REGIONAL GROWTH AND UNEMPLOYMENT IN THE MEDIUM RUN

Asymmetric Cointegrated Okun's Law for U.K. regions

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Key words:

Okun's Law, hidden cointegration, panel cointegration, regional growth, regional unemployment

JEL Codes:

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Main text:

1. Introduction

Okun's Law presupposes a macroeconomic correlation between the level of economic activity in the goods market and the performance on the labour market over the business cycle. It is often used as a benchmark for measuring the cost of unemployment increases (see for example Moosa 1997a) and recent papers show that professional forecasters do believe in Okun's Law and that this belief held up during the last Great Recession (see Mitchell and Pearce 2010 for the case of the U.S. or Pierdzioch *et al* 2011 for the G7 countries). Moreover, the relationship between revisions in unemployment and real GDP forecasts is in line with the Okun's Law main result (Okun, 1962) as unemployment forecasts are revised down when GDP forecasts are revised up (Ball et al., 2014).

Many recent papers question some basics of Okun's Law and the most highlighted limitations in the literature are threefold. First, the standard Okun's Law is often restricted to aggregate macroeconomic variables. However, the current economic recession has prompted a new debate on the association between GDP changes and unemployment, not only from a macroeconomic perspective, but also from a multi-regional perspective. A good illustration of this issue can be found in Europe where the unfavourable growth prospects are a reason for deep concern regarding the future employment situation both at the level of countries and regions. Therefore, the reliability of Okun's coefficients is not only of paramount importance for macroeconomic policy, but also for the regional distribution of unemployment rates in an open spatial system. Thus, a regional focus on Okun's Law is warranted. In addition, economic growth tends to exhibit more fluctuations at a regional scale than at a national scale due to spatial interdependencies and lower economic diversity of regions.

Secondly, while there seems to be consensus on the negative correlation between unemployment and GDP movements, a number of recent empirical studies find that the Okun's Law coefficient varies substantially over the phases of a business cycle, and does so in such a way that it seems plausible to model it as a non-linear, asymmetric relationship (see, for example, Altig et al. 1997, IMF 2010, Daly and Hobijn 2010, Crespo-Cuaresma 2003, Silvapulle et al. 2004). These authors argue that the Okun's Law coefficient varies according to recessions and expansions of the economy and that the effect of cyclical output on cyclical unemployment is significantly higher in case of a downturn in the economy. Lee (2000) finds an asymmetry threshold on the unemployment variable for various countries (e.g. Finland, Japan and the USA). Mayes and Viren (2002) show that rapid downturns in the economy have more than proportionate effects on unemployment, partly because of the mismatch between the relevant sectors and the regions where the jobs and unemployment show up. Another explanation for the asymmetry in Okun's Law is given by Harris and Silverstone (2001), who emphasize the asymmetric responses among heterogeneous production sectors in terms of job creation and job destruction when faced with economic shocks.

Lastly, the traditional Okun's Law uses a short-run economic framework linking the transitory components of output and unemployment. However, under conditions of hysteresis and related factors – where fired workers tend to have re-employment difficulties after longer unemployment spells – a drop in GDP may produce a higher rise in unemployment rates relative to a case when GDP increases. Moreover, Sinclair (2009) finds a negative and significant correlation between the permanent innovations of real GDP and the unemployment rate with U.S. data. This suggests that real output and unemployment might also be linked through their permanent component, thus exhibiting a negative correlation in the medium run.

The aim of this paper is to propose a re-examination of the unemployment rate - real output relationship with an empirical framework which avoids the three previously mentioned limitations. More precisely, the present paper takes these arguments further and presents a new regional statistical analysis inspired by Okun's Law that allows for medium run asymmetries between output and unemployment in a multiregional system within a hidden cointegration framework. Our objective is thus to test for the existence of a medium run Okun's Law relationship among UK regions with eventual asymmetric effects of local GDP movements on the regional unemployment rate. This framework does not require an *a priori* assumption on the exogeneity of either of these variables nor any trend-cycle decomposition procedure. The paper will take the cross-sectional dependence into account (in particular, whether a certain type of Okun correlation in one region will affect the Okun relationship in other regions). The new Okun model will be applied to 128 UK regions over the past 30 years. Our statistical Okun's Law model satisfies the following two conditions: (i) it should be able to represent and where applicable identify the existence of both linear and non-linear relationships between regional GDP and regional unemployment rates, and (ii) it should be able to take into consideration the extent to which Okun's relationship depends on the region's own characteristics and those of others (cross-sectional or spatial dependence). For this objective we combine a hidden cointegration approach by Granger-Yoon (2002) to accommodate asymmetries with a panel data approach suggested by Pedroni (2004) to remove cross-sectional dependence.

This paper proceeds as follows. Section 2 presents the model and the empirical strategy. Section 3 presents the data and Section 4 contains the empirical results of hidden cointegration tests. Section 5 concludes

2 Hidden cointegration with panel data and testing procedure

2.1. Hidden cointegration with panel data

To model a medium run version of the Okun's Law, we first suppose that unemployment (U) and the log of real GDP (Y) are two random walk time series described as:

$$U_{r,t} = U_{r,t-1} + u_{r,t} = U_{r,0} + \sum_{i=1}^{t} u_{r,i} \qquad r = 1, \cdots N \; ; \; t = 1, \cdots T \qquad \text{(1a)}$$

$$Y_{r,t} = Y_{r,t-1} + y_{r,t} = Y_{r,0} + \sum_{i=1}^{t} y_{r,i} \qquad r = 1, \cdots N \; ; \; t = 1, \cdots T \qquad \text{(1b)}$$

where $u_{r,t}$ and $y_{r,t}$ are both white noise terms with zero means and the subscripts r and t signify region and time. According to Engle and Granger (1987) U and Y are linearly cointegrated if there exist β such that $\{U_{r,t} - \beta Y_{r,t}\} \sim I(0)$. If it appears that the variables are not linearly cointegrated, there still might be nonlinear cointegration if there exists β such that

$$\{f(U_{r,t}) - \beta g(Y_{r,t})\} \sim I(0) \qquad \text{(2)}$$

where $f(\cdot)$ and $g(\cdot)$ are given nonlinear functions. As suggested by Granger and Yoon (2002), hidden cointegration is a special case of nonlinear cointegration where the functions $f(\cdot)$ and $g(\cdot)$ can be represented as follows.

Let $u_{r,t}^{+} = max(u_{r,t}, d_U)$, $u_{r,t}^{-} = min(u_{r,t}, d_U)$, $y_{r,t}^{+} = max(y_{r,t}, d_Y)$, and $y_{r,t}^{-} = min(y_{r,t}, d_Y)$ where d_U and d_Y are a priori given thresholds values. As $u_{r,t}$ is the variation of unemployment rate between period t and period $(t-1)$, $u_{r,t}^{+}$ equals $(U_{r,t} - U_{r,t-1})$ if $U_{r,t} - U_{r,t-1} > d_U$ and $u_{r,t}^{+}$ equals d if $U_{r,t} - U_{r,t-1} \leq d_U$. On the other hand, $u_{r,t}^{-}$ equals $(U_{r,t} - U_{r,t-1})$ if $U_{r,t} - U_{r,t-1} < d_U$ and $u_{r,t}^{-}$ equals d if $U_{r,t} - U_{r,t-1} \geq d_U$. The same holds for $y_{r,t}$ (note that we thus have $u_{r,t} = u_{r,t}^{+} + u_{r,t}^{-} - d_U$ and $y_{r,t} = y_{r,t}^{+} + y_{r,t}^{-} - d_Y$). In the simple case of a zero threshold ($d_U = d_Y = 0$), $u_{r,t}^{+}$ and $u_{r,t}^{-}$ ($y_{r,t}^{+}$ and $y_{r,t}^{-}$, respectively) can be interpreted as positive shocks (negative shocks, respectively) on unemployment (real GDP, respectively).

Equations (1a) and (1b) can thus be rewritten as:

$$U_{r,t} = U_{r,0} + \sum_{i=1}^{t} u_{r,i}^{+} + \sum_{i=1}^{t} u_{r,i}^{-} - d_U t = U_{r,0} + U_{r,t}^{+} + U_{r,t}^{-} - d_U t \quad (3a)$$

$$Y_{r,t} = Y_{r,0} + \sum_{i=1}^{t} y_{r,i}^{+} + \sum_{i=1}^{t} y_{r,i}^{-} - d_Y t = Y_{r,0} + Y_{r,t}^{+} + Y_{r,t}^{-} - d_Y t \quad (3b)$$

with the simplified notations: $U_{r,t}^{+} = \sum_{i=1}^{t} u_{r,i}^{+}$, $U_{r,t}^{-} = \sum_{i=1}^{t} u_{r,i}^{-}$, $Y_{r,t}^{+} = \sum_{i=1}^{t} y_{r,i}^{+}$, and $Y_{r,t}^{-} = \sum_{i=1}^{t} y_{r,i}^{-}$. In the limiting case $d_U = d_Y = 0$, $U_{r,t}^{+}$ and $Y_{r,t}^{+}$ are simply the cumulative sums of positive shocks in period t, while the negative counterparts are the cumulative sums of negative shocks on U and Y, respectively (in this case, we also have $\Delta U_{r,t}^{+} = u_{r,t}^{+}$, $\Delta U_{r,t}^{-} = u_{r,t}^{-}$, $\Delta Y_{r,t}^{+} = y_{r,t}^{+}$, and $\Delta Y_{r,t}^{-} = y_{r,t}^{-}$).

Assuming that $U_{r,t}^{+}$, $U_{r,t}^{-}$, $Y_{r,t}^{+}$, and $Y_{r,t}^{-}$ are all I(1), Granger and Yoon (2002) define U and Y to have hidden cointegration if their components are cointegrated, i.e. hidden cointegration involves cointegration for at least one of the four pairs of variables $\{U_{r,t}^{+}, Y_{r,t}^{+}\}$, $\{U_{r,t}^{+}, Y_{r,t}^{-}\}$, $\{U_{r,t}^{-}, Y_{r,t}^{+}\}$, and $\{U_{r,t}^{-}, Y_{r,t}^{-}\}$. Hidden cointegration is thus a special form of the non-linear cointegration model presented in equation (2) with $f(U_{r,t}) = U_{r,t}^{+}$ or $U_{r,t}^{-}$ and $g(Y_{r,t}) = Y_{r,t}^{+}$ or $Y_{r,t}^{-}$

2.2. Estimation and Testing procedure

Two alternative procedures are used to determine the threshold variable d which is used to calculate the positive and negative shocks on unemployment and GDP. The first procedure simply assumes that the threshold can be *a priori* fixed to zero so that $d_U = d_Y = 0$. In this case, $U_{r,t}^{+}$ and $U_{r,t}^{-}$ can be interpreted as the cumulated sums of positive and negative shocks on the unemployment rate while $Y_{r,t}^{+}$, and $Y_{r,t}^{-}$ are the cumulated shocks on the (log of) real GDP. While this procedure may seem *ad hoc*, it permits a first set of estimations which are easily and naturally interpretable. The second procedure for threshold selection is taken from Granger and Yoon (2002) and selects a pair of values for d_U and d_Y, which maximises the sum of the correlations between $\{U_{r,t}^{+}, Y_{r,t}^{-}\}$ and $\{U_{r,t}^{-}, Y_{r,t}^{+}\}$, when $u_{r,t}^{+} = max(u_{r,t}, d_U)$, $u_{r,t}^{-} = min(u_{r,t}, d_U)$, $y_{r,t}^{+} = max(y_{r,t}, d_Y)$, and $y_{r,t}^{-} = min(y_{r,t}, d_Y)$.

Moreover, tests for hidden cointegration and hidden cointegration vector estimation are performed with two alternative data series for regional unemployment and GDP. The first set of data series includes the raw values of the regional unemployment rate and regional GDP. The second set of series is aimed at taking into account the fact that as the Okun's Law relationship in an open regional economy may easily be affected by developments in other regional economies, some non-reliability may emerge from cross-sectional dependence when using the raw series. To do this, the across region average of $\Delta U_{r,t}$ ($\Delta Y_{r,t}$, respectively) at time t is denoted $\overline{\Delta U}_{.,t}$ ($\overline{\Delta Y}_{.,t}$, respectively) and is subtracted from $\Delta U_{r,t}$ ($\Delta Y_{r,t}$, respectively) for each period t and for each region r. In this case, note that $u_{r,t}^{+} = max(\Delta U_{r,t} - \overline{\Delta U}_{.,t}, 0)$, $u_{r,t}^{-} = min(\Delta U_{r,t} - \overline{\Delta U}_{.,t}, 0)$, $y_{r,t}^{+} = max(\Delta Y_{r,t} - \overline{\Delta Y}_{.,t}, 0)$, $y_{r,t}^{-} = min(\Delta Y_{r,t} - \overline{\Delta Y}_{.,t}, 0)$ with a zero threshold and $u_{r,t}^{+} = max(\Delta U_{r,t} - \overline{\Delta U}_{.,t}, d_U)$, $u_{r,t}^{-} = min(\Delta U_{r,t} - \overline{\Delta U}_{.,t}, d_U)$, $y_{r,t}^{+} = max(\Delta Y_{r,t} - \overline{\Delta Y}_{.,t}, d_Y)$ and $y_{r,t}^{-} = min(\Delta Y_{r,t} - \overline{\Delta Y}_{.,t}, d_Y)$ with non-zero thresholds.

The existence of hidden cointegration is tested with the residual-based test, based on Pedroni (2004). For example, if we retain the hypothesis that there is a medium run relationship between $U_{r,t}^{+}$ and $Y_{r,t}^{-}$, we first compute the residuals $\varepsilon_{r,t}$ in the following OLS regression:

$$U_{r,t}^{+} = \alpha_r + \beta_r Y_{r,t}^{-} + \varepsilon_{r,t} \quad t = 1, \cdots T;\ r = 1, \cdots, N \text{ (4)}$$

This regression is estimated for each cross-section so that both the slope parameter β_r and the intercept α_r can vary across each cross-section. The estimated residuals $\widehat{\varepsilon_{r,t}}$ from the cointegration regression are then used to test for cointegration: the null of no cointegration is retained if the residual $\widehat{\varepsilon_{r,t}}$ is I(1).

More precisely, Pedroni develops four panel statistics and three group panel statistics to test the null of no cointegration against the alternative hypothesis of cointegration. However, recent simulation studies (see for example Wagner and Hlouskova, 2010) show that the two tests of Pedroni that apply the ADF principle are best performers in the class of single equation panel cointegration tests. All other tests have very low power in many circumstances (and virtually none for T ≤ 25) and are partly severely undersized. These two tests are also the ones least affected by the presence of an I(2) component or short-run cross-sectional dependence.

Moreover, these two tests of Pedroni are the first choice in situations where the null hypothesis of no cointegration is of particular relevance or importance. Thus, in our study, we use the within-dimension based statistic (‘Panel-adf’) and the between-dimension-based statistic (‘Group-adf’) which are panel versions of the Augmented Dickey-Fuller statistic performed on the model:

$$\widehat{\varepsilon_{r,t}} = \rho_r \widehat{\varepsilon_{r,t-1}} + \omega_{r,t}$$

It is important to note that while the null hypothesis of no cointegration for the panel congregation tests is the same for each statistic ($H0 : \rho_r = 1$ for all r), the alternative hypothesis for the between-dimension-based and within-dimension-based panel cointegration test differs. The alternative hypothesis for the between-dimension-based statistic (Group-adf) is $H1 : \rho_r < 1$ for all r and a common value $\rho_r = \rho$ for all r is not required. In the case of the within-dimension-based statistic (Panel-adf), the adequate alternative hypothesis is $H1 : \rho_r = \rho < 1$ for all r with a common value for $\rho_r = \rho$.

Finally, four hidden cointegration cases can appear : i) neither $\{U_{r,t}^{+}, Y_{r,t}^{-}\}$ nor $\{U_{r,t}^{-}, Y_{r,t}^{+}\}$ are cointegrated so that $Y_{r,t}$ and $U_{r,t}$ are not cointegrated, ii) either $\{U_{r,t}^{+}, Y_{r,t}^{-}\}$ or $\{U_{r,t}^{-}, Y_{r,t}^{+}\}$ are cointegrated so that $Y_{r,t}$ and $U_{r,t}$ may have common opposite shocks but they are still not cointegrated, iii) both $\{U_{r,t}^{+}, Y_{r,t}^{-}\}$ and $\{U_{r,t}^{-}, Y_{r,t}^{+}\}$ are cointegrated but with different cointegration vectors so that $Y_{r,t}$ and $U_{r,t}$ are not cointegrated, iv) both $\{U_{r,t}^{+}, Y_{r,t}^{-}\}$ and $\{U_{r,t}^{-}, Y_{r,t}^{+}\}$ are cointegrated so that there is only one common shocks and $Y_{r,t}$ and $U_{r,t}$ are cointegrated.

3 Database unit root properties

The previous analysis framework has been used to test for and analyze the existence and relevance of possible medium run Okun's Law relationships between unemployment and real GDP for the 128 regions in the UK. Our data base comprises annual time series on GDP (value added) and unemployment rates during the period 1983-2009. The unemployment rate is in percent and the GDP variable is log transformed then multiplied by 100 (so that GDP growth rates are also in percentage units).

We first test for the existence of spatial correlation in the variables, using the cross-section dependence statistics (CD) suggested by Pesaran (2004). The test is applied to the model's variables so that its properties are not sensitive to specific assumptions regarding the retained panel model. Results are presented in Table 1 and show that the null of no cross section dependence is systematically rejected by the data with both the levels (U and Y) and the first differences (ΔU and ΔY) of the variables.

Table 1: Pesaran's cross section dependence test statistics

	U	Y	ΔU	ΔY
CD test stat	426.32	423.35	397.06	134.62
(P value)	(0.00)**	(0.00)**	(0.00)**	(0.00)**
Average $\hat{\theta}_{ij}$	0.92	0.93	0.86	0.29

The Pesaran CD statistic is given by $\sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{i=j+1}^{N}\hat{\theta}_{ij}\right)$ where the $\hat{\theta}_{ij}$s are the sample estimate of the pairwise correlation coefficients between all cross-sectional series and with $CD \rightarrow N(0;1)$ under the null of no spatial correlation.
* (**) : significant at the 10% (5%) confidence level.

Due to the presence of significant spatial correlation, we have to control for interactions among regional labour markets. Explicitly modelling the influence of spatial correlations with econometric techniques taken from the spatial econometric literature is beyond the scope of this paper (see for instance Palombi et al., 2015 for an application of specifications incorporating spatial effects in the form of spatial lags and/or spatially autoregressive error components to the case of a short-run version of the Okun's Law model estimated with regional U.K. data). In this paper, we chose to mitigate the problem of cross section dependence by taking output and unemployment series in deviation from their time means. This procedure amounts to assuming that regional unemployment is mainly driven by both local specific shocks and national aggregate shocks. Demeaning unemployment and real output thus washes out the effects of the common aggregate shocks without making any assumption concerning the way each region reacts to these common shocks at each date. An alternative procedure could be to estimate panel models incorporating time specific dummies so that common time effects are subtracted out from the variables. While this procedure should permit one to avoid omitted variable bias arising from omitted factors (such as aggregate shocks) that evolve over time, its main drawback is to assume that the effects of these omitted factors are the same for all regions and are constant over time.

As a starting point for the following cointegration analysis, we first test for the unit root properties of the variables by implementing three panel unit root tests: the Levin-Lin-Chu (2002) test, the Im-Pesaran-Shin (2003) test, and the cross-sectional dependent panel unit root test (CIPS) of Pesaran (2007). The Levin-Lin-Chu and Im-Pesaran-Shin tests retain the null of unit-root but the Im-Pesaran-Shin test relaxes the restrictive assumption of Levin-Lin-Chu that the root must be the same for all series under the alternative hypothesis. The Pesaran CIPS test is an extension of the test of Im et al. (2003) that allows for cress section dependence. Empirical results of the unit root tests are presented in Table 2.

Table 2: Panel unit root test results

	Levin-Lin-Chu[a]		Im-Pesaran-Shin[a]		Pesaran CIPS[b]	
	With trend	No trend	With trend	No trend	With trend	No trend
$U_{r,t}$	7.96	7.03	13.25	7.03	-1.44	-1.30
$Y_{r,t}$	4.92	7.56	7.67	6.21	-0.64	-1.59

(a) The Levin-Lin-Chu and Im-Pesaran-Shin statistics are weighted by long-run variances and are distributed N(0;1) under the null of unit root.
(b) The distribution of the test is non-standard. Critical values are tabulated by the author for different combinations of T and N. For the database at hand, the 5% and 10% critical values respectively are -2.07 and -2.00 for the model without trend or -2.57 and -2.51 for the model with trend.

According to the panel unit root test results, all the variables clearly appear as integrated of order one.

In order to apply the hidden cointegration procedure, we begin by calculating first differences for both $U_{r,t}$ and $Y_{r,t}$. First difference values are then partitioned into positive and negative variations so as to finally calculate the cumulative sums $U_{r,t}^{+}$, $U_{r,t}^{-}$, $Y_{r,t}^{+}$, and $Y_{r,t}^{-}$ according to equations 3a and 3b. For consistency with macroeconomic interpretability of the Okun's Law model, we assume that neither ($U_{r,t}^{+}$ and $Y_{r,t}^{+}$) nor ($U_{r,t}^{-}$ and $Y_{r,t}^{-}$) can exhibit interpretable cointegration relationships. We thus concentrate on testing for the presence of an equilibrium relationship between components ($U_{r,t}^{-}$ and $Y_{r,t}^{+}$) and components ($U_{r,t}^{+}$ and $Y_{r,t}^{-}$).

Figure 1 shows the positive and negative components of unemployment and GDP for both non demeaned and demeaned data. In order to avoid selecting a specific region, the graphs in Figure 1 correspond to the averages over the regions of the cumulative sums $U_{r,t}^{+}$, $U_{r,t}^{-}$, $Y_{r,t}^{+}$, and $Y_{r,t}^{-}$.

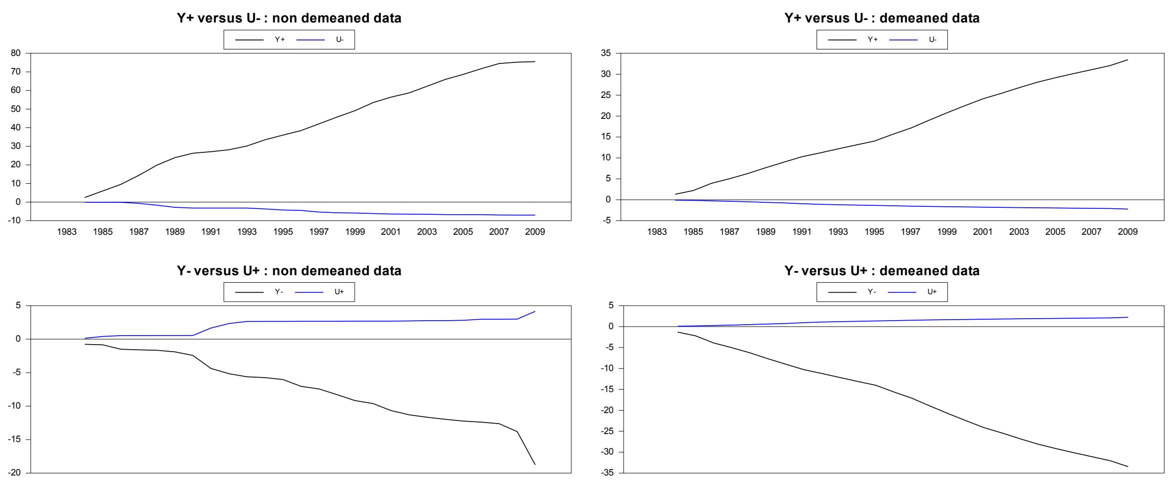

Figure 1: Cumulated sums of positive and negative components of GDP and Unemployment

The cumulative positive components are growing while the cumulative negative components are declining continuously. While these plots only correspond to across regions average values of cumulative sums $U_{r,t}^{+}$, $U_{r,t}^{-}$, $Y_{r,t}^{+}$, and $Y_{r,t}^{-}$, the time patterns appear to demonstrate reasonably plausible behaviours both with non-demeaned and demeaned data. Moreover, it is important to notice that the sudden breaks appearing in the $Y_{r,t}^{-}$ and $U_{r,t}^{+}$ components at periods 1990 and

2008 with non-demeaned variables have completely disappeared in the graphs with demeaned data.

4. Hidden cointegration tests

Empirical results of hidden cointegration tests performed with the Pedroni-testing procedure and with the *a priori* assumption of a zero threshold (i.e. $d_Y = d_U = 0$ in equations 3a and 3b) are presented in the first part (left column) of Table 3. For both Panel-adf and Group-adf tests, a general to specific method is used to determine the finally retained number of augmenting lags in adf regression (starting from a maximal lag order of two and the significance level to keep a lag in the adf regression is fixed at 10%).

Table 3: Hidden cointegration tests with zero thresholds and with nonzero thresholds

	Hidden cointegration tests		Hidden cointegration vectors	
	Panel adf	Group adf	β, FMOLS[(a)]	β, DOLS[(a)]
Zero thresholds				
$U^+ = \alpha + \beta \cdot lnY^-$	-3.26**	-2.11**	-0.096** (-116.93)	-0.094** (-124.02)
$U^- = \alpha + \beta \cdot lnY^+$	-4.12**	-3.38**	-0.082** (-113.19)	-0.081** (-125.45)
Nonzero thresholds				
$U^+ = \alpha + \beta \cdot lnY^-$	-3.08**	-1.52*	-0.069** (-172.29)	-0.067** (-187.44)
$U^- = \alpha + \beta \cdot lnY^+$	-3.22**	-4.11**	-0.056** (-56.99)	-0.052** (-58.48)

(a) The full sample estimates of β-coefficients are computed by taking a weighted average of the individual estimates. Each individual β is weighted by the diagonal matrix formed by taking the square root of the precision matrix of the estimates for that individual. With such a weighting procedure, the coefficients and covariance matrix reproduce the average *t*-statistic, so that the averaging done in calculating the *t*-statistics and the average β-coefficients match.
Legend: FMOLS = FMOLS estimator, DOLS = DOLS estimator; * (**) denotes significant at the 10% (5%) confidence level. t-statistics reported in parentheses.

Table 3 shows the null of no cointegration between unemployment and real GDP is never rejected by the data at the traditional 5% confidence level: hidden cointegration between $U^-_{r,t}$ and $Y^+_{r,t}$ and between $U^+_{r,t}$ and $Y^-_{r,t}$ is systematically significant. Regional output decreases (increases, respectively) larger than across regions average output decreases (increases, respectively) share a common stochastic trend with regional unemployment increases (decreases, respectively) larger than across regions average unemployment increases (decreases, respectively). In the case of negative or positive output shocks, there is a systematic medium run impact on regional unemployment. The presence of a nonlinear and asymmetric medium run relationship is consistent with Altissimo and Violate (2001) who also find a non-linear cointegration relationship between unemployment and GDP but with national data for the U.S.

We next investigate the presence of hidden cointegration by relaxing the a priori assumption of a zero threshold. In order to do so, we select the upper and lower threshold values that maximizes the sum of correlations between $\{U^+_{r,t}, Y^-_{r,t}\}$ and $\{U^-_{r,t}, Y^+_{r,t}\}$. The retained procedure for threshold selection involves the following steps. We first calculate the 10% and 90% fractals of $\Delta U_{r,t}$ and $\Delta Y_{r,t}$ for each region considered separately ($F10U_r$, $F90U_r$, $F10Y_r$, $F90Y_r$). We then calculate the average of these fractals across regions ($\overline{F10U}$, $\overline{F90U}$, $\overline{F10Y}$, and $\overline{F90Y}$). We finally select a threshold for unemployment from $d_U \in [\,\overline{F10U}\,,\ \overline{F90U}]$ with an increment of 0.01 and a threshold for real GDP from $d_Y \in [\,\overline{F10Y}\,,\ \overline{F90Y}]$ with an increment of 0.01. The threshold selection is performed with both non demeaned and demeaned data. The finally retained fractals are $(\overline{F10U}\,;\,\overline{F90U}) = (-0.246\,; 0.257)$ and $(\overline{F10Y}\,;\,\overline{F90Y}) = (-3.675\,; 3.792)$ while the selected threshold are $d_U = 0.041$ for the unemployment rate variation and $d_Y = -0.688$ for the first difference of the log of real GDP (sum of correlations: -1.05). These threshold are binding during 581 recession periods and 1238 expansion periods, i.e., nearly 55% of the full sample).

The empirical results of the hidden cointegration tests performed with non-zero thresholds are summarized in the second part (left column) of Table 3. Both the Panel-adf and the Group-adf test statistics are well beyond the 5% confidence limit (or the 10% limit for $(U^+_{r,t}\,; Y^-_{r,t})$ and with the Group adf test). The hidden cointegration thus appears to be significant for both $(U^+_{r,t}\,; Y^-_{r,t})$

and $\left(U_{r,t}^{-}\,; Y_{r,t}^{+}\right)$ so that panel cointegration tests performed with zero or non-zero thresholds show that hidden cointegration is never rejected by the data.

We now perform the estimation of the hidden cointegration vectors between the negative and positive component of unemployment and GDP. As the OLS estimator is a biased and inconsistent estimator when applied to cointegrated panels, the medium run coefficient β in equations such as (4) is estimated with both the between dimension FMOLS and the DOLS approach suggested by Pedroni (2000). These estimators control for the likely endogeneity of the regressors and serial correlation in order to generate consistent estimates of the β parameter. While the FMOLS estimator uses a non-parametric correction using $\widehat{\varepsilon_{r,t}}$ and $\Delta Y_{r,t}^{-}$ (or $\widehat{\varepsilon_{r,t}}$ and $\Delta Y_{r,t}^{+}$ according to the estimated equation), the DOLS estimator controls for endogeneity with a parametric correction achieved by augmenting the cointegration relationship with leads and lags of $\Delta Y_{r,t}^{-}$ (or leads and lags of $\Delta Y_{r,t}^{+}$ according to the estimated equation). In this paper, we retained two lags and two leads for the DOLS estimator. The empirical results with both methods are shown in Table 3 (right column).

The medium run β-coefficients estimated with the FMOLS and DOLS procedures are systematically significant with both zero and non-zero thresholds. Moreover, while the long-term coefficients shown in Table 3 are close to each other, it is important to note that when calculating the corresponding 95% confidence intervals[1], it clearly appears that these intervals never overlap so that the medium run equilibrium impact of local regional *GDP* on regional unemployment is slightly larger (in absolute terms) during contraction periods than during expansions. This

[1] Calculated 95% confidence intervals for the hidden cointegration vectors:

- For the $U^{+} = \alpha + \beta \cdot lnY^{-}$ relationship with **zero threshold**: $[-0.097; -0.094]$ with FMOLS ; and $[-0.095; -0.092]$ with DOLS
- For the $U^{-} = \alpha + \beta \cdot lnY^{+}$ relationship with **zero threshold**: $[-0.083; -0.081]$ with FMOLS ; and $[-0.082; -0.080]$ with DOLS.
- For the $U^{+} = \alpha + \beta \cdot lnY^{-}$ relationship with **nonzero threshold**: $[-0.070; -0.068]$ with FMOLS ; and $[-0.068; -0.066]$ with DOLS.
- For the $U^{-} = \alpha + \beta \cdot lnY^{+}$ relationship with **nonzero threshold**: $[-0.058; -0.054]$ with FMOLS and $[-0.054; -0.050]$ with DOLS.

comparison of the confidence intervals associated with the hidden cointegration vectors is finally supplemented by explicit tests for the null of equality of the β coefficients in the equations $U^{+} = \alpha + \beta \cdot lnY^{-}$ and $U^{-} = \alpha + \beta \cdot lnY^{+}$. The test results are presented in Table 4 and show that the null of equality is systematically rejected at the usual confidence intervals.

Table 4: Tests for equality of the hidden cointegration vectors

	Tests for equality of the hidden cointegration vectors β across equations $U^{+} = \alpha + \beta \cdot lnY^{-}$ and $U^{-} = \alpha + \beta \cdot lnY^{+}$	
	β, FMOLS	β, DOLS
Zero thresholds	-693.76 (0.000)	-708.42 (0.000)
Nonzero thresholds	-664.74 (0.000)	-849.25 (0.000)

P values are indicated between parentheses

As this asymmetry is obtained with both FMLOS and DOLS estimators and with both zero and nonzero thresholds, it appears to be quite robust so that the medium run impact of GDP on the unemployment rate is slightly larger (in absolute terms) during periods of recession than during periods of expansion. This result ultimately contributes to a justification of the adoption of the hidden cointegration methodology to the case at hand.

Empirical results obtained with the standard hidden cointegration procedure show that we can separate economic periods with both positive unemployment rate innovations and negative GDP innovations from periods characterized by the opposite situation. The first case, that can be interpreted as situations of economic contractions, has a medium run Okun's Law coefficient close to -0.095 while the second case, interpretable as an expansion situation, has a marginally lower coefficient of -0.082. While this difference is not large, it appeared as statistically significant at the 5% confidence level in Table 4.

Empirical results obtained with the threshold augmented hidden cointegration method seem to show that when examining the characteristics of the regional medium run Okun's Law it is possible to contend that periods of economics contraction should be defined as times with both unemployment rate innovations lower than 0.041 percentage points and real output innovations larger than -0.68%. Correspondingly, periods of expansions should be defined as periods with unemployment rate innovations lower than 0.041 percentage points and real output innovations larger than -0.68%. Compared to the results of the standard hidden cointegration procedure (with usual zero thresholds), this amounts to excluding times with severe output contraction but limited unemployment increases as well as times with limited output contraction but severe unemployment increases from the previously so-called economic contraction period. On the other side the adequate definition of expansion times - with regards to the medium-run regional Okun's Law – should be redefined correspondingly so as to incorporate times with output innovation larger than -0.68% but moderate unemployment increases (i.e. unemployment innovation between zero and 0.041 percentage points) as well as times with limited negative output innovations (i.e. comprised between -0.68% and zero) but unemployment shocks lower than 0.041 percentage points.

As with the results obtained with the standard zero threshold innovation method, we still find that the sensitivity of the unemployment rate is marginally larger (in absolute terms) during these redefined periods of contraction than during the redefined periods of expansion. These thresholds thus seem to indicate that the traditional separation of positive and negative innovations on unemployment and gdp might not be the best way to evaluate the nonlinear medium run effects of real output movements on unemployment in the case of UK regions.

Taken as a whole, these empirical results can be interpreted as indicating that regions having different GDP growth rates from the average across regions also have persistently different unemployment rates relative to the average unemployment. Regional shocks that lead to regional GDP variations larger than the across regions average GDP variation lead to persistent regional unemployment movements which are also larger than the across region average unemployment variation. The presence of hidden cointegration may thus be considered as a clue for the presence of a medium run link between regional and national ratios of GDP to unemployment. More precisely, while the traditional Okun's Law relationship addresses the short-run correlation between unemployment and GDP transitory movements, our result clearly show that this correlation also holds in the medium run at the decentralized level of regions. Various potential explanations such as insider/outsider models, human capital or regional mobility may be found in the literature for this medium run response of regional unemployment to regional GDP shocks.

These effects are all quantitatively smaller than the traditional Okun's Law coefficients obtained in the literature for the case of countries. To interpret this, we have to keep in mind two main points. First the traditional version of Okun's Law concerns a short-run time horizon in which the labour market and the nominal wages are predominantly rigid, so that there is no major regulation of unemployment and GDP movements through labour market adjustments. In this case, the labour market cannot adjust. The presence of hidden cointegration relationships indicates that our results typically concern a medium run time horizon. As the aggregate supply curve is generally taken to be much less steep in the medium run than in the short run due to labor market adjustments and partial convergence of actual and expected price levels, our empirical results are partly consistent with the neoclassical version of the aggregate demand-aggregate supply macroeconomic framework. However, while the neoclassical macroeconomic theory assumes that the medium run aggregate supply curve is vertical with no effects of short-run demand driven output movements on unemployment rates in the medium run, Table 2 seems to show that the permanent effects of regional real output movements on local unemployment rates are low but non zero in the U.K. The regional aggregate supply curves might thus be non-vertical in U.K regions. Our results thus suggest that regional labour market adjustment mechanisms are not able to fully encapsulate the variations of unemployment rates induced by large regional GDP shocks. However, the initial impacts of GDP shocks on unemployment are partly dampened by labour market and real wages adjustments in the medium term, while only a fraction of the initial impact can remain in the medium run. The second point concerns the fact that our sample includes regional data. As mobility is much more important across regions than across countries, regional unemployment rate movements are also partly influenced by spatial mobility. This mobility may thus also contribute to explain why our β-coefficients are smaller than those obtained with national data.

5. Conclusion

This paper aimed to test the existence of a medium run Okun's Law relationship in the case of small U.K. open regional economies. A methodological novelty of the paper is that it combines a test of hidden cointegration with a panel data methodology. Hidden cointegration is not rejected by the UK data so that empirical results are consistent with a medium run equilibrium relationship between regional output expansions (respectively regional output contractions) and regional unemployment decreases (respectively regional unemployment increases). Moreover, this medium run link appears to be slightly asymmetric: the impact of a GDP expansion on unemployment is smaller in absolute value than the impact of a GDP contraction. Positive and negative GDP shocks may thus have limited but significant medium run impact on the unemployment rate so that there are "Okun's law effects" beyond the short-term horizon.

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An important caveat worth noting is that not all forms of cross-sectional dependency are necessarily accommodated by simple common time effects +
This approach assumes that the disturbances for each member of the panel can be decomposed into common disturbances that are shared among all members of the panel and independent idiosyncratic disturbances that are specific to each member
For many cases this may be appropriate as , for example , when common business cycle shocks impact the data for all countries of the panel together

In other cases, additional cross-sectional dependencies may exist in the form of relatively persistent dynamic feedback effects that run from one country to another and that are not common across countries , in which case common time effects will not account for all of the dependency

States with government employment less than 8.8% of
the state population will have a coefficient of -0.357, whereas states with employment in government jobs more than 8.8% of the population will have a coefficient of -0.229
The coefficient is lowest (-0.190) for states with government employment rates above the 81st percentile
In both cases, states with a relatively small employment share in these sectors tend to have a less sensitive relationship between output gaps and unemployment

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