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Empirical studies on the topic of the national minimum wage (NMW) and its effects on employment are not rare nor consensual. Recent empirical studies in the U.K. have pointed to positive or neutral effects (Dolton *at al.* 2012). This paper revisits the topic and employs quarterly data from 1999 to 2015 to estimate the impact of an increase in the NMW on employment in the U.K. economy. We begin our theoretical construct from a paper from Ragacs (2007) and proceeded to estimate the long run solution using the VAR methodology. We find that the NMW does create a negative shock in the labour market and we present an estimation of the magnitude of the shock and the time period it takes to reach a new equilibrium.

1.   The Introduction

The effects of minimum wage laws are one of the most debated issues in labour economics. In the U.K., this topic has been particularly important since the introduction in April, 2016 of the National Living Wage (NLW hereafter), which replaces the previous, on-going minimum wage. Aiming to achieve a higher-wage lower-welfare economy, the NLW was set at £7.25 for all those that are over 25 years old[1]. This wage increase is unprecedented as it is the highest increase in a minimum wage among the G7 countries since 2009 and it corresponds approximately to a £900 increase for a full-time worker (HM Treasury, 2016).

The question arises who pays the cost for the higher wages? The classical theory of unemployment defends that a type of price floor like the National Minimum Wage (NMW) will create a surplus of demand of labour. In this light, the Office of Budget Responsibility has predicted a loss of 60,000 jobs by 2020 as a consequence of the NLW. Although this topic has been greatly-researched the findings of empirical evidence are far from being consensual. Therefore, the objective of this paper is to carry out an econometric estimation of a mathematical construct that flows from theory to derive an empirical model from U.K. data that allows the evaluation of the underlying theoretical model. It employs economic theory to claim that there are motives to expect that the legal requirement of minimum wages will have a negative impact on the number of workers employed.

In fact, policy makers should consider the end-results of this study because it does seem to support the Classical theoretical contention that any increase in the NMW will create a negative shock in the labour market before it returns back to a new equilibrium in the long run. The analysis estimates the magnitude of this shock and a time frame for the system to get

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[1] There are calls for the companies to go beyond this threshold and adopt the living wage established by the living wage foundation. This is meant to reflect the cost of living in a certain geographical area and thus it is set according to the differences in the cost of living.

back to par. The plan is to borrow the theoretical model suggested by Ragacs (2007) in the midst of short and long run dynamics. Like the paper by Dolton *at al.* (2012), the focus is on the long run solution. Before examining the theoretical construct, it is necessary to review the current state of the literature.

2. Review of the current literature

Ragacs (2007) found that in Austria, the minimum wage increases had positive effects on employment contrary to "text book analysis". This author is not alone in this finding, Stewart, (2002, 2004 a, 2004 b) found that employment in the U.K. had not been adversely affected with the introduction of the NMW nor with the rise in 2000 and again in 2001. Dolton *et al.* (2012) looked at the effects of national minimum wage (NMW) on employment and inequality in the U.K. since 1999. They found neutral effects for most of the time, with a small positive effect towards the end of the sample. De Linde Leonard *et al.* (2014) carried out a meta-analysis on all the empirical studies on the impact of the raise of NMW on U.K. employment. Looking at sixteen studies they found no evidence of a negative employment effect overall.

Nevertheless, Newmark *et al.* (2014) argue that the negative effects of the NMW are seen mainly when there is a distinction made between low and high skill employees. The NMW does negatively affect low skill employment. This was corroborated by Laporšek (2013) where the author focused on youth unemployment in the European Union and found a significant negative effect with the NMW.

In a seminal work trying to explain the sparing outcomes of the NMW on employment, Hirsch, Kaufman, and Zelenska (2015), distinguish three theoretical frameworks to examine the consequences of the minimum wage on costs. According to the authors these effects will vary depending on whether the market is considered competitive, frictional (a monopsony) or institutional. Furthermore, the authors point out that these theoretical frameworks allow for different types of adjustments as a response to an increase in NMW. Whereas the competitive

model points to a decrease on employment, if the labour market is a monopsony, employers will be working with some vacancies (due to the mismatch of demand and supply) and an increase in NMW might actually lead to an increase in the willingness to work, leading to a rise in employment instead. Finally, if the institutional model is considered, an increase in the NMW will prompt managers to implement strategies to increase productivity and efficiency which in the long run may neutralise the increase costs created by the NMW.

Moreover, Schmitt (2013) discusses how companies do react differently to the NMW by putting in place different arrangements which have been shown empirically: reducing the number of hours paid at minimum wages within contracts (Bryan *et al.* (2013), Dickens *et al.* (2009), Swaffield and Stewart (2008)), passing the higher costs onto the consumers in the form of greater prices (Lemos , 2006), compressing the internal pay distribution by awarding lower pay rises to high skill employees (Dube *et al.* 2007) and accepting lower profits (Draca *et al.* 2011).

Nonetheless, Newmark and Washer (2006) point out that "most of the existing research on the U.K. has been limited to estimating short run effects, and in our view, the question of the longer run influences of the NMW on U.K. employment has yet to be adequately addressed." To address this issue, the analysis considers adopting a theoretical model based on the Constant Elasticity of Substitution (CSE)-production function, as suggested by Ragacs (2007), which acts as a surrogate format for the possible long run end results, adding to the short run dynamics in an error correction model.

3.   The Theory and the Mathematical Configuration

Following the mathematical deviation from Chiang (1984) of the CSE-production function, which is of the following format:

$$Y_t = A_t(\delta L_t^{-\mu} + (1 - \delta)K_t^{-\mu})^{-1/\mu}, \tag{1}$$

$$(A > 0; 0 < \delta < 1; \mu > -1),$$

where L_t and K_t denote two inputs, labour and capital, of the production process with A_t, δ (lower-case Greek letter delta) and μ (lower-case Greek letter Mu) are three parameters. The A_t (the efficiency) serves as an indicator of the state of technology. The δ (the distribution), the μ, (the substitution) denotes the relative share in the production of a good or service and determines the value of the (constant) elasticity.

The study by Ragacs (2007) suggests that by assuming firms maximise profits, given the CES-production function, then it is possible to derive the expression for the marginal product of labour by differentiating expression [1] w.r.t L_t. Using the notation [......] as a shorthand for $\left(\delta L_t^{-\mu} + (1-\delta)K_t^{-\mu}\right)$, then

$$Y_L \equiv \frac{\partial Y_t}{\partial L_t} = A\left(-\frac{1}{\mu}\right)[\ldots\ldots\ldots]^{-(1/\mu)-1}\delta(-\mu)L_t^{-\mu-1},$$

$$= \delta A[\ldots\ldots]^{-(1+\mu)/\mu}L_t^{-(1+\mu)},$$

$$= \delta \frac{A^{1+\mu}}{A^\mu}[\ldots\ldots]^{-(1+\mu)/\mu}L_t^{-(1+\mu)},$$

using [1] with [.....], then the following is derived:

$$= \frac{\delta}{A^\mu}\left[\frac{Y_t}{L_t}\right]^{(1+\mu)} > 0. \tag{2}$$

According to the study, in the short run the capital stock as well as the costs are assumed to be exogenous and the price of goods along with the nominal, minimum wage are given, and therefore, firms maximise profits by setting employment, the optimal demand factor function, that is expression [2], equal to the 'real', minimum wage, M_t, in the form of

$$\frac{\delta}{A^\mu}\left[\frac{Y_t}{L_t}\right]^{(1+\mu)} = M_t. \tag{3}$$

Taking logarithms of [3] gives

$$\ln\delta - \mu\ln A_t + (1+\mu)(\ln Y_t - \ln L_t) = \ln M_t. \tag{4}$$

Now solving for $\ln L_t$ gives

$$\ln L_t = \sigma\ln\delta - \sigma\mu\ln A_t + \ln Y_t - \sigma\ln M_t, \qquad [5]$$

where the Greek-letter sigma, $\sigma = 1/(1 + \mu)$ in this format of [5]. Denoting the OLS-coefficients by β_i, $\sigma\ln\delta$ by constant, 'con', $-\sigma\mu\ln A_t$ as a 'trend' variable, and including ε_t, the residuals that take account of the deviations from the correct functional form and any omitted variables, then the study obtains:

$$\ln L_t = con - \beta_1 trend + \beta_2 \ln Y_t - \beta_3 \ln M_t + \varepsilon_t, \qquad [6]$$

whereby the expression suggests that the signs on the $con > 0$, $\beta_1 < 0$, $\beta_2 = 1$ with $\beta_3 < 0$. Clearly, the mathematical restriction of unity on β_2 should be imposed during the estimation and empirically tested for its statistical significant in order to avoid misspecification of the empirical model and auto-correlation problems. This is one of the tasks in the next section of the paper.

4.   The calculation of the empirical model

The next step is the estimation using a quarterly data set. The minimum wage rates, that prevail in the U.K. economy since 1999 has been formed, deflated by the implicit GDP deflator, (P_t) to convert them to real values, (M_t). In the case of employment, (E_t), this is measured by way of utilising a seasonally adjusted index of employment for the whole economy. With regard to output, the real figures of seasonally adjusted GDP at constant prices, (Y_t), using the chain link method of conversion, are adopted. All the variables are transformed into logarithm measures within the econometric software, *Microfit*. The Augmented Dickey-Fuller tests performed manually, so that the statistics were free of auto-correlation, resulting in white-noise disturbances. They revealed that the data sets were stationary processes on first-difference, although in the case of the real values of the minimum wage, the higher- order auto-correction

causing overfitting of the auto-regressive model had to be removed. The raw observations come from the data bases of the *Office of National Statistics* and *DataStream*.

Moreover, in order to impose the unitary restriction on output in equation [6], the non-linear regression technique embodied within VAR methodology is employed to estimate this long-run entity, representing a co-integrating vector. It is not possible to impose this restriction, embodied in the theory, with the Ordinary Least Squares method without imposing a weighting system that might well lead to mis-specification and serial correlation problems[2]. In order to combine the short run dynamics with this long term solution above, the empirical analysis adopts the error-correction mechanism with the notion of co-integration.

Moreover, according to Juselius (2006), the variables in [6] can be expressed as an error-correction expression in a general matrix form, representing a $I(1)$ process of changes and levels, namely

$$\Delta X_t = B_0 + B_1 t + B_2 \Delta X_{t-1} + \alpha \beta' X_{t-1} + B_3 \Delta X_{t-2} + \cdots + B_{K-1} \Delta X_{t-K+1} + \rho D_j + \epsilon_t, \qquad [7]$$

where $X_t = (\ln E_t, \ln Y_t, \ln M_t)'$ are the explanatory variables with K denoting the maximum lag, B_0 are the intercept terms, t denotes the presence of time trends, which can be included separately if required as indicated in above expression, or restricted to lie within X_{t-1} of [7], although not simultaneously at once. D_j represents a vector of non-stochastic variables such as structural break dummies with $j = 1$ to N, to maintain normality in the construction of the restricted error correction model, and ϵ_t is a column vector of random errors, which may be contemporaneously connected with one another but are assumed not to be serially correlated over time (Davidson, 2000).

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[2]Attempts were made to impose the restriction by moving output to the right-hand side and using Ordinary Least Squares on the changed dependent variable, but led to mis-specification.

The empirical analysis now proceeds to determine the number of co-integrating vectors existing between the variables of interest within $\alpha\beta'X_{t-1}$, representing the long-run relationships among the variables in [6]. The number of different co-integrating vectors can be found by examining the significance of the characteristic roots, which is equal to the rank of the co-integrating matrix (Johansen, 1988; Stock and Watson, 1988). The tests for the total number of roots that are significantly different from one, use the maximum and trace statistics, which often lead to conflicting results, although according to Enders (2010) the former rather than the latter is the preferred test for pinpointing the number of co-integrating vectors, which are reported in Table [1] below. It should be noted, however, on this occasion they were both in agreement. At the 95% critical value, the test statistic suggests one co-integrating vector with an unrestricted constant and trend as it is not possible to include them mathematically in the restricted format simultaneously[3].

Table [1]: Co-integration with unrestricted intercepts and no trends in the VAR
Co-integration LR Test Based on Maximal Eigen-values of the Stochastic Matrix
****
59 observations from 2001 Q2 to 2015 Q4. Order of VAR=8
List of variables included in the co-integrating vector:
$\ln E_t \ \ln Y_t \ \ln M_t$
List of Eigen-values in descending order:
0.40209   0.093510   0.031738
****

Null	Alternative	Statistic	95% Critical Value	90% Critical Value
$r = 0$	$r = 1$	30.3446	24.3500	22.2600
$r \leq 1$	$r = 2$	5.79230	18.3300	16.2800
$r \leq 2$	$r = 3$	1.90230	11.5400	9.75000

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The single solution is presented in Table [2] overleaf and represents the long-run equilibrium of expression [6] set equal to zero in the context of an unrestricted constant and time trend.

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[3] The optimum lag length based on the information criterions suggested VAR (1) or (2), but this led to under fitting with serial correlation and mis-specification problems that could not be removed, apart from extending the lag length to eight. The appropriate lag length plays a crucial role in the accuracy of the empirical model as the results of the VAR are sensitive to the selection of the lag length, especially the specification of the co-integrating vector (s). The autocorrelation from over-fitting was removed by employing general-to-specific data modelling, suggesting the correct lag length of eight.

The restrictions imposed were tested using the t-statistics and the log-likelihood statistic, which is distributed chi-square, at each stage.

		[**ec**]
lnE_t	a1	1.0000 (None)
lnY_t	a2	-1.0000 (None)
lnM_t	a3	0.66047 (0.032355)

Total number of restrictions (2) – number of just-identifying restrictions (1)
LR Test of Restrictions   CHSQ (1) = 2.5129 [0.113]
****

As suggested by the theory, actual employment turns out to be unitary elastic with respect to output in Table [2] above, which means that any positive change in the level of output translates into the same proportional change in the level of employment with an additional, significant negative effect coming from the real, minimum wage rates w.r.t. the long-run. It should be noted that the signs are interpreted the opposite way round because the expression in Table [2] is derived by setting it equal to zero with lnE_t normalised on one.

The empirical study has reached the stage where the long-run vector, **ec**, is put together with the short-run dynamics along with the constant and trend variables to give rise to the error correction model of changes in employment, which is shown below in expression [8]. This is the final restricted version with diagnostic tests derived by the 'manual' process of general-to-specific modelling, which means removing insignificant variables *via* t-statistics to expose the significant short-run dynamics that go alongside the long-run solution, **ec**, at $t-1$. At each stage of the simplification process, the diagnostic tests of the various models were checked for

encompassing with respect to the general form in terms of acceptable error properties, indicating proper signs of specification, see Hendry (1993) as well as Campos *et al*. (2005)[4].

This process allows the multiple search paths to be explored and compared with the all-encompassing general form at each stage of the process. The ultimate expression is as follows with the diagnostic tests in Table [3] below:

$$\Delta\ln L_t = 0.15478 + 0.0001162\, t + 0.18729\, \Delta\ln Y_{t-1} + 0.054103\, \Delta\ln M_{t-1}$$
$$\qquad (0.000) \qquad (0.000) \qquad (0.090) \qquad\quad (0.014)$$

$$+ 0.039685\, \Delta\ln M_{t-2} - 0.29529\, \Delta\ln L_{t-4} - 0.24117\Delta\ln L_{t-5} - \mathbf{0.12996\, ec_{t-1}} + \varepsilon_t$$
$$\quad (0.038) \qquad\qquad (0.011) \qquad\qquad (0.032) \qquad\qquad (0.000)$$

$$[8]$$

$R^2 = 0.52155,\ \overline{R}^2 = 0.45836,\ S = 0.0026710,\ RRS = 0.0003781,\ LL = 271.1771,\ DW = 2.1709,\ T = 59$.

Table [3]: the Diagnostic Statistics for Expression [8]

Test Statistics	LM Version
A: Auto-correlation	$\chi^2(4) = 6.4392\ [0.169]$
B: Functional Form	$\chi^2(1) = 0.1510\ [0.698]$
C: Normality	$\chi^2(2) = 1.1905\ [0.551]$
D:Heteroskedasticity	$\chi^2(1) = 1.7318\ [0.188]$

A: Lagrange multiplier test of residual serial correction,
B: Ramsey's RESET test using the square of the fitted values,
C: Based on attest of skewness and kurtosis of residuals,
D: Based on the regression of squared residuals on the squared fitted values.

The figures within the brackets of [8] are the probability values of the t-ratios corresponding to each variable included in the regression equation, indicating whether the coefficient is significantly different from zero at, say, the critical value of 0.05. In fact, the co-integrating vector, **ec**, is highly significant within the empirical model of [8] with a negative adjustment coefficient of -0.12996, which implies each period almost 13 percent of the error is corrected,

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[4] Hoover and Perez (1999a) have developed a computer algorithm for general-to-specific modelling.

meaning that any disequilibrium should be back on the path of equilibrium within approximately eight quarters, which embodies the positive output effect as well as the negative influence of real minimum wages on the growth of employment in the long-run. Furthermore, the constant reinforces the contribution and fits with the theory in terms of the sign in [6], but the trend variable, which is a proxy for the rôle of technology, in fact indicates a positive input to the growth rate of employment rather than being negative.

Moreover, in the case of the short-run dynamics of [8], the growth in output portrays the expected, positive impact on employment, although the positive growth in the past wage variables indicate a monopsony effect, that is as the real minimum wage grows over time, so does current employment rate in the short-term. Finally, the past growth rates in employment have negative effects on the current rate of employment, which may well be the impact of technological changes.

5.   The Conclusion and Summary

In conclusion, the empirical study constructed a statistical model of employment to evaluate the theoretical model of real, minimum wage rates on the U.K. economy. This led to the construction of a quarterly dataset to warrant meaningful statistical results for assessment of the theoretical model with the unitary restriction on output. What is more, the empirical study adopted the VAR methodology of calculation, allowing for the statistical estimation of an error-correction model, taking into account the empirical formation of short and long run effects on the rate of growth of employment. The long term exposed the traditional, negative effect of real, minimum wage rates.

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