NMW period, and so no evidence that younger workers fared better than older workers. This result is unaffected if the sample is restricted to low-paying sectors, and also if we measure the impact of the NMW by the proportion of workers earning at or near the NMW, rather than simply a before-and-after analysis of its introduction. It can therefore be claimed that in setting the youth rate, the development rate and the adult rate for the NMW, the relativities between these rates have been set at about the right level, so that the overall age-earnings profiles have not altered.

As for the age-productivity profiles, the results in the preferred Fixed Effects specification show that, if anything, the relative productivity differences between younger workers aged 16-21 and older workers are smaller in the post-NMW period, or when the bite of the NMW is greater. We cannot claim, based on the results here, that this is definitely a causal impact of the NMW. One possible explanation is the NMW can be viewed as an efficiency wage, motivating the effort response of workers. Then, although the increase in wages due to the NMW has been similar for all age groups, as shown by the unchanged age-earning profiles, this wage increase due to the NMW may have been valued more by the young (aged 16-21). For example, the wage increase may seem more of an increase to such workers, since they have fewer high earning peers to compare against, as most teenagers in work will be in relatively low paid jobs. If the increase is valued more by young workers, it could have more of a motivating effect on their effort, therefore explaining the reduced productivity differentials between young and old workers. We should stress however, that this is mere hypothesising on our part, and further work on individual level behavioural data would be required to test the theory. It is therefore only a potential way of reconciling the lack of change in the age-earnings profile with the flattening of the age-productivity proposal.

In summary, the results in this report show that the introduction of the NMW in 1999 has not created any distortions in the labour market for young workers. The slope of the age-earnings profile has not been significantly affected, and there is no evidence of a wedge being introduced between the wages and productivity of workers. Indeed, if there has been any effect at all, it has been to narrow any such wedge.

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FIGURES

Figure A1 – Real hourly earnings: 1990-2009 – All workers

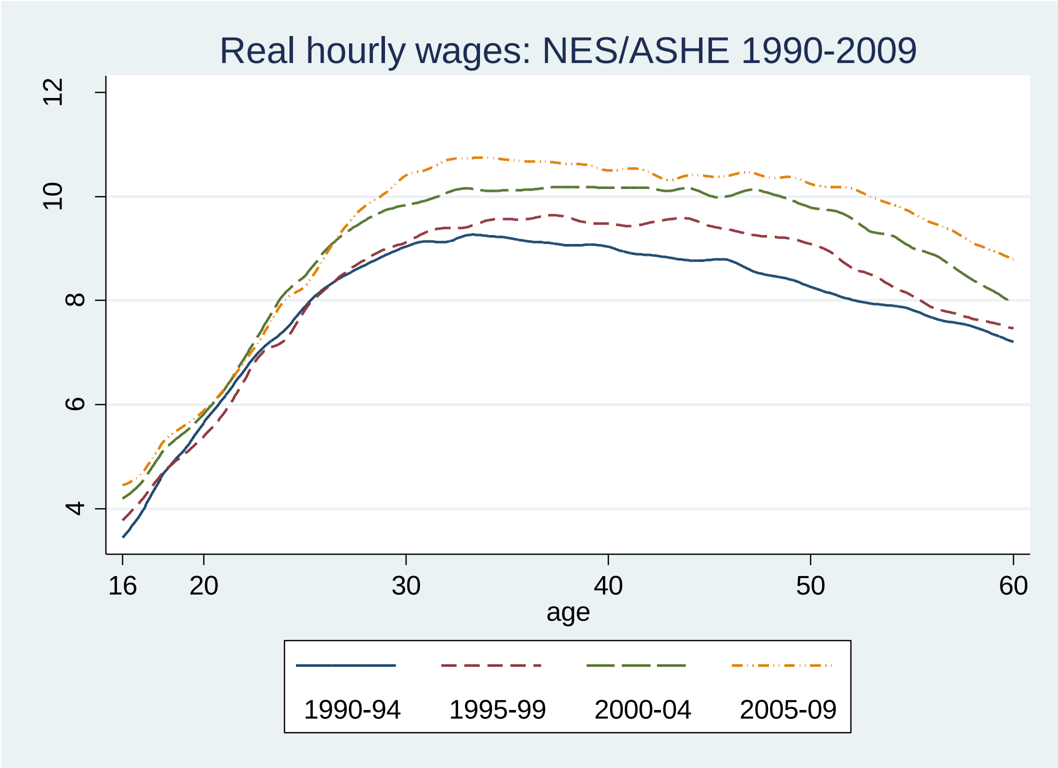


Figure A2 – Real hourly earnings: 1990-2009 – Younger workers

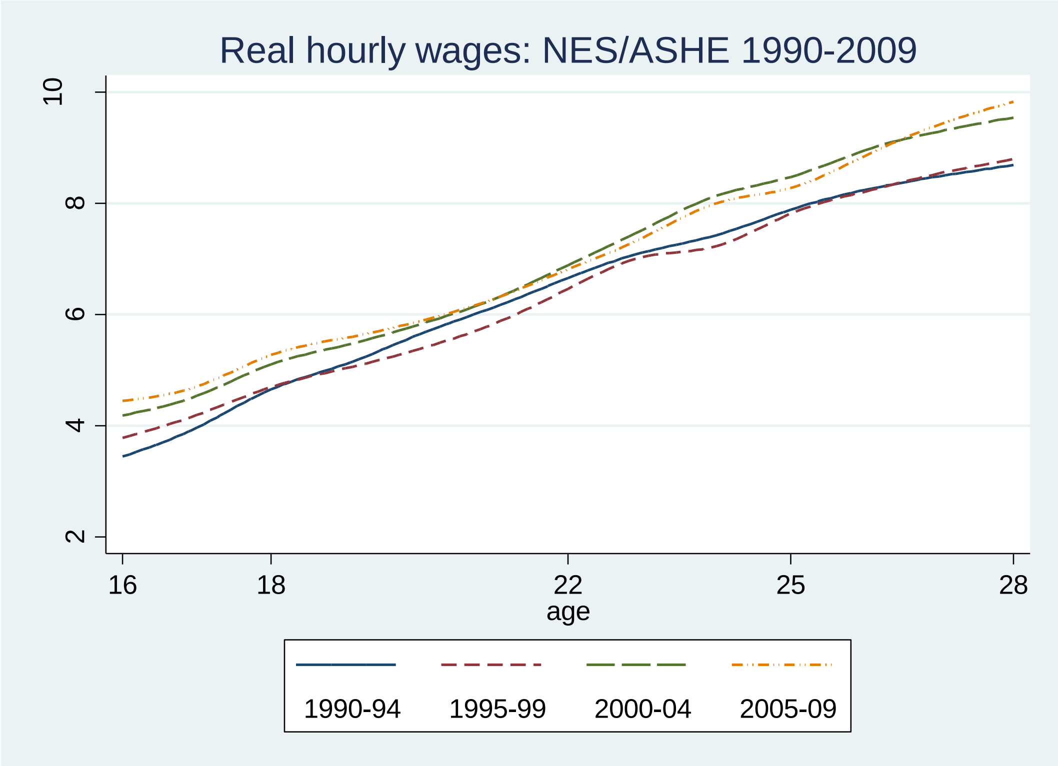
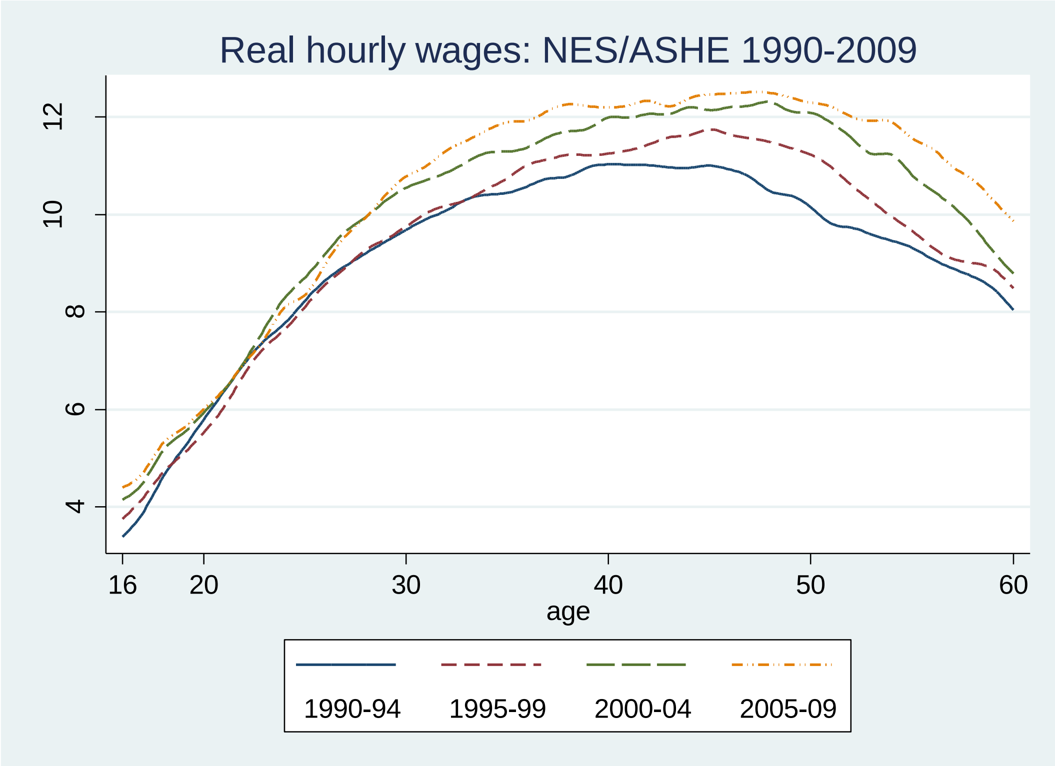


Figure A3 – Real hourly earnings: 1990-2009 – Male workers



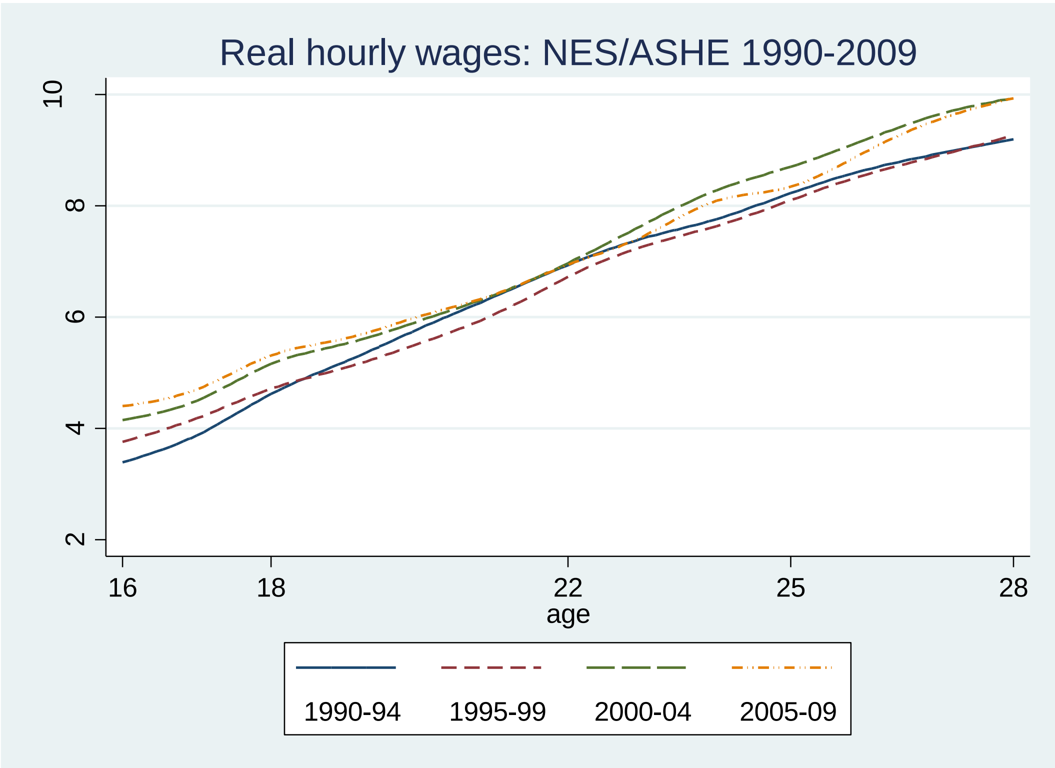
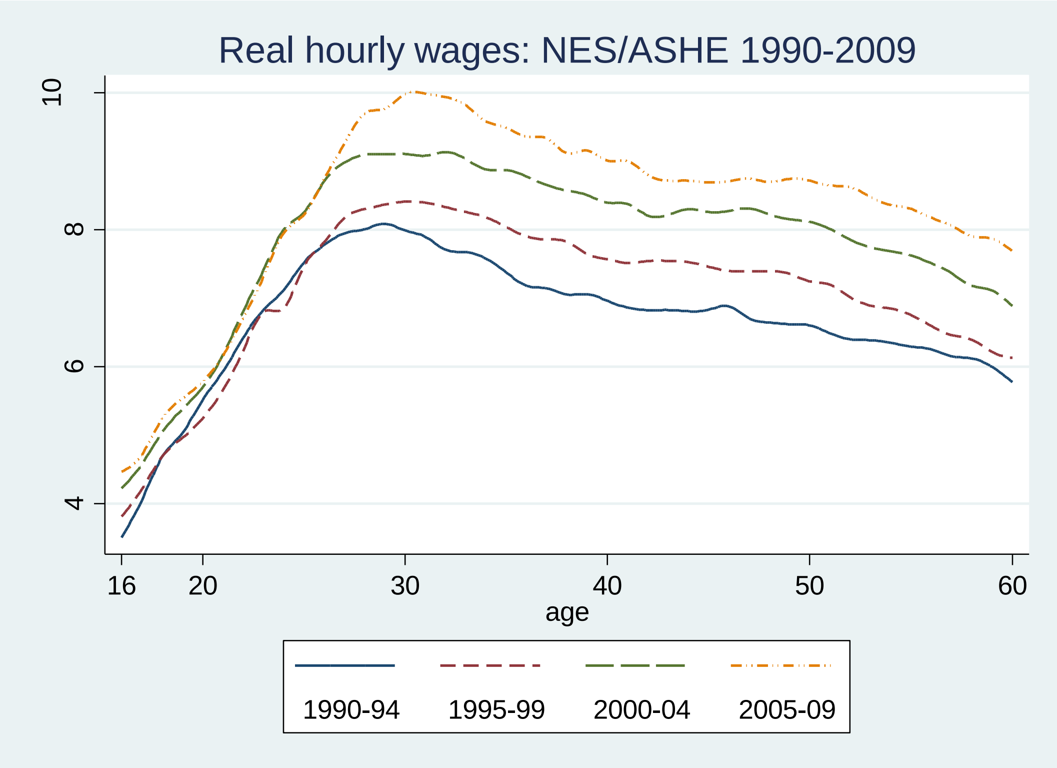


Figure A4 – Real hourly earnings: 1990-2009 – Female workers



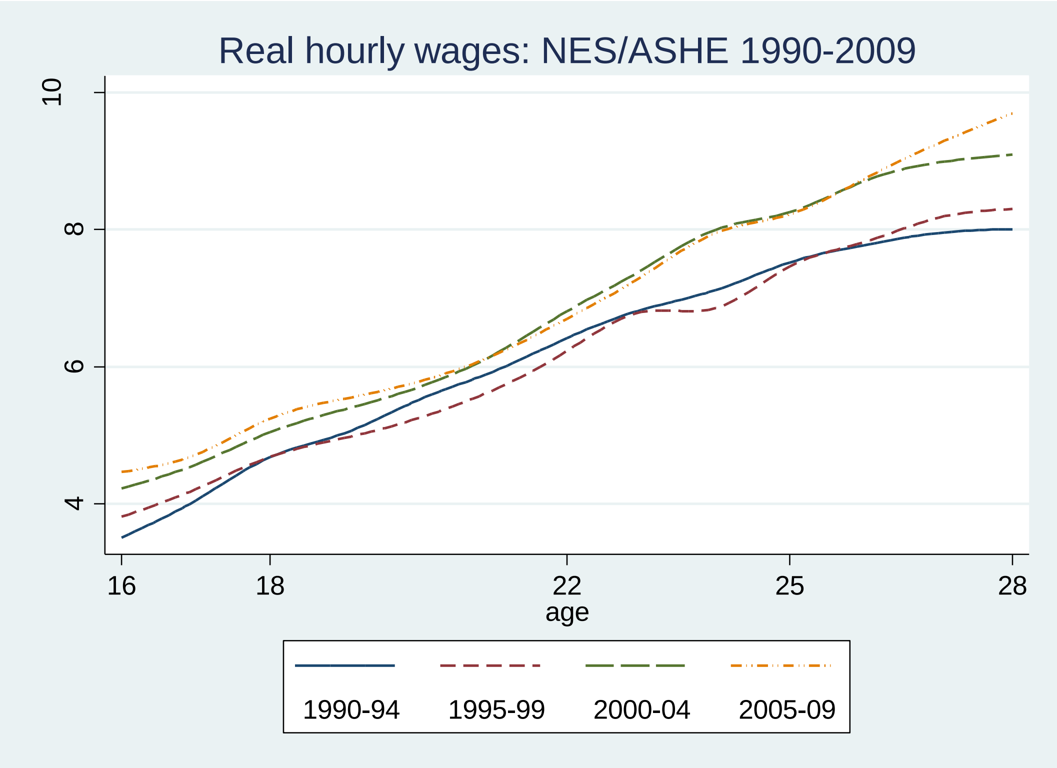
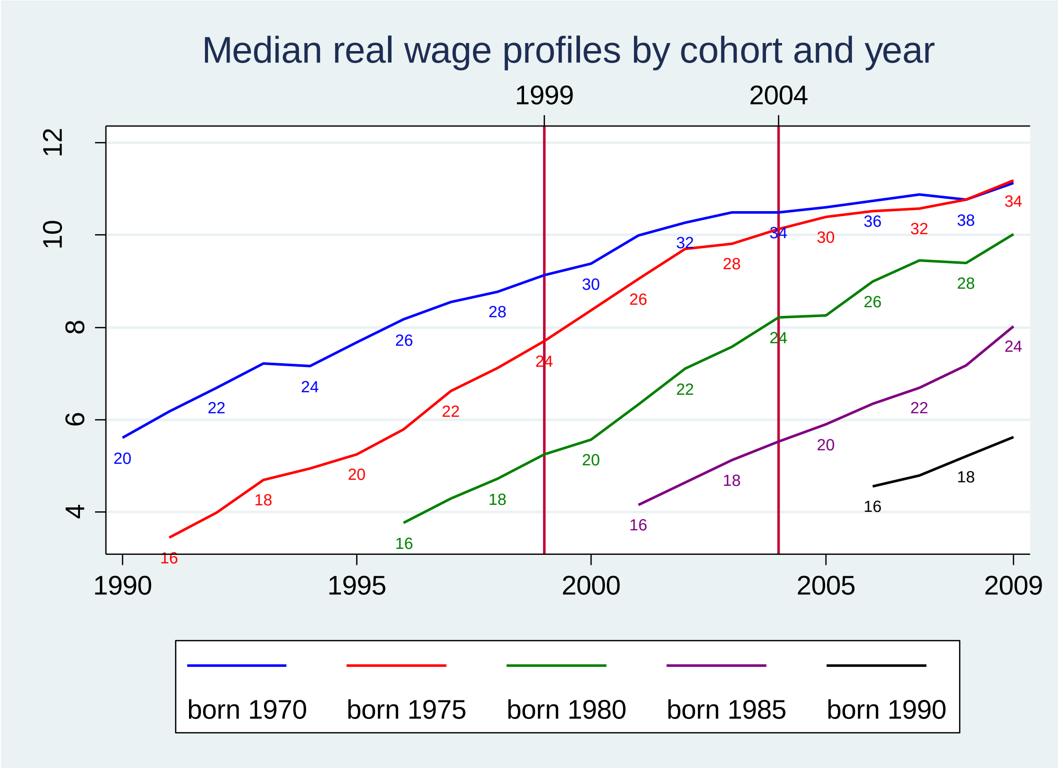


Figure A5 – Real wage profiles by cohort and year



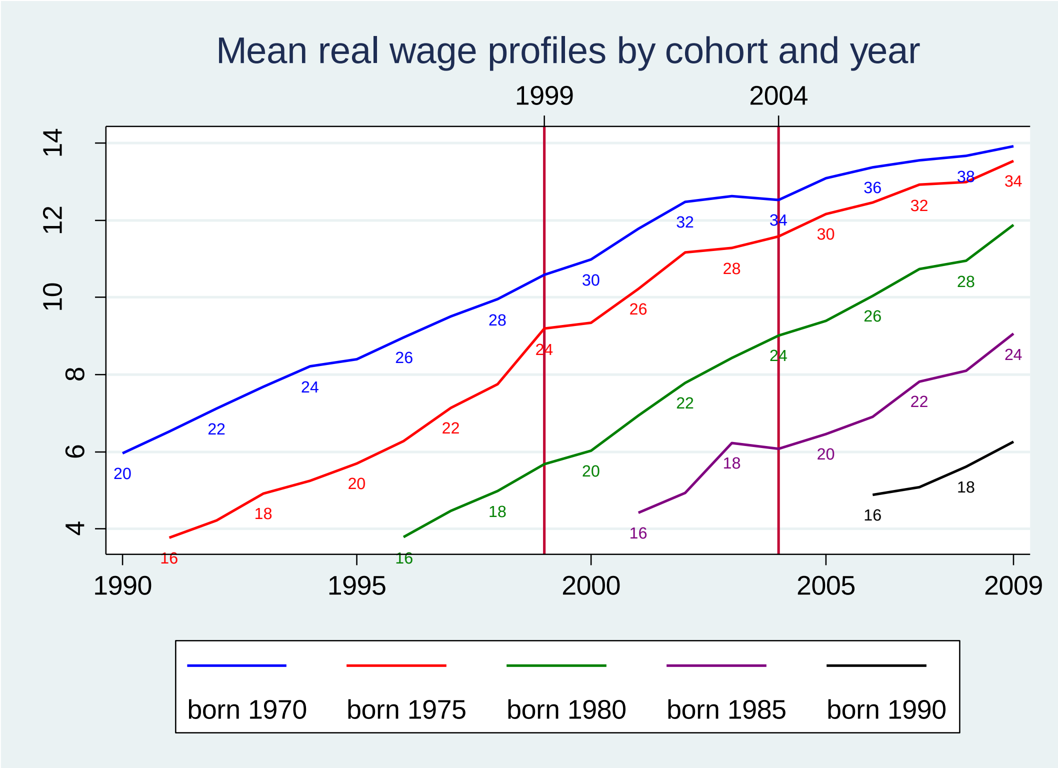
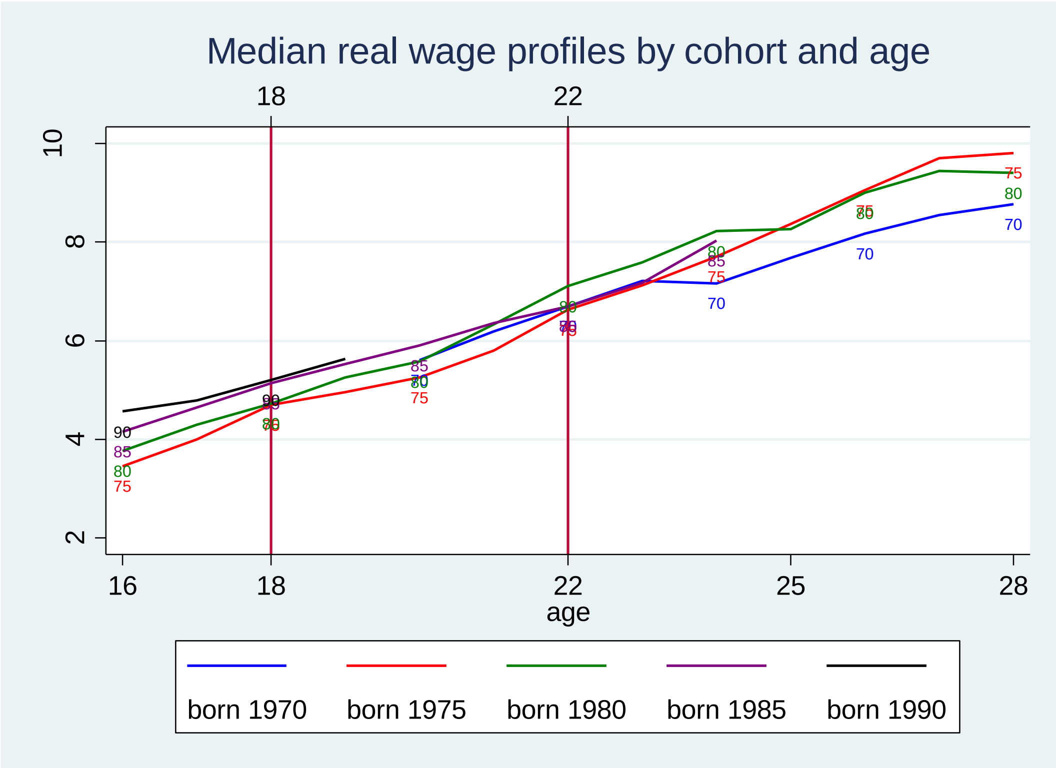


Figure A6 – Real wage profiles by cohort and age



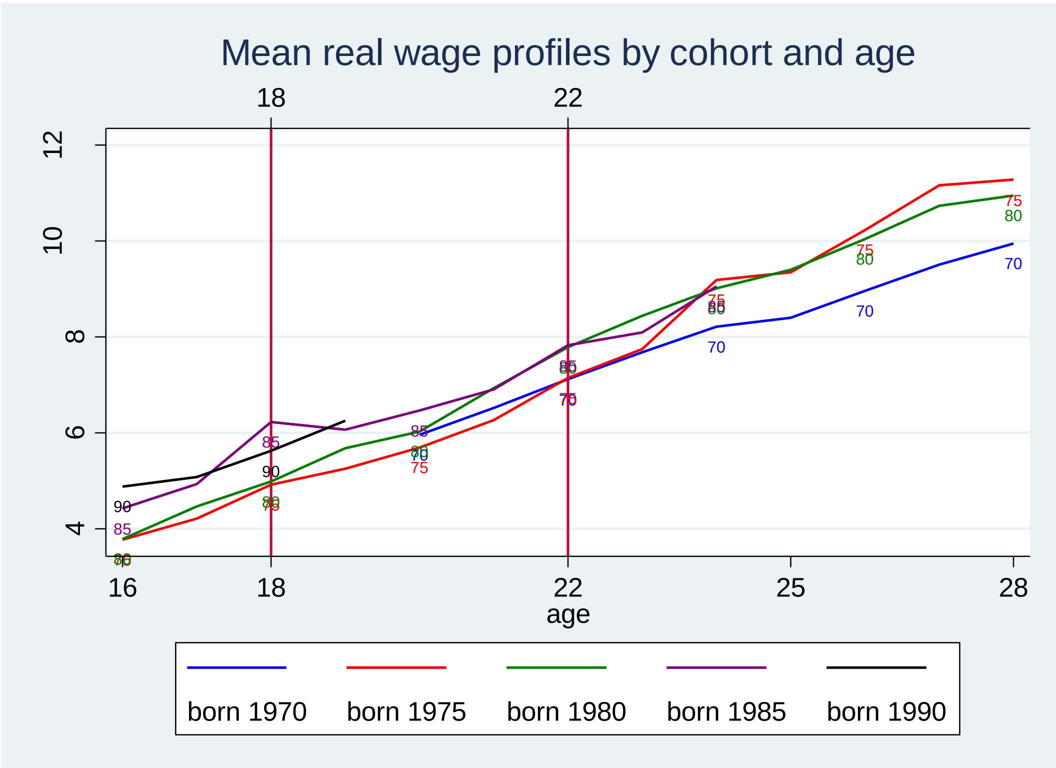


Figure A7 – Changes in real wage profiles before and after the introduction of the NMW

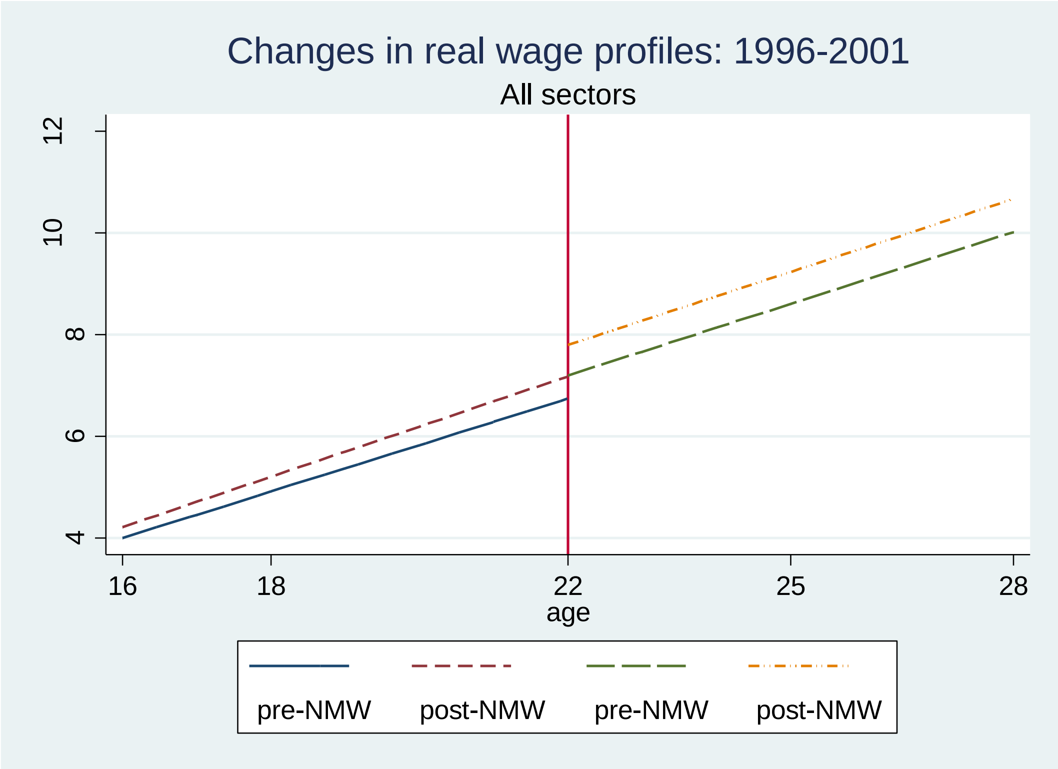


Figure A8 – Changes in real wage profiles before and after the introduction of the NMW: Low pay sectors

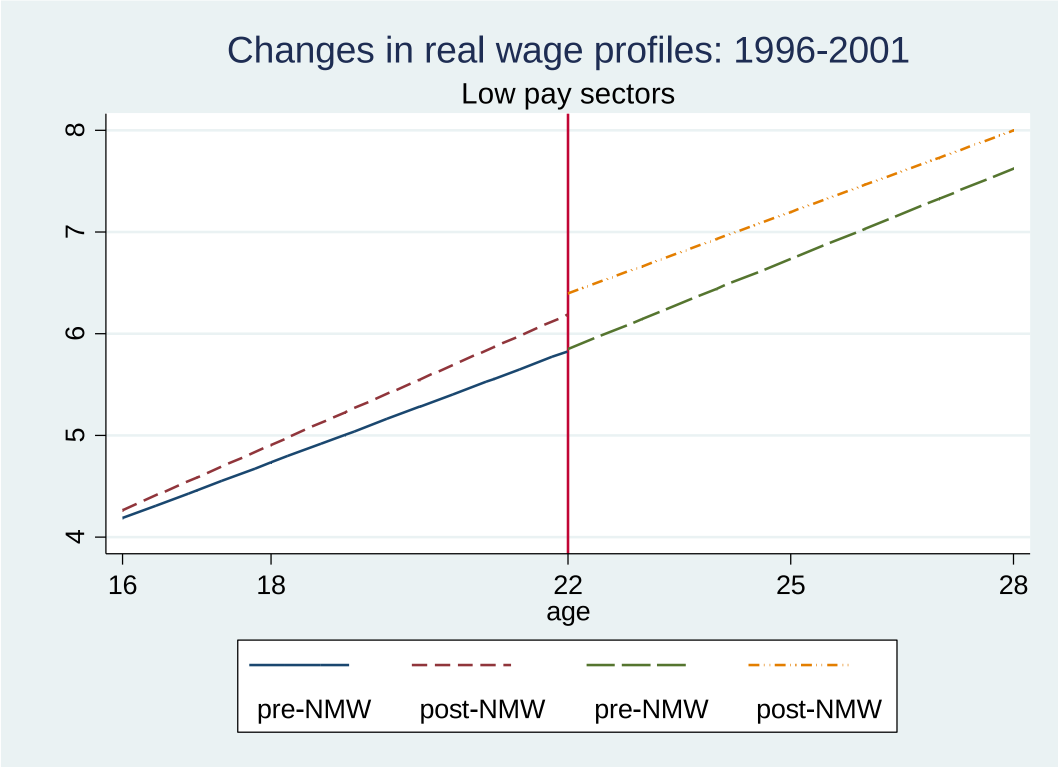
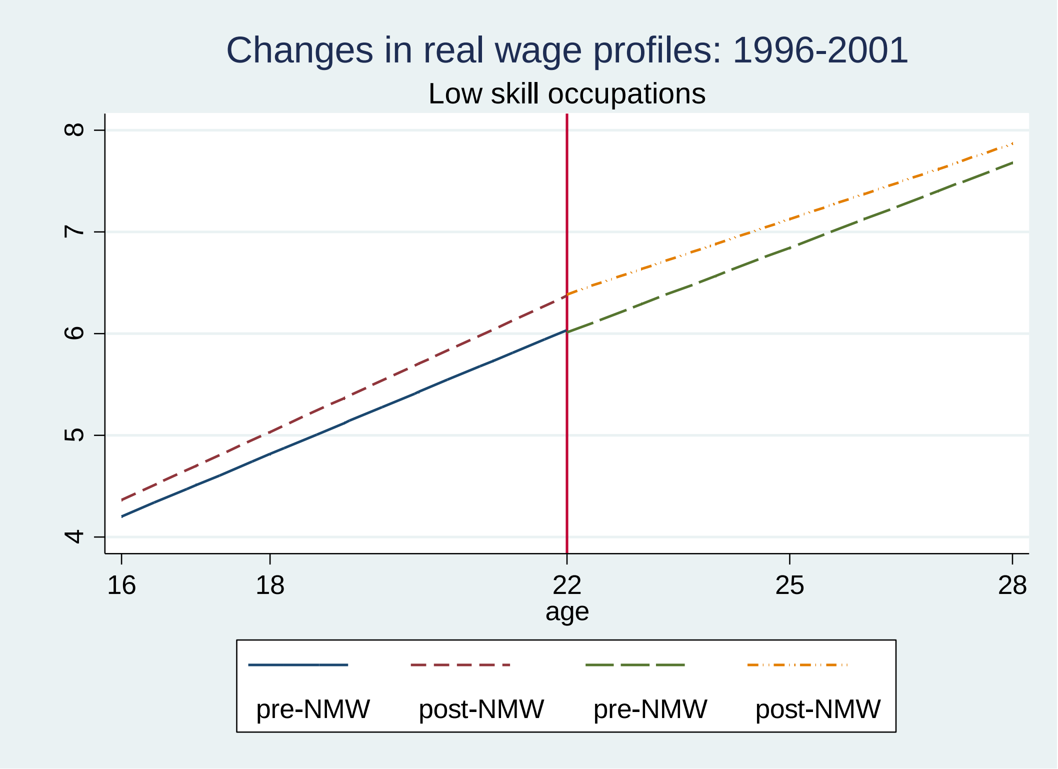


Figure A9 – Changes in real wage profiles before and after the introduction of the NMW: Low skill occupations



TABLES

Table A1 – Growth in real hourly earnings: 1990-94 to 2005-09

Mean earnings	All workers	Male	Female
All workers aged 16-60	24.6%	23.3%	31.0%
Age 16-21	9.7%	9.3%	10.1%
Age 22-28	11.7%	7.8%	16.7%
Age 29+	24.7%	23.5%	33.0%

Median earnings	All workers	Male	Female
All workers aged 16-60	17.9%	15.0%	24.7%
Age 16-21	6.3%	6.1%	6.4%
Age 22-28	7.3%	3.3%	11.5%
Age 29+	19.2%	16.4%	29.6%

Source: Authors' calculations based on NES/ASHE

Table A2 – Estimated age-earnings profiles 1996-2001

	Column 1	Column 2	Column 3	Column 4
$\mathrm{I}(22+)$	0.453	0.286	0.369	0.060
	(0.071)***	(0.043)***	(0.069)***	(0.062)
$A(16-21)$	0.457	0.407	0.445	0.369
	(0.019)***	(0.011)***	(0.019)***	(0.017)***
$A(22+)$	0.470	0.391	0.463	0.349
	(0.009)***	(0.005)***	(0.009)***	(0.008)***
NMW	-0.371	0.260	-0.381	-0.636
	(0.500)	(0.302)	(0.489)	(0.439)
$NMW \times \mathrm{I}(22+)$	0.162	0.180	0.112	-0.034
	(0.101)	(0.061)***	(0.099)	(0.089)
$NMW \times A(16-21)$	0.037	-0.001	0.040	0.049
	(0.026)	(0.016)	(0.026)	(0.023)**
$NMW \times A(22+)$	0.010	0.005	0.010	0.018
	(0.013)	(0.008)	(0.013)	(0.011)
female			-0.800	-0.865
			(0.021)***	(0.021)***
part time			-4.733	-2.753
			(0.056)***	(0.052)***
basic hours			-0.162	-0.108
			(0.002)***	(0.002)***
constant	-3.322	-2.708	3.773	6.566
	(0.358)***	(0.216)***	(0.360)***	(0.330)***
Occupation:9 1-digit dummies	NO	NO	NO	YES
Region: 11 GOR dummies	NO	NO	NO	YES
Observations	184,142	184,142	184,142	183,430
R-squared	0.134	N/A	0.173	0.334

Notes to Table A2:

1. The dependent variable is hourly real wages; sample is all individuals aged 16-28 years old.
2. Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1.
3. $\mathrm{I}(22+)$ is a dummy variable indicating individuals aged 22+. $A(16-21)$ and $A(22+)$ are linear spline variables which provide a piecewise linear function between wages and age with a node (or knot) at age 22. NMW is a dummy for years after the introduction of the NMW in 1999.
4. Column 1 reports (pooled) OLS results; column 2 reports quantile (median) regression estimates; column 3 includes additional regressions for gender, part-time status and weekly basic hours; column 4 additionally includes 9 SOC90 1-digit occupation dummies and 11 GOR regional dummies.

Table A3 – Estimated age-earnings profiles 1996-2001: Low pay sectors

	Column 1	Column 2	Column 3	Column 4
$\mathrm{I}(22+)$	0.020	-0.074	0.006	-0.168
	(0.090)	(0.048)	(0.089)	(0.084)
$A(16-21)$	0.274	0.245	0.242	0.235
	(0.021)***	(0.011)***	(0.021)***	(0.020)***
$A(22+)$	0.296	0.204	0.294	0.221
	(0.014)***	(0.007)***	(0.014)***	(0.013)***
NMW	-0.663	-0.130	-0.763	-0.936
	(0.542)	(0.289)	(0.535)	(0.502)
$NMW \times \mathrm{I}(22+)$	0.186	0.039	0.144	0.104
	(0.129)	(0.069)	(0.127)	(0.119)
$NMW \times A(16-21)$	0.046	0.017	0.053*	0.059
	(0.029)	(0.015)	(0.029)	(0.027)**
$NMW \times A(22+)$	-0.028	0.009	-0.031	-0.030
	(0.020)	(0.011)	(0.020)	(0.019)
female			-0.610	-0.604
			(0.030)***	(0.029)***
part time			-2.117	-1.326
			(0.071)***	(0.068)***
basic hours			-0.059	-0.048
			(0.003)***	(0.003)***
constant	-0.199	0.027	3.355	5.523
	(0.389)	(0.208)	(0.398)***	(0.386)***
Occupation:9 1-digit dummies	NO	NO	NO	YES
Region: 11 GOR dummies	NO	NO	NO	YES
Observations	57,714	57,714	57,714	57,455
R-squared	0.086	N/A	0.110	0.222

Notes to Table A3:

1. The dependent variable is hourly real wages; sample is all individuals aged 16-28 years old in low paying sectors (see text for details).
2. Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1.
3. $\mathrm{I}(22+)$ is a dummy variable indicating individuals aged 22+. $A(16-21)$ and $A(22+)$ are linear spline variables which provide a piecewise linear function between wages and age with a node (or knot) at age 22. NMW is a dummy for years after the introduction of the NMW in 1999.
4. Column 1 reports (pooled) OLS results; column 2 reports quantile (median) regression estimates; column 3 includes additional regressions for gender, part-time status and weekly basic hours; column 4 additionally includes 9 SOC90 1-digit occupation dummies and 11 GOR regional dummies.

Table A4 – Estimated age-earnings profiles 1996-2001: Low skill occupations

	Column 1	Column 2	Column 3	Column 4
$\mathrm{I}(22+)$	-0.027	-0.085	-0.030	-0.025
	(0.058)	(0.041)**	(0.057)	(0.056)
$A(16-21)$	0.306	0.270	0.269	0.273
	(0.014)***	(0.010)***	(0.014)***	(0.014)***
$A(22+)$	0.278	0.213	0.264	0.265
	(0.008)***	(0.006)***	(0.008)***	(0.008)***
NMW	-0.319	0.096	-0.246	-0.488
	(0.361)	(0.252)	(0.351)	(0.346)
$NMW \times \mathrm{I}(22+)$	0.041	0.023	0.021	0.000
	(0.083)	(0.058)	(0.081)	(0.080)
$NMW \times A(16-21)$	0.030	0.006	0.028	0.038
	(0.019)	(0.013)	(0.019)	(0.018)**
$NMW \times A(22+)$	-0.032	-0.002	-0.027	-0.022
	(0.012)**	(0.009)	(0.012)**	(0.012)*
female			-0.764	-0.826
			(0.019)***	(0.020)***
part time			-1.850	-1.748
			(0.044)***	(0.044)***
basic hours			-0.049	-0.044
			(0.002)***	(0.002)***
constant	-0.684	-0.344	2.615	2.094
	(0.260)***	(0.181)*	(0.260)***	(0.262)***
Occupation:4 1-digit dummies	NO	NO	NO	YES
Region: 11 GOR dummies	NO	NO	NO	YES
Observations	75,483	75,483	75,483	75,200
R-squared	0.137	N/A	0.184	0.21

Notes to Table A4:

1. The dependent variable is hourly real wages; sample is all individuals aged 16-28 years old in low paying occupations (see text for details).
2. Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1.
3. $\mathrm{I}(22+)$ is a dummy variable indicating individuals aged 22+. $A(16-21)$ and $A(22+)$ are linear spline variables which provide a piecewise linear function between wages and age with a node (or knot) at age 22. *NMW* is a dummy for years after the introduction of the NMW in 1999.
4. Column 1 reports (pooled) OLS results; column 2 reports quantile (median) regression estimates; column 3 includes additional regressions for gender, part-time status and weekly basic hours; column 4 additionally includes 4 SOC90 1-digit occupation dummies and 11 GOR regional dummies.

Table A5 – Estimated age-earnings profiles: Further robustness checks

	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Sample	All sectors		Low pay sectors		Low skill occupations	
Period	1994-2003	1998-99	1994-2003	1998-99	1994-2001	1998-99
$\mathrm{I}(22+)$	0.374	0.501	0.119	0.092	-0.051	-0.028
	(0.073)***	(0.134)***	(0.118)	(0.181)	(0.046)	(0.104)
$A(16-21)$	0.471	0.485	0.379	0.306	0.312	0.337
	(0.020)***	(0.035)***	(0.029)***	(0.040)***	(0.011)***	(0.024)***
$A(22+)$	0.481	0.453	0.341	0.286	0.278	0.273
	(0.009)***	(0.017)***	(0.017)***	(0.028)***	(0.007)***	(0.015)***
NMW	0.134	0.071	1.312	0.041	-0.170	0.338
	(0.530)	(0.924)	(0.726)*	(1.055)	(0.332)	(0.631)
$NMW \times \mathrm{I}(22+)$	0.187	0.211	0.134	0.133	0.064	0.116
	(0.105)*	(0.190)	(0.165)	(0.255)	(0.076)	(0.147)
$NMW \times A(16-21)$	0.020	0.007	-0.059	0.009	0.023	-0.006
	(0.028)	(0.049)	(0.038)	(0.056)	(0.018)	(0.034)
$NMW \times A(22+)$	0.048	-0.015	-0.045	-0.016	-0.032	-0.042
	(0.014)***	(0.024)	(0.025)*	(0.040)	(0.011)***	(0.022)*
constant	-3.633	-3.817	-2.057	-0.822	-0.833	-1.272
	(0.385)***	(0.656)***	(0.553)***	(0.753)	(0.211)***	(0.448)***
Observations	308,923	62,575	94,754	19,774	101,893	25,881
R-squared	0.080	0.115	0.045	0.072	0.128	0.137

Notes to Table A5:

1. The dependent variable is hourly real wages; sample is all individuals aged 16-28 years old.
2. Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1.
3. $\mathrm{I}(22+)$ is a dummy variable indicating individuals aged 22+. $A(16-21)$ and $A(22+)$ are linear spline variables which provide a piecewise linear function between wages and age with a node (or knot) at age 22. NMW is a dummy for years after the introduction of the NMW in 1999.
4. Columns 1 and 2 reports estimates for all sectors; columns 3 and 4 for low pay sectors; columns 5 and 6 for low skills occupations.
5. Odd numbered columns report results for 1994-2003 (5 years before and 5 years after the introduction of the NMW); even numbered columns report results for 1998-1999 (1 year before and 1 year after the introduction of the NMW). The exception is column 5 since a consistent definition of occupation is only available for the period 1994 to 2001.

Table B1 – Descriptive Statistics

	Total	Pre-NMW:1996-1998	Post-NMW: 1999-2007
Ln(real GVA per capita)	4.077	3.928	4.126
Ln(real wage)	2.355	2.268	2.384
Proportion aged 22-29	0.194	0.224	0.184
Proportion aged 30-39	0.279	0.280	0.279
Proportion aged 40-49	0.252	0.243	0.255
Proportion aged 50-59	0.197	0.180	0.203
Proportion female	0.402	0.406	0.401
Proportion part-time	0.196	0.188	0.199
Proportion private sector	0.932	0.912	0.939
Ln real net capital exp. per head	1.757	1.788	1.747
Workforce average qualifications	3.400	3.269	3.444
Percentage at NMW spike	2.441	0	3.255

Table B2 – Standard OLS Specification

	Ln real GVA per head	Ln real wage	Productivity-wage gap
Proportion aged 22-29	3.993	0.313	3.680
	(0.633)**	(0.150)*	(0.626)**
Proportion aged 30-39	2.836	1.481	1.354
	(0.491)**	(0.116)**	(0.485)**
Proportion aged 40-49	0.260	1.137	-0.877
	(0.575)	(0.136)**	(0.569)
Proportion aged 50-59	-1.061	0.166	-1.227
	(0.461)*	(0.109)	(0.456)**
Proportion female	-0.501	-0.146	-0.355
	(0.132)**	(0.031)**	(0.130)**
Proportion part-time	-0.956	-0.204	-0.753
	(0.218)**	(0.052)**	(0.216)**
Proportion private	1.125	0.064	1.060
	(0.090)**	(0.021)**	(0.089)**
Ln real net capital expenditure per head	0.375	0.024	0.351
	(0.014)**	(0.003)**	(0.014)**
Average Qualifications	-0.160	0.322	-0.482
	(0.032)**	(0.008)**	(0.032)**
Constant	1.494	0.415	1.079
	(0.391)**	(0.093)**	(0.387)**
Observations	1385	1385	1385
R-squared	0.71	0.82	0.70

Standard errors in parentheses * significant at 5%; ** significant at 1%

Table B3 – Effect of the Introduction of the National Minimum Wage on Productivity and Wage Equations: OLS

	Ln real GVA per head		Ln real wage		Productivity- wage gap	
	1996-98	1999-2007	1996-98	1999-2007	1996-98	1999-2007
Proportion aged 22-29	5.175	3.865	0.958	0.210	4.217	3.655
	(1.115)**	(0.759)**	(0.348)**	(0.169)	(1.134)**	(0.747)**
Proportion aged 30-39	3.106	2.695	1.900	1.439	1.206	1.256
	(0.856)**	(0.599)**	(0.267)**	(0.133)**	(0.871)	(0.588)*
Proportion aged 40-49	1.469	-0.266	1.663	1.083	-0.194	-1.350
	(1.017)	(0.685)	(0.318)**	(0.152)**	(1.035)	(0.674)*
Proportion aged 50-59	0.853	-1.291	0.719	0.069	0.134	-1.360
	(0.838)	(0.546)*	(0.262)**	(0.121)	(0.853)	(0.537)*
Proportion female	-0.436	-0.515	-0.098	-0.162	-0.338	-0.353
	(0.208)*	(0.161)**	(0.065)	(0.036)**	(0.211)	(0.158)*
Proportion part-time	-0.327	-1.208	-0.216	-0.181	-0.111	-1.027
	(0.331)	(0.273)**	(0.103)*	(0.061)**	(0.337)	(0.269)**
Proportion private	1.237	1.089	0.096	0.058	1.141	1.031
	(0.137)**	(0.111)**	(0.043)*	(0.025)*	(0.139)**	(0.109)**
Ln real net	0.412	0.367	0.029	0.022	0.382	0.344
cap.exp. / head	(0.022)**	(0.017)**	(0.007)**	(0.004)**	(0.022)**	(0.016)**
Qualifications	-0.029	-0.201	0.293	0.329	-0.322	-0.531
	(0.052)	(0.039)**	(0.016)**	(0.009)**	(0.053)**	(0.038)**
Constant	-0.209	2.142	-0.035	0.514	-0.174	1.628
	(0.726)	(0.454)**	(0.227)	(0.101)**	(0.739)	(0.446)**
Observations	343	1042	343	1042	343	1042
R-squared	0.81	0.69	0.80	0.83	0.79	0.68

Standard errors in parentheses * significant at 5%; ** significant at 1%

Table B4 – Effect of the Introduction of the National Minimum Wage on Productivity and Wage Equations: OLS – Low Paying Sectors Only

	Ln real GVA per head		Ln real wage		Productivity- wage gap	
	1996-98	1999-2007	1996-98	1999-2007	1996-98	1999-2007
Proportion aged 22-29	4.142	0.817	-0.174	-0.705	4.316	1.522
	(1.685)*	(0.946)	(0.538)	(0.296)*	(1.829)*	(0.911)
Proportion aged 30-39	2.064	1.184	1.791	0.294	0.273	0.890
	(1.717)	(0.832)	(0.548)**	(0.261)	(1.863)	(0.801)
Proportion aged 40-49	2.302	-2.082	1.464	0.980	0.839	-3.062
	(1.686)	(0.819)*	(0.538)**	(0.257)**	(1.831)	(0.789)**
Proportion aged 50-59	1.090	0.498	-0.137	-0.160	1.227	0.658
	(1.394)	(0.792)	(0.445)	(0.248)	(1.513)	(0.762)
Proportion female	-0.507	-0.099	-0.113	-0.197	-0.394	0.097
	(0.264)	(0.171)	(0.084)	(0.053)**	(0.286)	(0.164)
Proportion part-time	-0.023	-1.078	-0.191	-0.262	0.169	-0.815
	(0.423)	(0.277)**	(0.135)	(0.087)**	(0.459)	(0.267)**
Proportion private	1.600	1.825	-0.069	0.048	1.670	1.778
	(0.326)**	(0.289)**	(0.104)	(0.090)	(0.354)**	(0.278)**
Ln real net	0.320	0.300	0.057	0.042	0.263	0.258
cap.exp. / head	(0.039)**	(0.030)**	(0.013)**	(0.009)**	(0.043)**	(0.029)**
Qualifications	-0.267	-0.262	0.235	0.290	-0.502	-0.553
	(0.131)*	(0.079)**	(0.042)**	(0.025)**	(0.142)**	(0.076)**
Constant	0.494	2.564	0.734	1.189	-0.240	1.375
	(1.387)	(0.653)**	(0.443)	(0.204)**	(1.506)	(0.628)*
Observations	102	313	102	313	102	313
R-squared	0.75	0.60	0.74	0.67	0.72	0.60

Standard errors in parentheses * significant at 5%; ** significant at 1%

Table B5 – Including Minimum Wage 'Spike' Variable: OLS Specification

	Ln real GVA / head	Ln real wage	Productivity-wage gap
Proportion aged 22-29	5.021	0.612	4.409
	(0.707)**	(0.182)**	(0.700)**
Proportion aged 30-39	2.520	1.698	0.822
	(0.516)**	(0.132)**	(0.511)
Proportion aged 40-49	0.841	1.123	-0.283
	(0.635)	(0.163)**	(0.629)
Proportion aged 50-59	-1.021	0.541	-1.561
	(0.526)	(0.135)**	(0.521)**
Proportion female	-0.786	-0.087	-0.699
	(0.145)**	(0.037)*	(0.144)**
Proportion part-time	-0.753	-0.204	-0.549
	(0.234)**	(0.060)**	(0.232)*
Proportion private	1.087	0.065	1.022
	(0.088)**	(0.022)**	(0.087)**
Ln real net capital expenditure per head	0.309	0.021	0.288
	(0.013)**	(0.003)**	(0.013)**
Average Qualifications	-0.086	0.302	-0.388
	(0.034)*	(0.009)**	(0.034)**
NMW spike* proportion aged 22-29	-0.705	-0.062	-0.643
	(0.102)**	(0.026)*	(0.101)**
NMW spike* proportion aged 30-39	-0.216	-0.100	-0.115
	(0.091)*	(0.023)**	(0.090)
NMW spike* proportion aged 40-49	-0.263	0.024	-0.287
	(0.098)**	(0.025)	(0.097)**
NMW spike* proportion aged 50-59	-0.065	-0.073	0.008
	(0.092)	(0.024)**	(0.091)
NMW spike*proportion female	0.192	-0.001	0.193
	(0.024)**	(0.006)	(0.023)**
NMW spike*proportion part-time	0.012	0.021	-0.010
	(0.031)	(0.008)**	(0.030)
NMW spike*proportion private	-0.209	0.010	-0.219
	(0.051)**	(0.013)	(0.051)**
NMW spike*ln(real net capital exp/ head)	0.131	0.007	0.125
	(0.008)**	(0.002)**	(0.008)**
NMW spike*average qualifications	-0.056	-0.003	-0.053
	(0.009)**	(0.002)	(0.009)**
Constant	1.161	0.270	0.891
	(0.420)**	(0.108)*	(0.416)*
Observations	1385	1385	1385
R-squared	0.77	0.84	0.76

Standard errors in parentheses * significant at 5%; ** significant at 1%

Table B6 – Fixed Effects Specification

	Ln real GVA per head	Ln real wage	Productivity-wage gap
Proportion aged 22-29	0.342	-0.063	0.405
	(0.494)	(0.106)	(0.509)
Proportion aged 30-39	0.808	0.333	0.475
	(0.435)	(0.093)**	(0.448)
Proportion aged 40-49	1.419	0.467	0.952
	(0.427)**	(0.092)**	(0.439)*
Proportion aged 50-59	1.137	0.466	0.671
	(0.433)**	(0.093)**	(0.446)
Proportion female	-0.065	-0.286	0.221
	(0.296)	(0.063)**	(0.304)
Proportion part-time	-0.037	-0.001	-0.036
	(0.272)	(0.058)	(0.280)
Proportion private	0.952	0.039	0.912
	(0.133)**	(0.029)	(0.137)**
Ln real net capital expenditure per head	0.272	0.017	0.255
	(0.018)**	(0.004)**	(0.018)**
Qualifications	0.265	0.352	-0.088
	(0.077)**	(0.017)**	(0.080)
Constant	0.829	0.883	-0.054
	(0.470)	(0.101)**	(0.484)
Observations	1385	1385	1385
R-squared	0.44	0.70	0.32

Standard errors in parentheses * significant at 5%; ** significant at 1%

Table B7 – Robustness Checks – Fixed Effects Specification

	Ln real GVA / head	Ln real wage	Productivity- wage gap
a.) Full-time equivalent employment level			
Proportion aged 22-29	0.322	-0.063	0.385
	(0.494)	(0.106)	(0.508)
Proportion aged 30-39	0.785	0.334	0.451
	(0.435)	(0.093)**	(0.447)
Proportion aged 40-49	1.400	0.467	0.932
	(0.427)**	(0.092)**	(0.439)*
Proportion aged 50-59	1.115	0.466	0.649
	(0.433)*	(0.093)**	(0.445)
b.) No capital expenditure			
Proportion aged 22-29	0.782	-0.040	0.822
	(0.547)	(0.106)	(0.555)
Proportion aged 30-39	0.493	0.317	0.176
	(0.480)	(0.094)**	(0.488)
Proportion aged 40-49	1.250	0.455	0.795
	(0.471)**	(0.092)**	(0.478)
Proportion aged 50-59	1.838	0.506	1.332
	(0.476)**	(0.093)**	(0.484)**
c.) No year dummies			
Proportion aged 22-29	-0.227	-0.419	0.192
	(0.455)	(0.099)**	(0.465)
Proportion aged 30-39	-0.071	0.221	-0.292
	(0.436)	(0.095)*	(0.446)
Proportion aged 40-49	1.754	0.315	1.439
	(0.418)**	(0.091)**	(0.427)**
Proportion aged 50-59	1.520	0.515	1.005
	(0.444)**	(0.096)**	(0.453)*
d.) Manufacturing sectors only			
Proportion aged 22-29	-1.328	-0.084	-1.244
	(1.148)	(0.244)	(1.181)
Proportion aged 30-39	-1.273	0.032	-1.305
	(1.084)	(0.230)	(1.116)
Proportion aged 40-49	-1.025	0.141	-1.166
	(1.023)	(0.217)	(1.053)
Proportion aged 50-59	0.114	0.012	0.102
	(1.011)	(0.214)	(1.040)
e.) Service sectors only			
Proportion aged 22-29	0.438	-0.085	0.523
	(0.590)	(0.127)	(0.606)
Proportion aged 30-39	1.162	0.404	0.757
	(0.520)*	(0.112)**	(0.534)
Proportion aged 40-49	1.537	0.611	0.926
	(0.537)**	(0.116)**	(0.552)
Proportion aged 50-59	0.695	0.660	0.035
	(0.531)	(0.114)**	(0.546)

f.) LFS employment levels			
Proportion aged 22-29	-0.701	-0.131	-0.570
	(0.553)	(0.129)	(0.570)
Proportion aged 30-39	-0.692	0.332	-1.024
	(0.510)	(0.119)**	(0.526)
Proportion aged 40-49	-0.425	0.429	-0.854
	(0.494)	(0.116)**	(0.510)
Proportion aged 50-59	-2.179	0.455	-2.634
	(0.492)**	(0.115)**	(0.508)**
g.) LFS: using potential experience rather than age			
Pot. experience 6-15 years	-0.081	-0.169	0.088
	(0.315)	(0.075)*	(0.327)
Pot. experience 16-25 years	0.038	0.038	0.000
	(0.285)	(0.068)	(0.296)
Pot. experience 26-35 years	-0.110	0.009	-0.119
	(0.322)	(0.077)	(0.334)
Pot. experience 36-45 years	0.511	-0.084	0.596
	(0.322)	(0.077)	(0.334)

Standard errors in parentheses * significant at 5%; ** significant at 1%
Each panel contains results from a separate regression, which also controls for proportion female, proportion part-time, proportion in private sector, log real net capital expenditure per head and average qualifications of the workforce.

Table B8 – Effect of the Introduction of the National Minimum Wage on Productivity and Wage Equations: Fixed Effects

	Ln real GVA per head		Ln real wage		Productivity- wage gap	
	1996-98	1999-2007	1996-98	1999-2007	1996-98	1999-2007
Proportion aged 22-29	2.007	0.076	0.078	0.228	1.929	-0.152
	(1.387)	(0.452)	(0.232)	(0.123)	(1.435)	(0.466)
Proportion aged 30-39	1.534	0.153	0.727	0.339	0.807	-0.186
	(1.447)	(0.411)	(0.242)**	(0.112)**	(1.496)	(0.424)
Proportion aged 40-49	1.730	0.826	0.726	0.528	1.004	0.297
	(1.329)	(0.412)*	(0.223)**	(0.112)**	(1.374)	(0.425)
Proportion aged 50-59	2.440	1.150	0.762	0.714	1.678	0.436
	(1.389)	(0.414)**	(0.233)**	(0.113)**	(1.436)	(0.427)
Proportion female	1.005	-0.196	-0.431	-0.292	1.436	0.095
	(0.787)	(0.281)	(0.132)**	(0.076)**	(0.814)	(0.290)
Proportion part-time	0.488	-0.720	0.394	-0.056	0.094	-0.664
	(0.703)	(0.249)**	(0.118)**	(0.068)	(0.727)	(0.257)**
Proportion private	1.205	0.891	0.039	0.013	1.167	0.878
	(0.263)**	(0.170)**	(0.044)	(0.046)	(0.272)**	(0.176)**
Ln real net	0.543	0.156	0.003	0.018	0.540	0.139
cap.exp. / head	(0.046)**	(0.016)**	(0.008)	(0.004)**	(0.047)**	(0.017)**
Qualifications	0.595	-0.038	0.449	0.354	0.146	-0.392
	(0.258)*	(0.076)	(0.043)**	(0.021)**	(0.267)	(0.078)**
Constant	-2.304	2.740	0.322	0.826	-2.626	1.914
	(1.423)	(0.483)**	(0.238)	(0.131)**	(1.472)	(0.498)**
Observations	343	1042	343	1042	343	1042
R-squared	0.61	0.45	0.46	0.61	0.57	0.34

Standard errors in parentheses * significant at 5%; ** significant at 1%

Table B9 – Effect of the Introduction of the National Minimum Wage on Productivity and Wage Equations: Fixed Effects – Low Paying Sectors Only

	Ln real GVA per head		Ln real wage		Productivity- wage gap	
	1996-98	1999-2007	1996-98	1999-2007	1996-98	1999-2007
Proportion aged 22-29	3.470	1.085	-0.015	0.092	3.485	0.992
	(2.437)	(0.646)	(0.572)	(0.209)	(2.728)	(0.654)
Proportion aged 30-39	0.526	1.021	0.319	0.519	0.207	0.501
	(2.637)	(0.608)	(0.619)	(0.196)**	(2.951)	(0.616)
Proportion aged 40-49	3.497	0.986	0.601	0.675	2.895	0.311
	(2.501)	(0.660)	(0.587)	(0.213)**	(2.800)	(0.669)
Proportion aged 50-59	2.679	1.495	0.437	0.434	2.242	1.061
	(2.452)	(0.660)*	(0.575)	(0.213)*	(2.745)	(0.668)
Proportion female	-1.420	0.272	-0.266	-0.546	-1.154	0.819
	(2.014)	(0.443)	(0.473)	(0.143)**	(2.255)	(0.449)
Proportion part-time	-0.211	-0.720	0.023	0.074	-0.234	-0.794
	(1.709)	(0.440)	(0.401)	(0.142)	(1.913)	(0.445)
Proportion private	0.701	1.124	0.036	0.143	0.665	0.981
	(0.768)	(0.303)**	(0.180)	(0.098)	(0.860)	(0.307)**
Ln real net	0.356	0.097	-0.037	-0.001	0.393	0.097
cap.exp. / head	(0.082)**	(0.025)**	(0.019)	(0.008)	(0.092)**	(0.026)**
Qualifications	-0.534	0.288	0.712	0.331	-1.245	-0.043
	(0.617)	(0.136)*	(0.145)**	(0.044)**	(0.690)	(0.138)
Constant	2.660	0.767	-0.200	0.844	2.861	-0.077
	(3.585)	(0.720)	(0.841)	(0.232)**	(4.013)	(0.729)
Observations	102	313	102	313	102	313
R-squared	0.58	0.44	0.52	0.54	0.52	0.32

Standard errors in parentheses * significant at 5%; ** significant at 1%

Table B10 – Including Minimum Wage 'Spike' Variable: Fixed Effects Specification

	Ln real GVA / head	Ln real wage	Productivity-wage gap
Proportion aged 22-29	0.380	-0.137	0.517
	(0.551)	(0.123)	(0.572)
Proportion aged 30-39	0.310	0.312	-0.002
	(0.488)	(0.109)**	(0.507)
Proportion aged 40-49	1.159	0.473	0.686
	(0.480)*	(0.107)**	(0.498)
Proportion aged 50-59	0.784	0.465	0.319
	(0.479)	(0.107)**	(0.497)
Proportion female	-0.153	-0.273	0.120
	(0.293)	(0.066)**	(0.304)
Proportion part-time	-0.219	-0.022	-0.197
	(0.266)	(0.060)	(0.276)
Proportion private	1.185	0.059	1.125
	(0.131)**	(0.029)*	(0.136)**
Ln real net capital expenditure per head	0.247	0.016	0.231
	(0.017)**	(0.004)**	(0.018)**
Average Qualifications	0.225	0.356	-0.131
	(0.077)**	(0.017)**	(0.080)
NMW spike* proportion aged 22-29	-0.108	0.018	-0.126
	(0.061)	(0.014)	(0.064)*
NMW spike* proportion aged 30-39	-0.044	-0.008	-0.036
	(0.057)	(0.013)	(0.059)
NMW spike* proportion aged 40-49	-0.154	-0.007	-0.146
	(0.059)**	(0.013)	(0.061)*
NMW spike* proportion aged 50-59	0.039	0.011	0.028
	(0.057)	(0.013)	(0.059)
NMW spike*female	0.069	0.004	0.065
	(0.015)**	(0.003)	(0.016)**
NMW spike*part-time	-0.013	-0.002	-0.011
	(0.019)	(0.004)	(0.020)
NMW spike*private	-0.103	-0.007	-0.096
	(0.032)**	(0.007)	(0.034)**
NMW spike*ln(real net capital exp/ head)	0.055	0.002	0.053
	(0.005)**	(0.001)*	(0.006)**
NMW spike*average qualifications	-0.031	-0.002	-0.029
	(0.006)**	(0.001)	(0.007)**
Constant	1.108	0.875	0.233
	(0.493)*	(0.110)**	(0.511)
Observations	1385	1385	1385
R-squared	0.49	0.70	0.37

Standard errors in parentheses * significant at 5%; ** significant at 1%

Table B11 – GMM Specification

	Ln real GVA per head	Ln real wage	Productivity-wage gap
Proportion aged 22-29	3.857	-0.893	4.750
	(2.782)	(0.667)	(2.998)
Proportion aged 30-39	2.740	0.335	2.405
	(1.810)	(0.455)	(1.862)
Proportion aged 40-49	1.236	0.150	1.086
	(2.016)	(0.535)	(2.091)
Proportion aged 50-59	-2.567	-0.858	-1.709
	(1.918)	(0.432)*	(2.005)
Proportion female	-1.073	-0.222	-0.851
	(0.681)	(0.160)	(0.696)
Proportion part-time	-0.874	-0.508	-0.366
	(0.981)	(0.273)	(1.012)
Proportion private	0.551	0.106	0.445
	(0.323)	(0.094)	(0.310)
Ln real net capital expenditure per head	0.365	0.040	0.325
	(0.054)**	(0.018)*	(0.051)**
Qualifications	-0.027	0.378	-0.406
	(0.123)	(0.042)**	(0.117)**
Constant	1.748	1.222	0.526
	(1.654)	(0.479)*	(1.705)
Observations	1385	1385	1385

Standard errors in parentheses * significant at 5%; ** significant at 1%

Table B12 – Including Minimum Wage 'Spike' Variable: GMM Specification

	Ln real GVA / head	Ln real wage	Productivity-wage gap
Proportion aged 22-29	5.060	-0.733	5.792
	(2.357)*	(0.747)	(2.519)*
Proportion aged 30-39	3.049	0.346	2.703
	(1.903)	(0.540)	(1.933)
Proportion aged 40-49	0.279	0.223	0.056
	(1.625)	(0.553)	(1.605)
Proportion aged 50-59	-0.825	-0.693	-0.133
	(2.013)	(0.637)	(2.111)
Proportion female	-1.561	-0.228	-1.333
	(0.605)**	(0.181)	(0.622)*
Proportion part-time	-0.207	-0.480	0.273
	(0.926)	(0.328)	(0.924)
Proportion private	0.674	0.130	0.543
	(0.344)	(0.090)	(0.333)
Ln real net capital expenditure per head	0.279	0.034	0.245
	(0.058)**	(0.018)	(0.055)**
Average Qualifications	0.105	0.377	-0.272
	(0.114)	(0.039)**	(0.110)*
NMW spike* proportion aged 22-29	-0.367	0.006	-0.373
	(0.218)	(0.070)	(0.220)
NMW spike* proportion aged 30-39	0.243	-0.031	0.274
	(0.197)	(0.047)	(0.200)
NMW spike* proportion aged 40-49	-0.134	-0.049	-0.085
	(0.298)	(0.072)	(0.300)
NMW spike* proportion aged 50-59	-0.207	0.019	-0.226
	(0.238)	(0.077)	(0.246)
NMW spike*female	0.085	-0.002	0.087
	(0.076)	(0.027)	(0.079)
NMW spike*part-time	0.082	0.019	0.063
	(0.124)	(0.029)	(0.121)
NMW spike*private	-0.131	0.019	-0.150
	(0.175)	(0.031)	(0.186)
NMW spike*ln(real net capital exp/ head)	0.098	-0.000	0.098
	(0.041)*	(0.008)	(0.045)*
NMW spike*average qualifications	-0.088	-0.006	-0.082
	(0.027)**	(0.009)	(0.025)**
Constant	0.988	1.145	-0.157
	(1.424)	(0.531)*	(1.465)
Observations	1385	1385	1385
R-squared	0.49	0.70	0.37

Standard errors in parentheses * significant at 5%; ** significant at 1%

APPENDIX A

List of Sectors Used In the Sectoral Analysis – ASHE Employment Measure[19]

1 "agric, hunting, forestry and fishing"
2 "mining and quarrying"
3 "production and processing and preserving of food"
4 "manufacture of food products"
5 "manufacture of other food products"
6 "manufacture of drink and tobacco"
7 "manufacture of textiles"
8 "manufacture of clothes, leather and footwear"
9 "wood and wood products"
10 "manufacture of pulp, paper and paper products"
11 "publishing"
12 "printing and recording"
13 "manufacture of coke, petrol and nuclear fuels"
14 "manufacture of chemicals and related products"
15 "manufacture of pharma, soap and other chemicals"
16 "manufacture of rubber and plastics"
17 "manufacture of other non-metallic mineral products"
18 "manufacture of basic metals"
19 "manufacture of metal products"
20 "treatment and coatings of metals & general mechanical engineering"
21 "manufacture of cutlery and other metal goods"
22 "manufacture of machines for power"
23 "manufacture of other machines incl agricultural"
24 "manufacture of machine tools, etc"
25 "manufacture of office machinery etc"
26 "manufacture of radio and tv equipment"
27 "manufacture of medical and optical equipment etc"
28 "manufacture of motor vehicles"
29 "manufacture of trucks and motor parts"
30 "manufacture of other transport equipment"
31 "manufacture of aircraft and spacecraft"
32 "manufacture of furniture"
33 "other manufacturing n.e.s. and recycling"
34 "electricity, gas and water"
35 "general construction"
36 "specialist construction including roads"
37 "construction installation - electrical"
38 "construction installation - plumbing and insulation"
39 "construction - building completion"
40 "sale of motor vehicles"

[19] The numbers represent our own code, and do not correspond to any SIC codes.

41 "maintenance and repair of motor vehicles"
42 "sale of motor parts and motor bikes"
43 "retail vehicle fuel"
44 "wholesale: agents and agricultureal"
45 "wholesale: fruit/meat/dairy"
46 "wholesale: other food"
47 "wholesale: clothing and textiles"
48 "wholesale: other household goods"
49 "wholesale: non-agricultural intermediate products"
50 "wholesale: machinery, equipment and supplies"
51 "wholesale: other"
52 "retail: general food etc"
53 "retail: other general"
54 "retail: specialist food"
55 "retail: pharmaceuticals"
56 "retail: textiles and clothing"
57 "retail: footwear and leather"
58 "retail: furniture and lighting"
59 "retail: electrical household goods incl. radio and TV"
60 "retail: hardware, paints etc"
61 "retail: books, newspapers and stationery"
62 "retail: specialist other"
63 "retail: second-hand and repair"
64 "hotels"
65 "camp sites, short-stay"
66 "restaurants"
67 "bars"
68 "canteens and catering"
69 "transport: railways"
70 "other scheduled land transport"
71 "taxi and other land transport"
72 "road freight"
73 "water and air transport"
74 "cargo handling and storage"
75 "other supporting transort activities"
76 "travel agencies and tour operators"
77 "other transport agencies"
78 "post and couriers"
79 "telecommunications"
80 "real estate: own property"
81 "letting of own property"
82 "real estate agencies"
83 "management of real estate"
84 "rental of cars and other transport"
85 "rental of other machinery n.e.s."
86 "hardware and software consultancy and supply"

87 "other computing and related activities"
88 "research and development"
89 "legal activities"
90 "accounting and tax consultancy"
91 "market research"
92 "business and management consultancy services"
93 "management activities of holding companies"
94 "architecture and engineering"
95 "technical testing and analysis"
96 "advertising"
97 "labour recruitment"
98 "investigation and security activities"
99 "industrial cleaning"
100 "miscellaneous business activities"
101 "other business activity n.e.s."
102 "primary education"
103 "secondary education"
104 "higher education"
105 "adult and other education"
106 "hospitals"
107 "other human health activity"
108 "veterinary activity"
109 "social work with accommodation"
110 "social work without accommodation"
111 "sewage and refuse disposal"
112 "membership organisations n.e.s"
113 "cinema and video"
114 "radio and tv"
115 "other entertainment including news agencies"
116 "libraries and museums"
117 "sports arenas and stadia"
118 "other sporting activities"
119 "other recreational activities"
120 "hairdressing and beauty treatments"
121 "other service activities"

APPENDIX B

List of Sectors Used In the Sectoral Analysis – QLFS Employment Measure

1 "agriculture, hunting, forestry and fishing"
2 "mining and quarrying"
3 "production and processing and preserving of food"
4 "manufacture of food products"
5 "manufacture of other food products"
6 "manufacture of drink and tobacco"
7 "manufacture of textiles"
8 "manufacture of clothes, leather and footwear"
9 "wood and wood products"
10 "manufacture of pulp, paper and paper products"
11 "publishing"
12 "printing and recording"
13 "manufacture of coke, petrol and nuclear fuels"
14 "manufacture of chemicals and related products"
15 "manufacture of pharmaceuticals, soap and other chemicals"
16 "manufacture of rubber and plastics"
17 "manufacture of other non-metallic mineral products"
18 "manufacture of basic metals"
19 "manufacture of metal products"
20 "treatment and coatings of metals & general mechanical engineering"
21 "manufacture of cutlery and other metal goods"
22 "manufacture of machines for power"
23 "manufacture of other machines including agricultural"
24 "manufacture of machine tools, etc"
25 "manufacture of office machinery etc"
26 "manufacture of radio and TV equipment"
27 "manufacture of medical and optical equipment etc"
28 "manufacture of motor vehicles"
29 "manufacture of trucks and motor parts"
30 "manufacture of other transport equipment"
31 "manufacture of aircraft and spacecraft"
32 "manufacture of furniture"
33 "other manufacturing n.e.c. and recycling"
34 "electricity, gas and water"
35 "construction"
36 "sale of vehicles, parts, fuel"
37 "wholesale"
38 "retail"
39 "camp sites, short-stay"
40 "restaurants"
41 "bars"
42 "canteens and catering"
43 "transport: railways"

44 "other scheduled land transport"
45 "taxi and other land transport"
46 "road freight"
47 "water and air transport"
48 "cargo handling and storage"
49 "other supporting transport activities"
50 "travel agencies and tour operators"
51 "other transport agencies"
52 "post and couriers"
53 "real estate: own property"
54 "letting of own property"
55 "real estate agencies"
56 "management of real estate"
57 "rental of cars and other transport"
58 "rental of other machinery n.e.c."
59 "hardware and software consultancy and supply"
60 "other computing and related activities"
61 "research and development"
62 "legal activities"
63 "accounting and tax consultancy"
64 "market research"
65 "business and management consultancy services"
66 "management activities of holding companies"
67 "architecture and engineering"
68 "technical testing and analysis"
69 "advertising"
70 "labour recruitment"
71 "investigation and security activities"
72 "industrial cleaning"
73 "miscellaneous business activities"
74 "other business activity n.e.c."
75 "primary education"
76 "secondary education"
77 "higher education"
78 "adult and other education"
79 "hospitals"
80 "other human health activity"
81 "veterinary activity"
82 "social work with accommodation"
83 "social work without accommodation"
84 "sewage and refuse disposal"
85 "membership organisations n.e.c"
86 "cinema and video"
87 "radio and tv"
88 "other entertainment including news agencies"
89 "libraries and museums"

90 "sports arenas and stadia"
91 "other sporting activities"
92 "other recreational activities"
93 "hairdressing and beauty treatments"
94 "other service activities"