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Abstract

This paper presents difference-in-differences estimates of the impact of the British minimum wage on the wage growth of low-wage employees. Estimates of the probability of low-wage employees receiving positive wage growth have been significantly increased by the minimum wage upratings or hikes. However, whether the actual wage growth of these workers has been significantly raised or not depends crucially on the magnitude of the minimum wage hike considered. Findings are consistent with employers complying with the legally binding minimum wage but holding down or offsetting the wage growth that they might have awarded in periods of relatively low minimum wage hikes.

JEL classification J31, J38

Keywords Minimum wages, wage growth, difference-in-differences estimator, measurement error

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I. Introduction[1]

The introduction of the UK National Minimum Wage (NMW) in April 1999 and its subsequent upratings have provided an undoubted upward shift in the hourly earnings of the lowest paid workers in the UK economy. However it is less clear how this legal wage floor has affected the wage dynamics or wage growth of these low-wage employees. Understanding the wage setting behaviour of low-wage employers in a dynamic context, is important in its own right but will also have a particular policy relevance if the minimum wage regulation is a binding constraint on employers in setting wages for at least some of their employers.

Over the last decade the NMW has become a firmly established part of labour market regulation in the UK with the initial minimum wage rate providing an effective new wage floor for the labour market (LPC (2001), Stewart and Swaffield (2002), Dickens and Manning (2004a, 2004b)). Initial employer compliance has generally being considered high and well over a million adult employees were covered by the legislation (LPC (2010)). Annual NMW upratings or hikes since October 2000 have taken the current NMW adult rate to £6.08 per hour in October 2011.[2] Indeed the hikes have not only protected the real value of the NMW but have also increased the 'bite' (relative value in relation to a particular point in the earnings distribution). For example, the 7th NMW uprating took the adult rate to 51.0 per cent

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[2] See Table 1 for the full set of NMW rates over 1999-2011.

of the median pay, a peak since the NMW introduction when the bite was roughly 46 per cent (LPC (2010)). Although the NMW bite fell back marginally from this peak the recent low growth in median hourly earnings has resulted in the current bite increasing to nearly 52 per cent (LPC (2012)). The importance of the NMW within the UK wage distribution is unquestionable and clearly evidenced by observed changes in the lower end of the hourly pay distribution at the time of the minimum wage hikes. Figure 1 illustrates this point using UK Labour Force Survey (LFS) data taken one month before and after the October minimum wage hikes in 2001, 2004 and 2009. This evidence suggests that low-wage employers are being regulated by the NMW upratings both in terms of timings and amounts of the wage awards.[3] However such observations relate to the *levels* of the wage distribution, telling us relatively little (in a direct sense) about the wage dynamics or growth for low-wage workers.

The contribution of this paper is twofold; firstly to show through the use of difference-in-differences estimation that although the probability of low-wage employees receiving positive wage growth have been significantly increased by minimum wage hikes (resulting in endogenous intertemporal bunching of wage increases), whether the actual wage growth of these workers has been significantly raised or not depends crucially on the magnitude of the minimum wage hike considered. It is argued that these findings are consistent with employers complying with the legally binding minimum wage but holding down or offsetting the wage growth that they might have awarded in periods of relatively low minimum wage upratings. Secondly, to show through an alternative approach to the difference-in-differences estimator that reducing (likely) measurement error on the wage is crucial for identifying the effects of interest. This is done by using an estimator centred on

[3] See Ormerod and Ritchie (2007) for further discussion on the point of NMW upratings and timings of the wage increases.

differencing across additional control groups rather than time, that by construction allows use of the LFS directly collected (since spring 1999) gross hourly wage rate data for hourly paid workers.

The paper is organised as follows: Section 2 presents some theoretical expectations of firm behaviour in the presence of a binding minimum wage. Section 3 describes the baseline difference-in-differences estimation method and the alternative approach (centred on differencing across additional control groups rather than time). Section 4 provides a brief description of the data used, sample definitions and construction of the hourly wage measures. Section 5 presents the main results from the baseline difference-in-differences estimation along with estimates from the alternative estimator. Section 6 presents a summary of the main findings and conclusions.

II. Firm behaviour in the presence of a binding minimum wage

To motivate this paper from a theoretical perspective requires consideration of the individual firm's dynamic wage setting behaviour. For employers the initial question is whether the minimum wage rate binds or not, and the dynamics of the individual firm's response to the (likely) repeated minimum wage hikes. Assuming that the minimum wage binds and the penalties associated with non-compliance represent a reasonable threat, employers will optimise by raising the wages of their minimum wage workers at (or near to) the point of the minimum wage hike. The direct costs associated with wage changes and indirect costs arising from subsequent knock-on price changes (discussed in both the switching cost (Klemperer (1987)) and menu cost (Akerlof and Yellen (1985) literature) point to optimal firm behaviour of reviewing the pay of minimum wage workers at the time of the official hike.

Although the timing point is reasonable clear the question of how much the employer should uprate the minimum wage worker's hourly rate is less so. If a worker's wage (within a perfectly competitive market setting) represents their marginal productivity, a change in the wage between two periods should also represent a change in that worker's productivity. With a binding minimum wage rate and regular hikes to this rate, the wage growth for minimum wage workers will be censored (at least nominally) to be upward. Firms could well be paying employees a level of wage growth that is above their productivity change. To the extent that average productivity changes (although varying over workers) can be considered relatively constant over short periods of time (particularly in typical labour intensive minimum wage occupations such as caring and cleaning) then the optimal strategy for firms will be to pay all minimum wage workers the wage growth defined by the hike rather than by individual productivity changes. A method of offsetting the variation in individual productivity changes in the face of a binding (and at least nominally positive) minimum wage hike.

Such implicit cross-subsidisation of wage growth from those minimum wage employees with higher productivity growth (above the hike) to those with less (or no) productivity growth between periods is inconsistent with the perfectly competitive model. However the presence of significant market rigidities such as costs of job search would allow such cross-subsidisation to arise, as would alternative models of the labour market e.g. monopsony.

In the dynamic setting this point is extended by the uncertainty faced by firms in regards to future minimum wage hikes, and the degree to which this will raise the minimum wage above the average productivity growth in the same period. Here the cross-subsidisation of average productivity growths of minimum wage workers arises

over time, rather than individual workers. Theoretically then both within and across time periods firms will face an optimal strategy for (dynamic) wage bill minimisation of setting the wage growth for minimum wage workers equal to the minimum wage hike (rather than the individual worker's productivity growth). The central research question of this paper then, is the extent to which the empirical evidence is consistent with this prediction?

III. Estimation approach

To estimate the impact of the NMW on the wage growth of low-wage workers a difference-in-differences estimator is used and three measures relating to real wage growth constructed. The first two measures of wage growth relate to the observed change in wages between two consecutive time periods, roughly 12 months apart. The first is defined as the absolute change in wages ($\Delta w_{it} = w_{it+1} - w_{it}$) between periods, where w_i denotes the hourly wage of an employee, i at a particular time period t. The second measure is defined as the percentage or relative change in wages ($\%\Delta w_{it} = [(w_{it+1} - w_{it}) / w_{it}]*100$) over the same two time periods.

Two measures of wage growth are used as "[t]here is some controversy in the literature regarding the proper measure of wage growth" Grossberg and Sicilian (1999, pp.546). With reference to Leighton and Mincer (1981), Grossberg and Sicilian (1999) argue that the problem with percentage wage growth is that the probability of finding a minimum wage effect is increased if the wage growth variable is defined in this way. As a result, the "dollar growth provides a more convincing test of the effect of the minimum wage on wage growth than percentage growth" Leighton and Mincer (1981, pp.164). The third measure of interest is that of the probability of receiving

positive (real) wage growth ($\Pr(\Delta w_{it} > 0)$) between t and t+1, where the variable of interest (W_{it}) is defined as $W_{it} = 1 \; if \; \Delta w_{it} > 0$ zero otherwise.

For each of these three measures, the difference-in-differences estimator is used to assess the impact of the NMW uprating on the wage growth. This is done by comparing the experience of wage growth for those individuals directly affected by the minimum wage with the experience of a similar group who were not affected in this way, before and after the NMW upratings (and introduction). Specifically, the questions to be investigated are what would have been the change in wage growth (absolute or relative), or the probability of positive wage growth between two consecutive periods, for those employees directly affected by the minimum wage if the minimum wage had not been uprated, and are the observed changes in wage growth significantly different from this?

In using the difference-in-differences estimator the treatment and control groups need to be defined, as does the pre minimum wage period. The 'before' period is defined as the period after the abolition of the UK Wages Councils in 1993 and before the NMW introduction in 1999. The affected or treatment group for each pair of time periods (t and t+1) consists of those individuals who were earning at t a wage below the minimum wage that would (legally) be in place by the time period t+1.[4] This identifies employees for whom the wage at time period t would be expected to increase to comply with the minimum rate in effect by t+1. Ideally we would wish to

[4] As the individual is being classified into this treatment group at t for a NMW rate applicable by t+1, it should be considered whether the classifying wage at t should be real or nominal. In this paper the following classification method is used: The real wage for the introduction periods is the nominal wage at time t deflated to April 1999 (when the NMW was introduced). For the lagged period the wage at time period t is the nominal wage rather than a real (deflated) wage. For the uprating periods the base for the real wage is the October of the year of the uprating (when the uprating takes place i.e. the first uprating is October 2000, the second uprating is October 2001 etc). For the pre-period the real wage is defined in relation to whether the introduction (April 1999) or which of the upratings (October 2000, 2001 etc) is being modelled. Although this use of the real wage at t to classify treatment individuals may result in some individuals with a nominal wage at t below the NMW t+1 being defined as the control group, none of those earning the NMW at t are misclassified into the control group.

compare this affected group with "itself" in an alternative state of the world when the minimum wage had not been introduced or uprated. As we obviously can not do this we need to construct a second group of employees who act as the control group. The importance of the control group within this methodology is clear. If this group is not constructed to be similar enough to the low-wage employee group directly affected by the minimum wage introduction, the estimation results will be of limited use.[5] The baseline the control group has been defined as those employees earning (at t) up to 10% above the NMW that is in place by t+1.

Following the exposition in Stewart and Swaffield (2008) and Stewart (2004a, 2004b) the minimum wage can be considered to have a constant effect, θ_1, θ_2, θ_3 on the three measures relating to wage growth between t and t+1, Δw_{it}, $\%\Delta w_{it}$, $\Pr(\Delta w_{it} > 0)$, for those directly affected or treated by the NMW introduction or uprating and no effect on those in the control group. The before and after time periods to consider in each case are the before period where starting at t, there was no minimum wage in place at either t or t+1, and the after period where the minimum wage is introduced or uprated between t and t+1. Differencing across these the two groups and across these two time periods for each of the three wage growth measures gives the difference of interest.

The difference-in-differences estimates can be found by estimating regressions with a pooled sample of individual-level data, and including a set of controls to give the "regression adjusted" difference-in-differences estimate. The inclusion of

[5] The implication of including employees that are non NMW compliant at t in the treatment group is a particular point worth noting in relation to the analysis of the upratings periods in this paper. Whether the affected group should include these non NMW compliant employees is a point for debate, due to the fact that we cannot (for either of datasets) identify why a sub-minimum wage is being paid to an adult worker. Clearly some of those with below NMW rates may well be entirely legitimate (due to training or NMW exemptions applying on the grounds of accommodation offsets) and some may be due to the construction of the implied hourly wage rate leading to an inexactness potentially caused by the mismatch of usual working hours and the weekly wage.

additional pre period time periods can also be easily included along with additional time dummies (aggregate time effects (γ_t)). This is shown in Equations (1), (2) and (3) below where in relation to each equation the dummy variable G_T takes the value 1 for the treatment group (those individuals earning at time period t below the minimum wage introduced by t+1 or uprated by t+1), zero otherwise. The control group is defined as the excluded base category for whom the $NMW_{t+1} \leq w_{it} < NMW_{t+1} * 1.1$ (those earning up to 10% above the national minimum wage rate in place by t+1). The additional G_H term denotes the remaining and higher end of the wage distribution, such that $w_{it} \geq NMW_{t+1} * 1.1$. The dummy variable MW takes the value 1 when the time periods t and t+1 cover the introduction of the national minimum wage or an uprating, zero otherwise. The coefficients of interest are those attached to the interaction term $\mathrm{MW}_t * G_{Ti}$.[6]

$$\Delta w_{it} = \alpha_0 + \alpha_1 G_{Ti} + \alpha_2 G_{Hi} + \alpha_3 \mathrm{MW}_t + \theta_1 (\mathrm{MW}_t * G_{Ti}) + \alpha_4 (\mathrm{MW}_t * G_{Hi}) + x_{it}' \beta + \gamma_t + \varepsilon_{it} \quad (1)$$

$$\%\Delta w_{it} = \lambda_0 + \lambda_1 G_{Ti} + \lambda_2 G_{Hi} + \lambda_3 \mathrm{MW}_t + \theta_2 (\mathrm{MW}_t * G_{Ti}) + \lambda_4 (\mathrm{MW}_t * G_{Hi}) + x_{it}' \beta + \gamma_t + \varepsilon_{it} \quad (2)$$

$$\Pr\left[\Delta w_{it} > 0 \mid G_{Ti},\ G_{Hi},\ \mathrm{MW}_t,\ x_{it}\right]$$

$$= \Phi\left\{\varphi_0 + \varphi_1 G_{Ti} + \varphi_2 G_{Hi} + \varphi_3 \mathrm{MW}_t + \theta_3 (\mathrm{MW}_t * G_{Ti}) + \varphi_4 (\mathrm{MW}_t * G_{Hi}) + x_{it}' \beta\right\} \quad (3)$$

where Φ denotes the standard normal cumulative distribution function which needs to be considered in the context of modelling the regression adjusted probability

[6] A crucial assumption underlying the validity of the difference-in-differences estimator in the present context is that in the absence of a minimum wage the difference in the average wage growth (absolute or percentage) and average probability of receiving positive wage growth between the treatment and control groups would be the same in each time period. This means that the difference between the treatment and control group needs to remain constant in the pre-period. Following Stewart (2004b) this was formally investigated using LFS data sets by focussing on the pre minimum wage period and considering interaction terms between the treatment group and time period controls. Pre-periods for which there was some evidence of a change in the evolution of the wage growth between these groups were excluded from the sample.

of positive wage growth between t and t+1 and where the estimate of interest is the marginal effect based on the coefficient estimate of θ_3.[7]

A crucial underlying assumption of the difference-in-differences estimator is that the control group has not been affected by the "treatment". For the NMW introduction there is little evidence of spillovers (Dickens and Manning (2004a)). Further, Dickens and Manning (2004b) note for care home workers that NMW "compliance is widespread, that there was little anticipation and virtually no spillover effects" (pp.C100). Recent evidence on wage spillovers as a result of the NMW upratings is slightly more mixed with Metcalf (2008), Nanos (2008), LPC (2009, Section 2.45) and Butcher et al (2010) suggesting the possibility of spillovers from more recent NMW upratings. However, Stewart (2011, 2012) details very clearly that the choice of the counterfactual wage distribution is key to whether such spillovers are found to be significant or not.

An alternative approach to the standard difference-in-differences estimation

The baseline difference-in-differences approach is centred on comparing the affected and control group before and after the NMW "treatment". Comparing the pre-period with progressively later NMW upratings seems inherently less appealing as the uprating analysed moves further away from this point. So what can be done? An alternative approach is to compare the treatment and control group (control group 1) across another dimension. This is done by comparing two further control groups constructed from further up the wage distribution. A crucial identifying assumption is that the wage growth trends between the additional control groups (control groups

[7] It should be noted that the marginal effects reported for the probit are the direct effects (as suggested by Puhani (2008)) rather than the marginal effect calculated from two interacted variables (as in Ai & Norton (2003)).

2 and 3) are the same as between the treatment and control group in the absence of the NMW uprating.

Following the application in Stewart (2004a, pp.115) three methods for additional control group construction are undertaken. Firstly, (method 1) the width of the two additional control groups are defined in relation to the original one, such that the three control groups become (NMW - NMW*1.1), (1.1*NMW – 1.2*NMW) and (1.2*NMW – 1.3*NMW). A second method is to construct the additional control groups to be equivalent in sample size to the original control group. The third method is to define the additional control groups such that the medians of the hourly wage distribution (within each of the groups) were of equal distance from each other.[8]

One practical advantage of using this alternative difference-in-differences estimation procedure is that the LFS data on the wage rate of hourly paid workers can be used. This provides the second main contribution of the paper, by allowing an assessment of how important the accurate identification of the 'treatment group' is for the difference-in-differences methodology.

In spring 1999 an additional question asking hourly paid workers about their hourly wage rate was added to the LFS questionnaire. As there is no "pre" NMW period with the hourly paid wage rate data collected on the LFS the standard difference-in-differences methodology can not be applied. However, with the proposed alternative estimation approach this is not a problem as no pre-period is

[8] E.g. In relation to the 7th NMW uprating, the method 1control group boundaries are defined as group 1 from £5.35(inclusive) - (strictly less than) £5.89, group 2 £5.89 (inclusive) - (strictly less than) £6.42 and group 3 £6.42 (inclusive) - (strictly less than) £6.96. For method 2 the three control groups had sample sizes of 1,373 and 2,470 for male and females respectively (and 1,339 and 2,395 for the percentage wage growth samples). For method 3 the differences between the medians were approximately £0.52 and £0.44 for females, with the treatment group median (nominal) wage rate defined as £5.08 and £5.13 for males and females respectively at time period t (where the NMW at t was £5.05 and £5.35 at t+1).

required. Why this is particularly useful in relation to the LFS is that measurement error on the constructed (implied) hourly wage could well obscure any clear findings for the difference-in-differences estimates of the NMW wage growth effects for low-wage workers. This is due to problems with classification in the treatment group and the actual observed wage changes. The alternative estimation approach allows us to use this hourly wage rate data thereby (potentially) reducing the measurement error on the wage variable.[9]

A further sensitivity check on the baseline estimates focuses on equalising the reach of the control group across the wage distribution within the difference-in-differences estimator for each of the individual NMW upratings analysed. The baseline difference-in-differences estimator uses the NMW plus 10% as the control group cut-off. But this means the size of the control group may well vary over time across the NMW upratings considered. Here the control group is defined as those employees earning a real wage at t that is above the NMW that is in place by t+1, up to the 10th percentile of the real wage distribution.[10] This sensitivity check relates to the appropriateness of comparability of the control groups across the seven NMW upratings considered rather than issues of appropriate modelling within a particular uprating.[11]

[9] Although the caveat that the hourly paid workers are unlikely to be a random sample of all employees should be noted.

[10] Alternative specifications of this control group could be defined for example, the NMW plus the next 5 percentiles (rather than up to the 10th percentile as defined here). However the 10th percentile wage point is identified for each of the upratings from the joint male and female wage distribution of the t period of the t and t+1 paired periods used for the wage growth analysis (compared to for example, the full unconstrained ASHE wage distribution). These points were applied then as the upper point to determine the (before and after) control groups using the real wage distributions (in each case with the real wage deflated to the October uprating year of interest). It is clear that even within this approach to the sensitivity check additional and alternative approaches could have been undertaken. For example (a) splitting the real (after) wage distribution by gender and defined in NMW up to 10th percentile points by gender and (b) defining the NMW up to the 10th percentile point for both the before and after wage distributions.

[11] For the approach taken here the NMW uprating control group upper bound comparison points: For the 7th NMW uprating, 10% of £5.89 compared to the 10th percentile of £6.07, for the 6th uprating, 10% of £5.56 compared to the 10th percentile of £5.76, for the 5th uprating £5.34 compared to £5.51, for the

IV. Data

The Annual Survey of Hours and Earnings (ASHE) and the Labour Force Survey (LFS) are the two longitudinal datasets used for the analysis. The ASHE is an employer reported individual-level dataset and the LFS is a household level survey with individual employee questionnaires. Using these two datasets is appealing as both have strengths and weaknesses. For example, although the ASHE has larger sample sizes than the LFS and a greater likelihood of accuracy in reported wage rates (and hours) due to employers reporting this information directly from their payroll the ASHE sampling frame restricts the sample of employees to be earning at or above PAYE deduction threshold. This will reduce coverage of those at the lower end of the earnings distribution.[12]

The LFS has different problems, mainly associated with the accuracy of the reported earnings and the working hour data. Firstly, the LFS has a number of responses provided by proxy rather than by the employee in question thus increasing the possibility of measurement error. Secondly, the survey is answered by the individual employee rather than the employer, and it is generally considered that the degree of measurement error will be greater when an individual employee self-reports his/her earnings rather than an employer (who is likely to be reporting it directly from the pay-roll). On the other hand the LFS does not under sample the low paid and contains a range of detailed questions on the individual and their employment.

4th uprating £4.95 compared to £5.34, the 3rd uprating £4.62 compared to £5.09, the 2nd uprating £4.51 compared to £4.86 and for the 1st uprating £4.07 compared to £4.67.

[12] More recently effects at improving coverage at the lower end of the distribution have been made as the ASHE sampling frame (2004 onwards) have been widen by a supplementary survey of those businesses which are registered for Value Added Tax (VAT) but not registered for PAYE.[12] In addition, follow-up surveys have been introduced for those changing jobs, or new entrants starting jobs, between when the initial PAYE sample is constructed in January and the survey reference period in April. However, the ASHE dataset with these additional supplementary surveys is only available for the last three years of the ASHE data period presented here (2004, 2005 and 2006) and prior to 2004 there was no ASHE survey per se. Instead the available ASHE data for the period 1997-2003 is an edited version of the New Earnings Survey (NES) data.

Sample definitions

For both datasets a sample of adult employees, defined as aged between 22 and 59 (inclusive) for women, and between 22 and 64 (inclusive) for men at time t is used. For wage growth measures to be constructed the datasets need to be used as two-period matched panels with a gap of approximately 12 months between t and t+1. For each of the datasets these two-period matched panels are grouped into four time period samples; the pre-period, the NMW introduction period, the lagged NMW introduction period and the upratings periods.[13]

The annual ASHE data is utilised from April 1997 (first ASHE period after the abolition of the Wages Councils) through to April 2007. Data from the quarterly LFS are used from the first quarter of 1997 (March-May 1997) through to the September of the third quarter of 2006. The LFS can only be used from 1997 quarter 1 onwards, when earnings questions, previously only collected in wave 5 were also added to the wave 1 questionnaire.

Definitions of the hourly wage and measurement error on the wage variable

The minimum wage applies to the hourly wage rate an employee earns. To accurately identify minimum wage workers we require the basic hourly wage rate an individual earns, however not all low-wage workers are hourly paid. The question clearly arises of how to accurately construct the implied hourly wage measure. Indeed this point has

[13] The introduction includes t and t+1 periods which have the time period t strictly before the introduction of the minimum wage at April 1999 and the time period t+1 at or after April 1999. The lagged period is defined as time periods where the t period is at or after NMW introduction but the t+1 period is strictly before the first uprating (on 1st October 2000). The uprating periods are each defined as those t and t+1 time periods which straddle a NMW uprating, so that time period t is strictly before the uprating (each of which are on the 1st of October) and the time period t+1 is at or after the October uprating in question (but before the next). For a summary of the data used throughout this paper please see the Appendix Tables A.1 and A.2 for the ASHE and LFS datasets respectively.

had serious implications for the official assessment of how many people have been affected by the minimum wage introduction (and upratings).[14]

For the ASHE dataset the hourly wage variable is defined as the average gross weekly earnings excluding overtime for the reference period minus any additional premium payments during the pay period for shift work and night or weekend work (not treated as overtime) divided by basic weekly hours of work. A definition that is closer to the LPC recommended hourly wage rate measure that is best compared with the NMW rate. For the LFS the hourly wage is defined as the gross weekly earnings divided by the sum of basic usual hours in a week and the number of paid overtime hours usually worked in a week.

As with all survey data there is the likelihood that the wage variables have a degree of measurement error arising from misreporting by the individual (such as on the LFS) or due to some misalignment between the weekly wage and normal hours used to construct an hourly wage rate. The implications of this measurement error are twofold. Firstly it can affect the classification of individuals into the treatment, control and higher wage groups and secondly, it affects the measurement of the wage growth.

In dealing with this measurement error one approach would be to exclude observations based on the likely degree of measurement error. In terms of the full samples, the regression samples are therefore defined to exclude (real) wage observations at t and t+1 that are less than £0.50 and have a 1% trim (top and bottom) of the wage growth distribution underlying the analysis.[15] Choosing further

[14] See Stuttard and Jenkins (2001) and Skinner et al (2002) for how imputation of the hourly earnings based on a regression model approach has been undertaken by ONS. Manning and Dickens (2004a) for an alternative approach and further discussions on these points and difficulty of using derived rather than actual hourly rates in the LPC reports (particularly LPC (2000)), Metcalf (2002) and Stewart and Swaffield (2002).

[15] Although the sample sizes are the same for the absolute and relative wage growth samples the actual individual employees in the sample may be slightly different. The reason for this is that the 1% trim of the absolute wage growth distribution excludes a slightly different 1% than the 1% trim on the relative wage growth distribution.

observations to exclude based on the likelihood of measurement error is difficult as the measurement error can arise due to measurement of the wage levels at t and/or t+1 and in excluding further observation one has to trade off possible reductions in measurement error against the definite reductions in sample (and cell) sizes.

An alternative approach is to consider estimators which may be more robust to the presence of measurement error, arising either from reporting error and/or potential mismatches of the weekly wage and usual weekly working hours. Examples of such estimators include both the robust and median regression estimators which are less sensitive to outliers (and arguably those with a higher probability of measurement error).[16]

V. Estimation results

In Table 2 the difference-in-differences estimates of the impact of the NMW introduction and upratings on the probability of positive wage growth ($\hat{\theta}_3$) are presented. The ASHE estimates clearly show that the NMW introduction and upratings have significantly increased the probability of the low-wage employees receiving a (real) wage increase, compared to the pre-period. In addition Table 2 also shows two further points of interest; firstly that the picture seems reasonable consistent across both the ASHE male and female sub-samples. Secondly, that the estimate for probability of positive real wage growth for the 3rd NMW uprating is negatively signed for both male and females (although not formally significant). In summary, the difference-in-differences estimates of the impact of the NMW upratings (and introduction) on the probability of positive wage growth for low-wage

[16] The robust regression estimator works by removing outliers from the sample then calculating starting values, Huber iterations then biweights iterations are then undertaken to reach the convergence point. The median estimator is a least absolute residual/deviation estimator such that the sum of the absolute residuals is minimised.

employees suggest a significant and positive impact across the ASHE. For the LFS, shown in the lower part of the table, the estimates tend not to be significant although they were (generally) positively signed.

As discussed previously the possibility of measurement error in the wage levels at t and t+1 is potentially quite high. Therefore using regression techniques that are more robust to potential outliers is appealing.[17] Tables 3 and 4 present the summary estimates for each of the two wage growth measures (absolute and relative) using the robust regression for males and females respectively. Although the results here are less unambiguous than those in Table 2, a number of interesting points do emerge. For example, in Table 4 the female ASHE estimates show a significant and positive impact on wage growth for the 2nd, 4th, 5th and 7th NMW upratings as well as for the NMW introduction.[18] For males (Table 3) similar results are found for the relative wage growth using the ASHE, though the absolute wage growth figures are slightly less significant; only the 4th and 5th of the NMW uprating showing a positive and significant impact. For both the male and female ASHE samples the estimates for the impact of the 3rd NMW uprating are negative, and significantly so for females. This is interesting to note, though maybe not so surprising, as although the 3rd NMW uprating was a 10p nominal uprating the real wage increase was notably less.[19] For the LFS estimates in Tables 3 and 4, for both males and females, the results are mixed, both in terms of sign, significance and magnitude.

To summarise, difference-in-differences estimates of the impact of the minimum wage upratings on relative wage growth using the ASHE, suggest that the

[17] Table A.4 illustrates the sensitivity of 7th NMW uprating estimates to the choice of estimator.

[18] These results are similar to Stewart (2004b) in Table 1 (pp.78), where the raw difference-in-differences estimate (for the NES) for the percentage change in wage growth of the impact of the introduction of the NMW for a (joint) sample of male and female employees is reported as 4.033 (t ratio 4.92) using OLS and with a robust regression estimator of 4.178 (t ratio 10.11).

[19] Approximately 2p if the RPI all-items index is used as a deflator. See Appendix Table A.3 for the real wage rate equivalents of the NMW upratings.

NMW introduction along with the 2nd, 4th, 5th and 7th NMW upratings (nominal NMW increases of £0.40, £0.30, £0.35, £0.40 respectively) have significantly raised the relative wage growth of low-wage workers over that which would have occurred in the absence of a minimum wage. In comparison the 1st and 6th NMW upratings (nominal increases of £0.10 and £0.20 respectively) have a mixed set of estimates – male estimates for both upratings were positively signed but only the 1st uprating was significant for relative wage growth. Female estimates for both the 1st and 6th NMW upratings were insignificant with the relative wage growth being positively signed and the absolute negatively signed. Finally, the 3rd NMW uprating (a nominal increase of £0.10) seemed to have a consistently negative impact on the wage growth (absolute and relative) for both males and females (and significantly so for females). Although the estimated magnitudes of these seven NMW upratings seem generally in line with the nominal magnitudes of the NMW upratings, this is even more strongly the case if consideration is given to the real values of these NMW upratings.

These findings suggest that employers may well be holding down the annual wage growth during smaller minimum wage hikes to compensate for the other large hikes. Even and Macpherson (2004) discuss this in relation to their empirical analysis on the wage growth of minimum wage workers in the US (based on the Current Population Survey (CPS) 1979-2003) arguing that "an increase in the minimum wage may improve wage growth for workers in the year of the hike, but could have a negative effect on subsequent wage growth" such that "employers may eventually shift the cost of this minimum wage hike back to their workers by reducing the rate of wage growth" (pp.15).

Tables 5, 6 and 7 present equivalent estimates to those in Tables 2, 3 and 4 using the alternative estimation approach (based on method 1 of constructing the

additional comparison groups). As detailed above this alternative estimation approach allows the use of the LFS hourly wage rate data for hourly paid workers. Table 5 shows the estimated impacts on the probability of positive wage growth. For male and female low-wage workers (using the ASHE) estimates are positive and significant for all of the seven NMW upratings with the exception of the 3rd uprating. These estimates are generally similar in magnitude to those reported in Table 2 using the baseline difference-in-differences estimation. LFS estimates in Table 5 for the full sample and the hourly paid only sample are all positively signed and significant for the female full LFS sample and both the male and female hourly paid sample. The full LFS male sample estimates are a little mixed in significance though the majority are not formally significant (only the 1st and 7th NMW uprating are significant).

Tables 7 and 8 present the wage growth (absolute and relative) estimates using this alternative estimator for male and female low wage workers respectively over the three samples (ASHE, LFS and LFS hourly paid only). ASHE estimates based on the alternative estimator show the 2nd, 4th, 5th and 7th NMW upratings to have significantly and positively raised wage growth (both absolute and relative) for male and female low-wage workers (and additionally so for the 6th uprating for female low-wage workers). In comparison the 3rd NMW uprating did not raise wage growth in this way, for low-wage males the estimates were insignificant (though positively signed) and for females the estimates were negative and significant for both the absolute and relative wage growths. This alternative estimation method produces estimates (using the ASHE data) which support the (baseline) difference-in-differences estimation results.

For the full LFS male and female samples in Tables 7 and 8 the wage growth estimates tend to be positive and also significant (and relatively large in magnitude for

the low-wage female employees). These estimates are clearly quite distinct from the mixed estimates (in terms of sign and significance) seen in Tables 4 and 5. Possibly more interesting to note are the LFS estimates for the hourly paid employees, particularly for the hourly paid female low-wage workers. In the bottom panel of Table 8 the female LFS hourly paid sample estimates show a significant and positive impact of the 2nd, 5th and 7th NMW upratings on both absolute and relative wage growth of low-wage workers. In addition the estimates for the 1st NMW uprating are negative and insignificant and the 3rd NMW uprating are insignificant. Thus, with this restricted LFS sample of hourly paid workers the estimates show a pattern or profile of wage growth effects for (female) low-wage workers over the first seven NMW upratings - in terms of sign, significance but also very interestingly in terms of magnitude - that are in line with the (full sample) ASHE female estimates.

Table 8 presents a sensitivity check on the (baseline) difference-in-differences estimates of wage growth (using the ASHE) and focuses on equalising the reach of the comparison group for the first seven NMW upratings.[20] The estimates in Table 8 should be compared with those in Tables 2, 3 and 4. These difference-in-differences estimates, across the wage growth (absolute and relative) and probability of positive wage growth are similar to those of the baseline difference-in-differences estimates. For example, the probability of positive wage growth for low-wage workers (male and female) has been significantly and positive increased across the first seven NMW

[20] Further robustness checks included using propensity score matching with the difference-in-differences estimator, wage gap estimation along with a selection of additional robustness checks based on control group constructions (15% rather than 10%), exclusion of proxy respondents on the LFS, alternative choice of wage deflator, actual rather than usual hours on the LFS and restricting the analysis to the job stayers only. The overall point of note was that the (raw) difference-in-differences estimates are remarkably robust. Even so, the sensitivity of the estimated impact of the 3rd NMW uprating on the probability of positive wage growth using the ASHE to whether the wage growth was defined as the real or nominal change should be noted. For the LFS there seemed to be some sensitivity to using actual hours rather than usual hours in the construction of the hourly wage rate. However, proxy exclusions on the LFS do seem to distort some of the measurement of the magnitude of the effects, possible due to sample/cell sizes after exclusions (see Swaffield (2008)).

upratings (compared to the period before the NMW introduction) with the exception of the 3rd NMW uprating (which is sensitive to the choice of nominal or real wage growth). For female low-wage workers Table 8 shows the 2nd, 4th, 5th and 7th NMW upratings to have had a positive and significant impact on both the absolute and relative wage growth and a negative and significant impact of the 3rd NMW uprating (as was also seen in Table 4 for the baseline difference-in-differences estimates). For males the estimates in Table 8, for both the absolute and relative wage growth measures, are again supportive of the (baseline) difference-in-differences findings in Table 3.

VI. Conclusions

This paper contributes to understanding how UK minimum wage and low-wage employers are adjusting their (dynamic) wage setting behaviour under a binding minimum wage. Estimates from the ASHE strongly suggest that the probability of low-wage employees receiving positive wage growth have been significantly increased by the minimum wage upratings or hikes. Further, that when the NMW hikes are larger in real terms (such as the 4th and 5th NMW hikes in October 2003 and 2004 respectively but also the 2nd and 7th NMW hikes in October 2001 and 2006) then the wage growth of low-wage workers is positively and significantly raised above what it would have been in the absence of the NMW hike. However when the increases are relatively small (particularly so with the 3rd NMW uprating in October 2002) the observed wage growth is smaller than it would have been in the absence of the NMW.

In comparison the baseline LFS difference-in-differences estimates provided relatively little in the way of significant impacts of the NMW upratings on wage

growth. However when the alternative estimator was used, allowing use of the LFS hourly wage rates for hourly paid workers a profile of NMW wage growth effects emerged which was consistent with the ASHE. The sensitivity of the LFS results to measurement error highlights the crucial importance of identifying treated individuals accurately.

So what can we conclude about the wage growth or short-run wage dynamics of low-wage workers? The findings are consistent with the minimum wage hikes defining the annual pay review for employees within the lower end of the wage distribution or more formally that the NMW upratings are regulating the annual wage growth afforded to low-wage/minimum wage workers by employers. In periods of larger relative increases, the observed wage growth is higher than it would have been in periods prior to the minimum wage. Conversely, in periods of smaller minimum wage increases, observed wage growth is lower. These results are largely consistent with predicted firm behaviour in the presence of a binding minimum wage. Employers are complying with the legally binding minimum wage but holding down or offsetting the wage growth that they might have awarded in periods of low minimum wage increases, possibly to compensate for future or past minimum wage upratings.

These findings provide some indication as to what the wage setting behaviour of current minimum wage employers might be if the NMW is not uprated annually or if the official uprating does not lead to an effective *real* minimum wage increase. Such considerations are particularly relevant as the strong economy and rising labour market that formed the background to the first decade of the NMW are no longer, and changes in the UK government (from Labour to a Liberal-Conservative coalition) in May 2010 may yet reveal a further shift in the government stance on annual minimum wage hikes.

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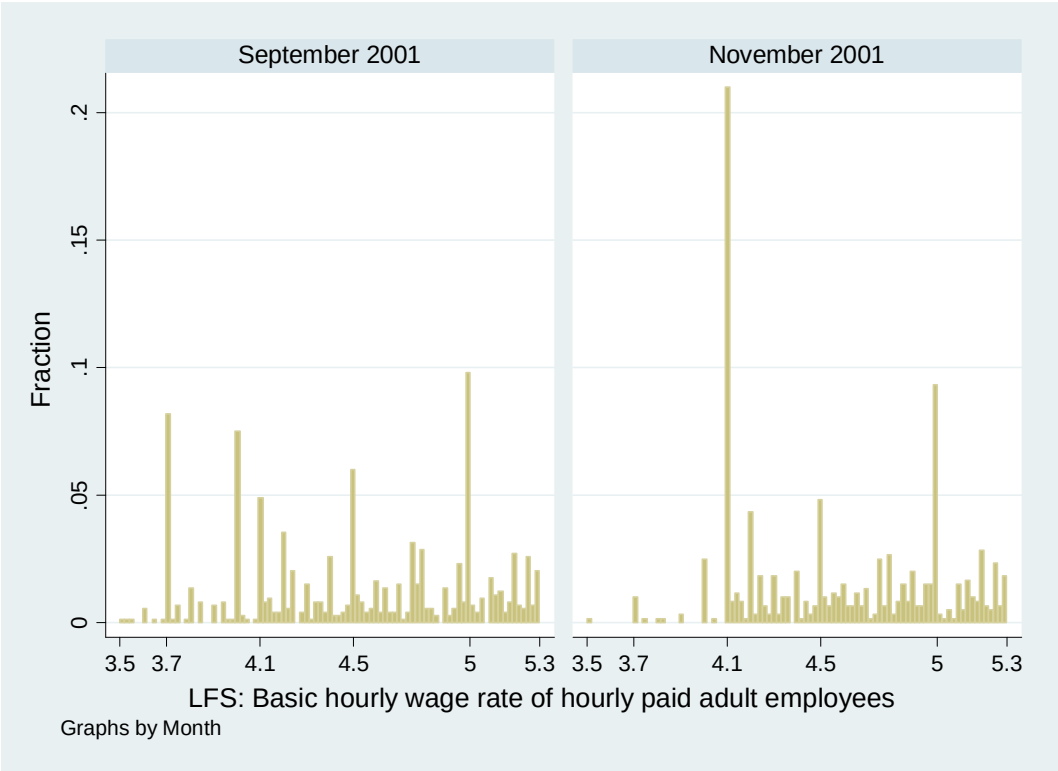
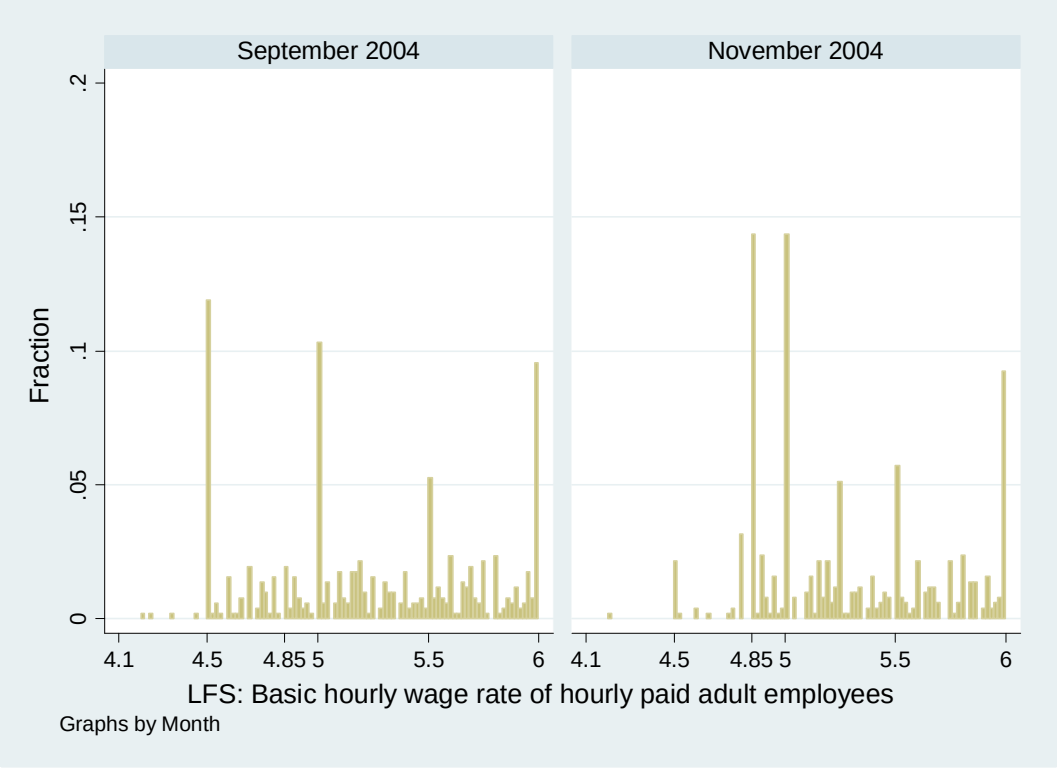
Figure 1. Illustration of the impact of the NMW upratings using the lower end of the wage distribution one month before and after the hike

Impact of the 2nd NMW hike on 1st October 2001 from £3.70 to £4.10



Impact of the 5th NMW hike from £4.50 to £4.85 on 1st October 2004



Impact of the 10th NMW hike from £5.73 to £5.80 on 1st October 2009

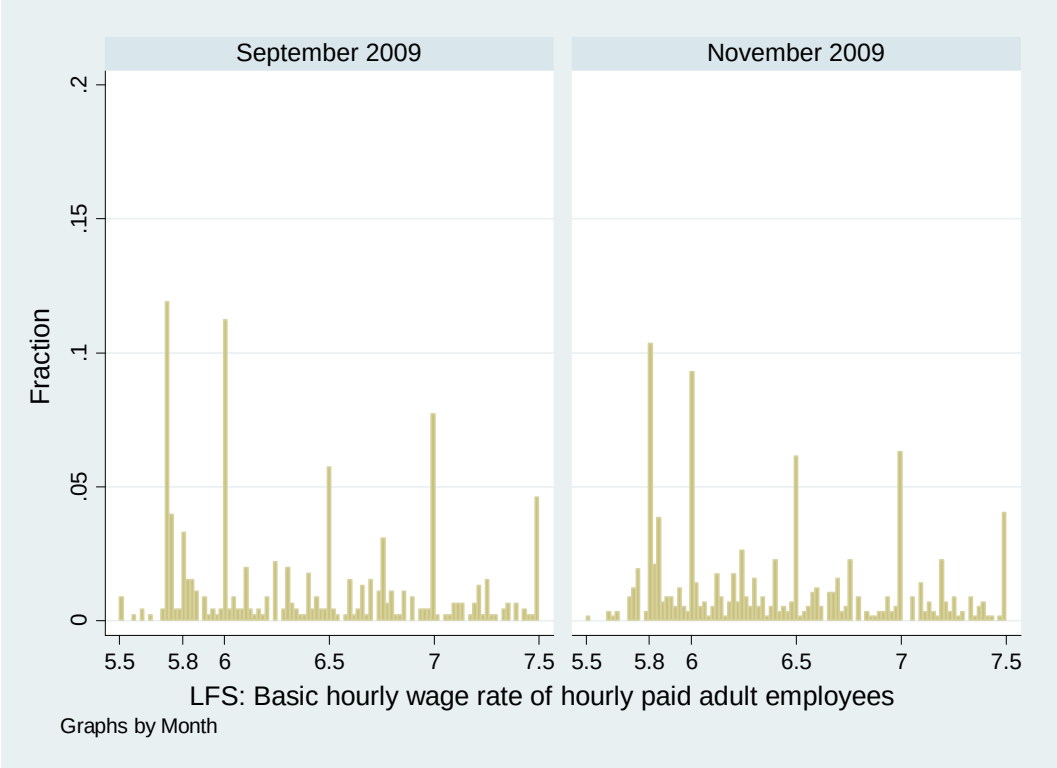


TABLE 1

National Minimum Wage Rates, April 1999-October 2011

		Adult employees (aged 22+)*		Development Rate (for workers aged 18-21)*	16-17 year olds
NMW introduction	1st April 1999	£3.60	1st April 1999	£3.00	
NMW upratings					
1st uprating	Oct 2000	£3.70	1st June 2000	£3.20	
2nd uprating	Oct 2001	£4.10		£3.50	
3rd uprating	Oct 2002	£4.20		£3.60	
4th uprating	Oct 2003	£4.50		£3.80	
5th uprating	Oct 2004	£4.85		£4.10	£3.00
6th uprating	Oct 2005	£5.05		£4.25	£3.00
7th uprating	Oct 2006	£5.35		£4.45	£3.30
8th uprating	Oct 2007	£5.52		£4.60	£3.40
9th uprating	Oct 2008	£5.73		£4.77	£3.53
10th uprating	Oct 2009	£5.80		£4.83	£3.57
11th uprating	Oct 2010	£5.93*		£4.92*	£3.64
12th uprating	Oct 2011	£6.08*		£4.98*	£3.68

Note:
* Since October 2010 the adult rate covers workers aged 21+ and the development rate covers workers aged 18-20.

TABLE 2
Difference-in-difference estimates of the impact of the NMW introduction and upratings on the probability of positive wage growth
(ASHE & LFS)

Difference-in-differences estimates of the probability of positive wage growth ($\hat{\theta}_3$)	*Males*	*Females*
ASHE		
Introduction (NMW £3.60)	0.124 (3.28)	0.117 (5.05)
Lagged (NMW £3.60)	0.280 (6.68)	0.134 (5.11)
1st NMW uprating (increase to £3.70)	0.230 (5.24)	0.144 (4.88)
2nd NMW uprating (increase to £4.10)	0.155 (3.94)	0.195 (8.68)
3rd NMW uprating (increase to £4.20)	-0.074 (1.92)	-0.038 (1.68)
4th NMW uprating (increase to £4.50)	0.219 (6.15)	0.242 (11.03)
5th NMW uprating (increase to £4.85)	0.251 (9.06)	0.227 (12.39)
6th NMW uprating (increase to £5.05)	0.129 (4.53)	0.148 (8.09)
7th NMW uprating (increase to £5.35)	0.280 (10.0)	0.246 (13.06)
LFS		
Introduction (NMW £3.60)	0.168 (2.57)	0.016 (0.43)
Lagged (NMW £3.60)	0.161 (1.87)	-0.041 (0.87)
1st NMW uprating (increase to £3.70)	0.004 (0.05)	0.005 (0.11)
2nd NMW uprating (increase to £4.10)	0.093 (1.37)	0.002 (0.06)
3rd NMW uprating (increase to £4.20)	0.106 (1.50)	0.061 (1.63)
4th NMW uprating (increase to £4.50)	-0.057 (0.78)	0.012 (0.31)
5th NMW uprating (increase to £4.85)	0.006 (0.10)	0.102 (2.91)
6th NMW uprating (increase to £5.05)	0.002 (0.03)	0.075 (2.12)
7th NMW uprating (increase to £5.35)	0.129 (2.20)	0.093 (2.56)

Notes:
1. Figures reported above are marginal effect estimates from a probit equation with a full control vector.
2. Robust t-ratios are reported in the parentheses.

TABLE 3
Difference-in-difference estimates of the impact of the NMW introduction and upratings on absolute and relative wage growth
(Male employees)

MALES: Difference-in-differences estimates of wage growth ($\hat{\theta}_1$, $\hat{\theta}_2$)	*Absolute wage growth* $\hat{\theta}_1$	*Relative wage growth* $\hat{\theta}_2$
ASHE		
Introduction (NMW £3.60)	0.205 (3.25)	5.020 (6.98)
Lagged (NMW £3.60)	0.432 (5.91)	9.345 (10.7)
1st NMW uprating (increase to £3.70)	0.007 (0.10)	2.432 (3.04)
2nd NMW uprating (increase to £4.10)	0.107 (1.89)	3.735 (6.31)
3rd NMW uprating (increase to £4.20)	-0.050 (0.76)	-0.668 (1.00)
4th NMW uprating (increase to £4.50)	0.180 (3.36)	3.867 (7.25)
5th NMW uprating (increase to £4.85)	0.191 (3.80)	3.044 (6.42)
6th NMW uprating (increase to £5.05)	0.003 (0.05)	0.077 (0.17)
7th NMW uprating (increase to £5.35)	0.043 (0.84)	1.666 (3.73)
LFS		
Introduction (NMW £3.60)	0.185 (0.82)	9.798 (3.52)
Lagged (NMW £3.60)	0.172 (0.57)	5.867 (1.60)
1st NMW uprating (increase to £3.70)	-0.044 (0.17)	-3.118 (1.00)
2nd NMW uprating (increase to £4.10)	0.227 (1.00)	3.092 (0.93)
3rd NMW uprating (increase to £4.20)	0.271 (1.11)	3.647 (1.32)
4th NMW uprating (increase to £4.50)	-0.037 (0.15)	-2.608 (0.97)
5th NMW uprating (increase to £4.85)	0.025 (0.11)	0.266 (0.11)
6th NMW uprating (increase to £5.05)	-0.050 (0.21)	-0.914 (0.39)
7th NMW uprating (increase to £5.35)	1.181 (3.35)	3.266 (1.39)

Notes:
1. Figures reported above estimates from a robust regression with a full control vector.
2. Robust t-ratios are reported in the parentheses.

TABLE 4
Difference-in-difference estimates of the impact of the NMW introduction and upratings on absolute and relative wage growth
(Female employees)

FEMALES: Difference-in-differences estimates of wage growth ($\hat{\theta}_1$, $\hat{\theta}_2$)	*Absolute wage growth* $\hat{\theta}_1$	*Relative wage growth* $\hat{\theta}_2$
ASHE		
Introduction (NMW £3.60)	0.128 (4.82)	4.374 (11.46)
Lagged (NMW £3.60)	0.190 (6.29)	3.927 (8.87)
1st NMW uprating (increase to £3.70)	-0.032 (0.10)	0.556 (1.30)
2nd NMW uprating (increase to £4.10)	0.102 (4.12)	3.584 (10.95)
3rd NMW uprating (increase to £4.20)	-0.081 (2.77)	-1.018 (2.69)
4th NMW uprating (increase to £4.50)	0.131 (4.92)	3.462 (10.45)
5th NMW uprating (increase to £4.85)	0.075 (3.10)	2.740 (9.54)
6th NMW uprating (increase to £5.05)	-0.010 (0.41)	0.394 (1.43)
7th NMW uprating (increase to £5.35)	0.066 (2.57)	1.792 (6.34)
LFS		
Introduction (NMW £3.60)	0.051 (0.65)	3.581 (2.72)
Lagged (NMW £3.60)	-0.051 (0.50)	-0.839 (0.49)
1st NMW uprating (increase to £3.70)	0.028 (0.31)	-1.861 (1.23)
2nd NMW uprating (increase to £4.10)	-0.036 (0.92)	-0.345 (0.19)
3rd NMW uprating (increase to £4.20)	0.065 (0.69)	2.424 (1.75)
4th NMW uprating (increase to £4.50)	-0.079 (0.84)	-0.317 (0.24)
5th NMW uprating (increase to £4.85)	0.144 (1.54)	3.826 (2.98)
6th NMW uprating (increase to £5.05)	0.103 (1.02)	2.388 (1.80)
7th NMW uprating (increase to £5.35)	0.335 (2.40)	2.308 (1.72)

Notes:
1. Figures reported above are estimates from a robust regression with a full control vector.
2. Robust t-ratios are reported in the parentheses.

TABLE 5
Alternative estimator (method 1) summary tables
Estimates of the impact of the 1st – 7th NMW upratings on the probability of positive wage growth

Alternative estimator (method 1) for estimating the impact on the probability of positive wage growth ($\hat{\theta}_3$)	*Males*	*Females*
ASHE		
1st NMW uprating (increase to £3.70)	0.129 (4.68)	0.133 (7.99)
2nd NMW uprating (increase to £4.10)	0.115 (5.22)	0.134 (10.68)
3rd NMW uprating (increase to £4.20)	-0.021 (0.64)	-0.007 (0.35)
4th NMW uprating (increase to £4.50)	0.193 (8.11)	0.221 (12.67)
5th NMW uprating (increase to £4.85)	0.221 (11.16)	0.231 (17.07)
6th NMW uprating (increase to £5.05)	0.037 (3.19)	0.147 (6.97)
7th NMW uprating (increase to £5.35)	0.268 (10.46)	0.282 (15.56)
LFS		
1st NMW uprating (increase to £3.70)	0.128 (2.19)	0.092 (2.43)
2nd NMW uprating (increase to £4.10)	0.102 (1.98)	0.089 (2.46)
3rd NMW uprating (increase to £4.20)	0.117 (1.81)	0.149 (3.72)
4th NMW uprating (increase to £4.50)	0.061 (0.96)	0.083 (2.05)
5th NMW uprating (increase to £4.85)	0.100 (1.76)	0.170 (4.34)
6th NMW uprating (increase to £5.05)	0.092 (1.53)	0.177 (4.23)
7th NMW uprating (increase to £5.35)	0.209 (3.44)	0.187 (4.32)
LFS – Hourly paid only		
1st NMW uprating (increase to £3.70)	0.052 (1.75)	0.151 (4.93)
2nd NMW uprating (increase to £4.10)	0.125 (2.43)	0.220 (6.96)
3rd NMW uprating (increase to £4.20)	0.227 (3.64)	0.145 (3.93)
4th NMW uprating (increase to £4.50)	0.155 (1.85)	0.141 (3.63)
5th NMW uprating (increase to £4.85)	0.143 (2.83)	0.209 (6.11)
6th NMW uprating (increase to £5.05)	0.195 (3.57)	0.145 (4.13)
7th NMW uprating (increase to £5.35)	0.149 (2.58)	0.176 (4.83)

Notes:
1. Figures reported above are marginal effect estimates from a probit equation with a full control vector.
2. Robust t-ratios are reported in the parentheses.

TABLE 6
Alternative estimator (method 1) summary tables
Estimates of the impact of the 1st – 7th NMW upratings on male wage growth

Alternative estimator (method 1) for estimating the impact on the wage growth $(\hat{\theta}_1, \hat{\theta}_2)$	*Absolute wage growth* $\hat{\theta}_1$	*Relative wage growth* $\hat{\theta}_2$
ASHE		
1st NMW uprating (increase to £3.70)	0.035 (1.00)	0.726 (0.93)
2nd NMW uprating (increase to £4.10)	0.123 (4.16)	3.143 (5.08)
3rd NMW uprating (increase to £4.20)	0.014 (0.39)	0.011 (0.02)
4th NMW uprating (increase to £4.50)	0.193 (5.90)	4.093 (6.58)
5th NMW uprating (increase to £4.85)	0.222 (7.97)	4.129 (8.48)
6th NMW uprating (increase to £5.05)	0.032 (1.25)	0.517 (1.18)
7th NMW uprating (increase to £5.35)	0.125 (4.78)	2.313 (5.56)
LFS		
1st NMW uprating (increase to £3.70)	0.141 (0.86)	-0.251 (0.07)
2nd NMW uprating (increase to £4.10)	0.483 (2.92)	12.589 (3.53)
3rd NMW uprating (increase to £4.20)	0.372 (2.03)	7.440 (1.96)
4th NMW uprating (increase to £4.50)	0.200 (1.15)	3.930 (1.12)
5th NMW uprating (increase to £4.85)	0.260 (1.50)	6.101 (1.84)
6th NMW uprating (increase to £5.05)	0.263 (1.39)	5.941 (1.69)
7th NMW uprating (increase to £5.35)	0.393 (1.94)	7.319 (2.15)
LFS – Hourly paid only		
1st NMW uprating (increase to £3.70)	-0.107 (0.98)	-2.448 (0.92)
2nd NMW uprating (increase to £4.10)	0.080 (1.03)	2.404 (1.42)
3rd NMW uprating (increase to £4.20)	0.100 (1.13)	1.943 (1.01)
4th NMW uprating (increase to £4.50)	0.099 (1.03)	2.372 (1.28)
5th NMW uprating (increase to £4.85)	0.040 (0.50)	1.035 (0.69)
6th NMW uprating (increase to £5.05)	0.124 (1.48)	2.498 (1.68)
7th NMW uprating (increase to £5.35)	0.035 (0.34)	0.782 (0.44)

Notes:
1. Figures reported above are robust regression estimates with a full control vector.
2. Robust t-ratios are reported in the parentheses.

TABLE 7
Alternative estimator (method 1) summary tables
Estimates of the impact of the 1st – 7th NMW upratings on female wage growth

Alternative estimator (method 1) for estimating the impact on the wage growth $(\hat{\theta}_1, \hat{\theta}_2)$	*Absolute wage growth* $\hat{\theta}_1$	*Relative wage growth* $\hat{\theta}_2$
ASHE		
1st NMW uprating (increase to £3.70)	0.048 (3.23)	0.856 (2.48)
2nd NMW uprating (increase to £4.10)	0.185 (13.77)	4.475 (15.39)
3rd NMW uprating (increase to £4.20)	-0.047 (2.45)	-1.251 (3.17)
4th NMW uprating (increase to £4.50)	0.165 (8.73)	5.674 (8.70)
5th NMW uprating (increase to £4.85)	0.180 (11.31)	3.625 (12.61)
6th NMW uprating (increase to £5.05)	0.047 (3.23)	0.807 (3.16)
7th NMW uprating (increase to £5.35)	0.158 (10.90)	2.766 (11.62)
LFS		
1st NMW uprating (increase to £3.70)	0.271 (3.41)	7.229 (3.67)
2nd NMW uprating (increase to £4.10)	0.302 (3.72)	8.190 (4.30)
3rd NMW uprating (increase to £4.20)	0.264 (2.97)	7.314 (3.68)
4th NMW uprating (increase to £4.50)	0.115 (1.32)	3.998 (2.19)
5th NMW uprating (increase to £4.85)	0.381 (4.26)	8.843 (4.99)
6th NMW uprating (increase to £5.05)	0.403 (4.04)	9.096 (4.74)
7th NMW uprating (increase to £5.35)	0.368 (3.58)	6.956 (3.88)
LFS – Hourly paid only		
1st NMW uprating (increase to £3.70)	-0.000 (0.01)	-0.054 (0.07)
2nd NMW uprating (increase to £4.10)	0.220 (7.77)	5.623 (8.65)
3rd NMW uprating (increase to £4.20)	0.017 (0.55)	0.151 (0.22)
4th NMW uprating (increase to £4.50)	0.067 (1.93)	1.680 (2.39)
5th NMW uprating (increase to £4.85)	0.175 (5.49)	3.987 (6.41)
6th NMW uprating (increase to £5.05)	0.062 (1.68)	1.230 (1.83)
7th NMW uprating (increase to £5.35)	0.156 (3.60)	2.768 (3.65)

Notes:
1. Figures reported above are robust regression estimates with a full control vector.
2. Robust t-ratios are reported in the parentheses.

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TABLE 8
Additional sensitivity check on the difference-in-differences estimates of absolute and relative wage growth: Equalising the reach of the comparison group
(ASHE)

Difference-in-differences estimates of wage growth ($\hat{\theta}_1$, $\hat{\theta}_2$) and the probability of positive wage growth ($\hat{\theta}_3$)	*Absolute wage growth* $\hat{\theta}_1$	*Relative wage growth* $\hat{\theta}_2$	*Probability of positive wage growth* $\hat{\theta}_3$
MALES			
1st NMW uprating (increase to £3.70)	-0.016 (0.26)	1.334 (1.99)	0.167 (3.94)
2nd NMW uprating (increase to £4.10)	0.107 (2.20)	3.734 (7.34)	0.167 (4.84)
3rd NMW uprating (increase to £4.20)	-0.006 (0.10)	-0.550 (0.94)	-0.088 (2.63)
4th NMW uprating (increase to £4.50)	0.233 (5.06)	4.522 (9.83)	0.243 (7.76)
5th NMW uprating (increase to £4.85)	0.185 (3.97)	3.184 (7.24)	0.252 (9.60)
6th NMW uprating (increase to £5.05)	0.004 (0.08)	0.376 (0.93)	0.145 (5.50)
7th NMW uprating (increase to £5.35)	0.050 (1.06)	1.880 (4.47)	0.288 (10.97)
FEMALES			
1st NMW uprating (increase to £3.70)	-0.021 (0.80)	0.675 (1.85)	0.142 (5.30)
2nd NMW uprating (increase to £4.10)	0.136 (6.34)	4.395 (15.46)	0.214 (10.74)
3rd NMW uprating (increase to £4.20)	-0.067 (2.63)	-0.690 (2.07)	-0.059 (2.98)
4th NMW uprating (increase to £4.50)	0.173 (7.48)	4.386 (15.17)	0.276 (14.35)
5th NMW uprating (increase to £4.85)	0.075 (3.39)	2.864 (10.86)	0.223 (13.69)
6th NMW uprating (increase to £5.05)	-0.006 (0.26)	0.532 (2.12)	0.162 (9.50)
7th NMW uprating (increase to £5.35)	0.083 (3.48)	2.089 (7.90)	0.273 (15.70)

Notes:
1. Figures reported in columns 1 and 2 above are estimates from a robust regression with a full control vector, column 3 includes marginal effect estimates from a probit equation with a full control vector.
2. Robust t-ratios are reported in the parentheses.

Appendix Tables

TABLE A.1

Data used from the Annual Survey of Hours and Earnings (ASHE)

ASHE	*t*	*NMW rate at time period t*	*NMW rate at time period t+1*	*t+1*
Pre NMW introduction	April 97	No NMW	No NMW	April 98
Introduction of NMW	April 98	No NMW	£3.60	April 99
Lagged introduction of NMW	April 99	£3.60	£3.60	April 00
1st uprating October 2000	April 00	£3.60	£3.70	April 01
2nd uprating October 2001	April 01	£3.70	£4.10	April 02
3rd uprating October 2002	April 02	£4.10	£4.20	April 03
4th uprating October 2003	April 03	£4.20	£4.50	April 04
5th uprating October 2004	April 04*	£4.50	£4.85	April 05*
6th uprating October 2005	April 05*	£4.85	£5.05	April 06*
7th uprating October 2006	April 06†	£5.05	£5.35	April 07†

Notes:
* denotes 2004-2006 ASHE including supplementary information
†denotes 2006-2007 ASHE using 2007 methodology

TABLE A.2

Data used from the Labour Force Survey (LFS)

LFS	*t*	*NMW rate at time period t*	*NMW rate at time period t+1*	*t+1*
Pre NMW introduction	Mar-May 97	No NMW	No NMW	Mar-May 98
Pre NMW introduction	Jun-Aug 97	No NMW	No NMW	Jun-Aug 98
Pre NMW introduction	Sep-Nov 97	No NMW	No NMW	Sep-Nov 98
Pre NMW introduction	Dec 97-Feb 98	No NMW	No NMW	Dec 98-Feb 99
Pre NMW introduction	Mar-May 98	No NMW	No NMW	Mar 99*
Initial effect of NMW introduction	Mar-May 98	No NMW	£3.60	April-May 99*
Initial effect of NMW introduction	Jun-Aug 98	No NMW	£3.60	Jun-Aug 99
Initial effect of NMW introduction	Sep-Nov 98	No NMW	£3.60	Sep-Nov 99
Initial effect of NMW introduction	Dec 98-Feb 99	No NMW	£3.60	Dec 99-Feb 00
Initial effect of NMW introduction	Mar 99*	No NMW	£3.60	Mar-May 00
Lagged effect of NMW introduction	April-May 99*	£3.60	£3.60	Mar-May 00
Lagged effect of NMW introduction	Jun-Aug 99	£3.60	£3.60	Jun-Aug 00
Lagged effect of NMW introduction	Sep-Nov 99	£3.60	£3.60	Sep 00*
1st uprating October 2000	Oct-Nov 99	£3.60	£3.70	Oct - Nov 00*
1st uprating October 2000	Dec 99-Feb 00	£3.60	£3.70	Dec 00-Feb 01
1st uprating October 2000	Mar-May 00	£3.60	£3.70	Mar-May 01
1st uprating October 2000	Jun-Aug 00	£3.60	£3.70	Jun-Aug 01
1st uprating October 2000	Sep 00*	£3.60	£3.70	Sep 01*
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
7th uprating October 2006	Oct - Dec 05	£5.05	£5.35	Oct - Dec 06
7th uprating October 2006	Jan – Mar 06	£5.05	£5.35	Jan – Mar 07
7th uprating October 2006	April – June 06	£5.05	£5.35	Mar-May 07
7th uprating October 2006	July – Sep 06	£5.05	£5.35	July – Sep 07

TABLE A.3

Real wage rate equivalents of the National Minimum Wage Adult Rates

	NMW wage expressed as <u>nominal</u> wage in:		*NMW wage prior to uprating expressed as <u>real</u> wage in:*		*RPI all-items index*
					April 1999 165.2
NMW introduction	1st April 1999	£3.60	October 2000	£3.74	October 2000 171.6
1st uprating	1st October 2000	£3.70	October 2001	£3.76	October 2001 174.3
2nd uprating	1st October 2001	£4.10	October 2002	£4.18	October 2002 177.9
3rd uprating	1st October 2002	£4.20	October 2003	£4.31	October 2003 182.6
4th uprating	1st October 2003	£4.50	October 2004	£4.65	October 2004 188.6
5th uprating	1st October 2004	£4.85	October 2005	£4.97	October 2005 193.3
6th uprating	1st October 2005	£5.05	October 2006	£5.24	October 2006 200.4
7th uprating	1st October 2006	£5.35			
	NOMINAL wage uprating of NMW		REAL wage uprating of NMW		
1st uprating	10p	2.8%	-4p		
2nd uprating	40p	10.8%	34p		
3rd uprating	10p	2.4%	2p		
4th uprating	30p	7.1%	19p		
5th uprating	35p	7.8%	20p		
6th uprating	20p	4.1%	8p		
7th uprating	30p	5.9%	11p		

Note
1. The base period for real wage calculations is October of NMW uprating in question

TABLE A.4
Illustration of the sensitivity of the difference-in-differences estimates of the impact of the NMW on wage growth (ASHE: 7th NMW uprating)

		Male			*Female*		
7th NMW uprating October 2006 (increase of 30p to £5.35)		Absolute change in real wage between t and t+1	Percentage change in real wage between t and t+1	Change in probability of positive real wage growth between t and t+1	Absolute change in real wage between t and t+1	Percentage change in real wage between t and t+1	Change in probability of positive real wage growth between t and t+1
Pre and post							
Raw	OLS	-0.068 (0.81)	-1.322 (1.32)	0.220 (9.57)	0.052 (1.24)	-0.450 (0.70)	0.213 (13.04)
	Robust	0.053 (1.05)	1.769 (4.01)	-	0.082 (3.19)	1.996 (7.07)	-
	Median	-0.056 (1.64)	-1.390 (3.95)	-	0.036 (1.99)	0.521 (2.07)	-
	Probit	-	-	0.276 (10.07)	-	-	0.254 (13.77)
		96,710	96,710	96,710	85,303	85,303	85,303
With control vector	OLS	-0.065 (0.77)	-1.364 (1.39)	0.216 (9.49)	0.015 (0.36)	-0.796 (1.25)	0.200 (12.26)
	Robust	0.043 (0.84)	1.666 (3.73)	-	0.066 (2.57)	1.792 (6.34)	-
	Median	-0.002 (0.05)	-0.131 (0.44)	-	0.074 (4.11)	1.077 (5.66)	-
	Probit	-	-	0.280 (10.00)	-	-	0.246 (13.06)
		96,358	96,363	96,358	85,019	85,018	85,019
Control group constructions:							
Method 1							
Raw	OLS	0.105 (1.36)	1.850 (2.09)	0.239 (9.80)	0.267 (6.14)	3.787 (6.55)	0.279 (15.51)
	Robust	0.117 (4.54)	2.178 (5.41)	-	0.165 (11.15)	2.867 (11.97)	-
	Median	0.037 (1.20)	0.351 (0.75)	-	0.078 (3.85)	1.390 (5.83)	-
	Probit	-	-	0.261 (10.30)	-	-	0.284 (15.80)
		5,963	5,844	5,963	11,333	11,162	11,333
With control vector	OLS	0.099 (1.31)	1.896 (2.22)	0.238 (9.91)	0.226 (5.35)	3.384 (6.01)	0.272 (15.28)
	Robust	0.125 (4.78)	2.313 (5.56)	-	0.158 (10.90)	2.766 (11.62)	-
	Median	0.094 (4.56)	1.913 (6.76)	-	0.126 (11.65)	2.316 (13.05)	-
	Probit	-	-	0.268 (10.46)	-	-	0.282 (15.56)
		5,963	5,844	5,963	11,333	11,162	11,333

Notes:

1. The difference-in-differences estimate of θ_3 is presented for both OLS (linear probability model) and the probit model (marginal effects).

2. Robust t-ratios are reported in the parentheses.

TABLE A.4 (contd.)
(ASHE: 7th NMW uprating)

		Male			*Female*		
Method 2							
Raw	OLS	0.183 (1.70)	3.445 (3.76)	0.242 (9.35)	0.300 (5.54)	4.273 (7.59)	0.287 (16.52)
	Robust	0.123 (3.25)	2.495 (5.98)	-	0.169 (9.26)	2.793 (11.79)	-
	Median	0.065 (2.21)	1.161 (2.96)	-	0.078 (3.35)	1.487 (7.86)	-
	Probit	-	-	0.267 (9.90)	-	-	0.294 (16.66)
		5,215	5,064	5,215	11,989	11,803	11,989
With control vector	OLS	0.175 (1.64)	3.253 (3.62)	0.235 (9.16)	0.282 (5.25)	4.067 (7.38)	0.287 (16.62)
	Robust	0.114 (2.92)	2.564 (6.09)	-	0.165 (8.90)	2.775 (12.03)	-
	Median	0.094 (3.39)	2.131 (8.09)	-	0.113 (9.41)	2.460 (13.53)	-
	Probit	-	-	0.269 (9.80)	-	-	0.297 (16.73)
		5,215	5,064	5,215	11,989	11,803	11,989
Method 3							
Raw	OLS	0.112 (1.46)	1.950 (2.20)	0.240 (9.87)	0.263 (5.89)	4.082 (6.70)	0.282 (14.69)
	Robust	0.115 (4.47)	2.151 (5.35)	-	0.148 (10.02)	2.662 (10.84)	-
	Median	0.037 (1.20)	0.351 (0.74)	-	0.078 (3.74)	1.346 (5.60)	-
	Probit	-	-	0.262 (10.36)	-	-	0.286 (15.08)
		5,988	5,869	5,988	9,951	9,796	9,951
With control vector	OLS	0.105 (1.41)	1.992 (2.34)	0.240 (9.98)	0.218 (5.02)	3.604 (6.08)	0.272 (14.35)
	Robust	0.122 (4.66)	2.272 (5.47)	-	0.140 (9.60)	2.558 (10.52)	-
	Median	0.094 (4.46)	1.886 (6.25)	-	0.126 (10.11)	2.327 (11.16)	-
	Probit	-	-	0.269 (10.51)	-	-	0.282 (14.73)
		5,988	5,869	5,988	9,951	9,796	9,951

Notes:

1. The difference-in-differences estimate of θ_3 is presented for both OLS (linear probability model) and the probit model (marginal effects).

2. Robust t-ratios are reported in the parentheses.