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an Application to the U.S. Economy**

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# Cointegration and Asymmetric Adjustment between Output and Unemployment: an Application to the U.S. Economy<sup>1</sup>

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## Abstract

This paper focuses on the properties of the adjustment between the real output and the unemployment rate for the U.S. economy in the period from 1975 to 2006. It starts by checking the order of integration of the two series and then tests for the presence of asymmetry in the Okun's law relationship through a cyclical equation, a first differences equation and an  $ADL(p,q)$ . Using the threshold cointegration approach this study also accounts for the possible existence of a long-run equilibrium relationship and its ability to test for the asymmetric adjustment hypothesis. It is found that Okun's coefficient ranges between -0.41 and -0.59, being the latter estimated by the cointegrating equation. Furthermore, the unemployment rate behaves differently along the business cycle and increases faster in recessions than it recovers in expansions. A long-run equilibrium relationship is established where adjustment is made asymmetrically. Positive deviations away from equilibrium are corrected slightly faster than negative ones. Our explanation concerns the higher speed of flows within the labor market during a recession than during an expansion which may also be related to the existence of nominal rigidities in the US economy that causes imperfectly flexible prices.

**Keywords:** Okun's Law, Threshold Cointegration, Asymmetric Adjustment, Monte Carlo Simulations, U.S. Economy.

**JEL Classification:** E30, E32, C22

## 1. Introduction

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One of the most well known stylized facts in Macroeconomics is the inverse relation between real output and the rate of unemployment, or as commonly called, the “Okun Law”. In his seminal paper, Arthur Okun (1962) states that the increase in one percent in the growth of real output decreases the unemployment rate by 0.3 points<sup>1</sup>. Moreover, this number represents more than a simple measure of the reduction in the unemployment rate as a result of output fluctuations.

The subject under scrutiny in this paper, has extremely important implications, not only for the analysis of economic policy decisions to be taken by policymakers, but also, on the (re)definition and (re)orientation of measures that have to be adopted. The understanding with precision how markets adjust, allow selecting correct policies when facing to shocks. Specifically, the aim of this paper is to analyse the adjustment of the U.S. labor market, taking into account the literature that has focused on the hypothesis of asymmetric adjustment towards the equilibrium. The following research question is asked: is the adjustment of the North American labor market symmetric or asymmetric along the business cycle and towards the long-run equilibrium?

A second motivation is related to the selected time period of analysis, which covers the years from 1975 to 2006. During this period, the U.S. economy faced great transformations, in part due to specific policies implemented by policymakers and in part due to external shocks, namely, the two oil shocks and their consequences, the disinflation period, the expansionist fiscal policy during Reagan’s Presidency, the rise in the interest rates, the consequence of the last two, the debt crisis in the Latin American economies as a consequence of the rise in the interest rates, the European Integration Process, the introduction of the euro, the 2001 recession and the recent depreciation of the dollar against the euro.

The paper is organized as follows: in section 2, we review briefly the literature; in section 3 we describe the data and its sources; in section 4 we describe the methodology used for the analysis; in section 5 we present the results and section 6 discusses them. Last section concludes.

## **2. Literature Review**

Many studies have been conducted in the field of economic adjustment and presenting “Okun’s law” as one of the most reliable facts in macroeconomics, see for example, Evans (1989), Prachowny (1993), Weber (1995), Moosa (1999) and Lee (2000). It is common sense to think that an economy in expansion is able to create new vacancies and so to absorb some

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<sup>1</sup> This number refers to the first differences equation estimated by Okun (1962) although he also provided estimates from a cyclical equation and an elasticity equation.

unemployment level and reduce the unemployment pool. In the inverse case, it is quite simple to think that during a recession, firms act according to their natural behavior of profit maximizing agents and adjust their costs in the short run through the employment level, preventing possible losses, hence, increasing the unemployment pool of the economy. As such, “Okun’s law” was rapidly accepted, being largely used in subsequent years for policymaking purposes. In this paper, we depart from this general acceptance without a previous and exhaustive scrutiny and present below three reasons that go against it.

Blanchard and Quah (1989) give the necessary motivation for the first reason, specifically to the view that Okun’s law is a typical supply side phenomenon; see for example, Prachowny (1993). Based on the SVAR approach, Blanchard and Quah (1989), impose identifying restrictions on a bivariate VAR between real output and the rate of unemployment that allow the extraction of supply and demand shocks, which are represented as linear combinations of the innovations from the reduced form VAR model. In a typical Keynesian framework, the first one has permanent effects on output and transitory effects on the unemployment rate, whereas the second one only has transitory effects on both variables. Their results, suggest that Okun’s coefficient is nothing more than a combined effect of supply and demand disturbances, or a “mongrel” coefficient that varies dependently of the shock that hits the economy. In fact, they find evidence that there is a strong negative relation between output and unemployment in the presence of a permanent shock in demand, but the strength of that relation is not so obvious in the presence of a supply shock since unemployment in the short run can either increase or decrease, depending on the adjustment undertaken by prices, real wages and aggregate demand. Although we understand that these results can be constrained by the identifying restrictions imposed on the system, we completely agree that attributing the inverse relationship only to the supply adjustment can be misleading. Assuming that Okun’s coefficient is a combined effect of all the adjustment can be less appealing in terms of policymaking since the uncertain nature of the relation doesn’t help to define clear policies. Moreover, it is clear that this question is not definitively closed and more tests on this subject need to be performed.

The stability of Okun’s law needs also to be discussed, or in a more refined way, the stability of Okun’s coefficient. Some literature, such as Weber (1995), has paid attention to the alleged stability of the 3:1 ratio. The main findings indicate that this can not be generalized, and this paper also presents the estimates that differ in magnitude, depending on the used method. For instance, Prachowny (1993) estimates a coefficient of 0.668 for the U.S. in the period 1975-1988, specifying the output-unemployment relation through a production function based on the first differences of the cyclical components. Weber (1995) estimated for the U.S. economy along the period 1948-1988, coefficients that range between -0.314 and -0.224 using several different approaches such as the relation between innovations from a bivariate VAR, a

cointegrating equation and an ADL(p,q). Moosa (1999) presents an estimate of -0.38 using an ADL(p,q) in the period 1947-1992. The list could go on, but these examples clearly show that, in fact, Okun's coefficient depends on the method used and the period under analysis, hence, it is not stable.

Another fact that has been ignored in the literature, with the exception of Lee (2000) and Harris and Silverstone (2001), is the possibility that the unemployment rate can behave differently along the business cycle. The asymmetry hypothesis that we test in this paper has its foundations on the fact that the unemployment rate may differ in terms of adjustment in recessions and in expansions. Recessions can produce permanent effects on the labor market structure such as the well known Hysteresis effect and as a consequence, change the adjustment.

Recently McKay and Reis (2007) analyzed the hypothesis of asymmetry in the U.S. business cycle, i.e., they claim that recessions are briefer and more violent than expansions. Their results partially confirm the claim, suggesting that contractions in employment are shorter than expansions although for output the results are not so strong. They suggest that the difference lies on the fact that employment lags output at peaks but coincides with it through, pointing for an asymmetric synchronization between the two variables. They also suggest a model in which firms can vary overtime hours but face costs on adjusting the employment level, in the overall accounting for these new finds in terms of duration and violence of each stage of the business cycle.

Holmes and Silverstone (2006) use the Markov-Switching approach to test the presence of asymmetries in Okun's law, and find it both within and across regimes of the U.S. business cycle. Lee (2000) incorporates asymmetric effects on the evolution of the unemployment rate constraining Okun's coefficient to be dependent on the state of the economy<sup>2</sup>. His findings suggest the presence of asymmetry in the behavior of the unemployment rate along the different states of the economy, but his results seem to be sensitive to the cycle extraction method. Since it is quite possible that the relation between output and unemployment display a long run equilibrium, and ignoring this possibility when it occurs would lead to biased results such as the ones presented by Lee (2001). So, the cointegration analysis appears to be the best strategy to obtain a consistent measure of the trade-off and also, to test the possibility of asymmetry. By their side, Harris and Silverstone (2001) used a method developed by Enders and Granger (1998) and Enders and Siklos (2001) known as "threshold cointegration", concluding that not only the unemployment and output series are cointegrated with asymmetry of adjustment towards the long run in the US economy but also the adjustment process is extremely underestimated with the typical cointegration approach. They estimate that 21.4% of disequilibrium is corrected each quarter in the case of positive deviations from the equilibrium

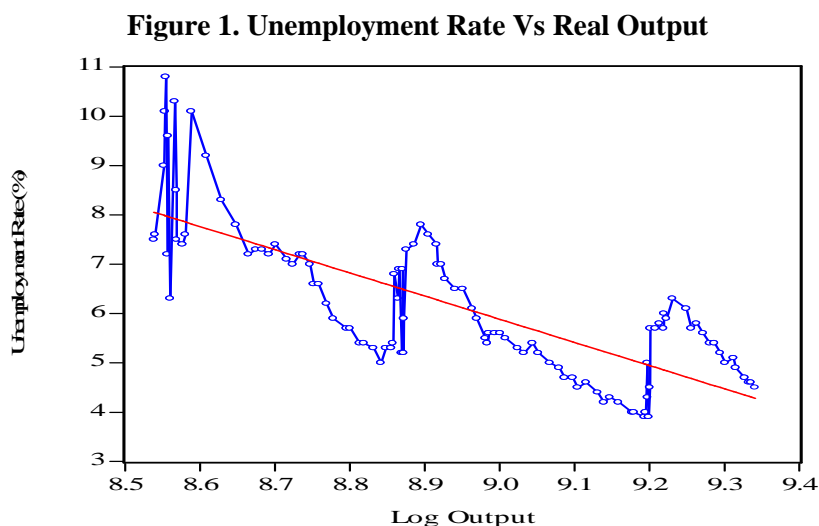
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<sup>2</sup> Since we will also use this method, we leave the rest of the explanations to the methodology section.

and find that the error correction term is not significant in the presence of negative deviations. Furthermore, they estimate a degree of correction of 11.6% in the symmetric case.

### 3. Data

We use quarterly time series data for the United States economy relative to the period 1975:1-2006:4. For the output, we use seasonally adjusted Real GDP in Billions of Chained 2000 dollars from the Bureau of Economic Analysis dataset with code 10106. For the unemployment, we use the seasonally adjusted civilian non institutional unemployment rate from the Bureau of Labor Statistics available with code LNS14000000 collected in October 2007. All data are available online at the websites of the two entities. Regarding the unemployment rate, data are available in a monthly frequency, so, we consider the last month of each quarter to obtain quarterly measures. The relation between these two variables is plotted in Figure 1.



The graph presented in figure 1 shows that the relation between the unemployment rate and real output is clearly non-linear.

We decided to start the series in 1975 to avoid a potential break in the series as a consequence of the first oil shock. This fact has been pointed frequently in the literature. Weber (1995) assumes that, both the unemployment rate and output, are stationary along a broken trend and Lee (2000) detects a break in the output series in the year 1974 and a break in the unemployment rate series in the year 1975. The existence of a break in the series would obviously change the main econometric procedures, for example, the usual unit root test procedure couldn't be used since the test loses its power.

### 4. Econometric Methodology

Since in this paper we want to test the dynamic relationship between real output and the unemployment rate, we will not only consider the cointegration framework but also, some specifications that are commonly used in the literature as a way to obtain a comparative platform with the asymmetry tests results.

First, we start performing two unit root tests, to assess the order of integration of the two series. The two tests considered were the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. The results from these tests will be presented in section 5.

#### 4.1. Symmetric Models

In order to obtain a comparison with the literature and the considered asymmetric estimations that are going to be considered, we use three of the most well known specifications of Okun's law. For the first specification, let  $U_t$  be the unemployment rate in and  $y_t$  the log of real output, so the first model relates the annual change in the unemployment rate with the annual growth rate of real output which can be specified as follows:

$$\Delta U_t = \alpha + \beta \Delta y_t + \varepsilon_t \quad (1)$$

where  $\Delta U_t$  is the annual change in the unemployment rate and  $\Delta y_t$  is the annual growth in real output. The parameter  $\beta$  is the well known Okun's coefficient and  $\alpha$  can be seen as the mean change of the unemployment rate over the considered time period. The second specification is the cyclical version of the Okun law, which can be defined as:

$$U_t^c = \beta y_t^c + \varepsilon_t \quad (2)$$

Where  $U_t^c = U_t - U_t^*$  and  $y_t^c = y_t - y_t^*$  are the cyclical components of the unemployment rate and real output respectively. The problem with these specifications is that they don't account for short run dynamics, so they will probably display serial correlation problems. The last specification considered is an ADL(p,q) which includes this possibility and may be written as:

$$U_t^c = \sum_{j=1}^p \alpha_j U_{t-j}^c + \sum_{i=0}^q \beta_i y_{t-i}^c + \varepsilon_t \quad (3)$$

$$\beta^{LR} = \frac{\sum_{i=0}^q \beta_i}{1 - \sum_{j=1}^p \alpha_j} \quad (4)$$

In this specification, Okun's coefficient is  $\beta^{LR}$  which measures the long run impact and  $\beta_0$  is the short-run impact coefficient of output fluctuations. The last two specifications bring the problem of identifying the trend and the cyclical component of both series. We decompose each series in a trend and in a cycle using the Hodrick and Prescott (1997) filter<sup>3</sup>. The cyclical component can then be computed as the difference between the observed series and the computed trend<sup>4</sup>. The penalty factor used is  $\lambda=1600$  which is the one recommended for quarterly data.

#### 4.2. Initial Asymmetric Models

In order to test the hypothesis that the unemployment rate behaves in a differentiated manner in each phase of the cycle, we apply two models proposed by Lee (2000), which incorporates an asymmetry process given by equations (1) and (2). These models allow an explicit test of the hypothesis that the unemployment rate increases faster in recessions than it decreases during expansions. In this case, equation 1 is written as:

$$\Delta U_t = \alpha + (\beta^+ I_t^+ \Delta y_t + \beta^- I_t^- \Delta y_t) + \varepsilon_t \quad (5)$$

The asymmetry process is introduced using a Heaviside variable  $I_t$  that separates the effects of expansions from the effects of recessions and can be written as:

$$I_t^+ = \begin{cases} 1 & \text{if } \Delta y_t \geq 0 \\ 0 & \text{if } \Delta y_t < 0 \end{cases} \quad (6)$$

$$I_t^- = \begin{cases} 1 & \text{if } \Delta y_t < 0 \\ 0 & \text{if } \Delta y_t \geq 0 \end{cases} \quad (7)$$

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<sup>3</sup> The Hodrick-Prescott filter identifies the trend of a given series  $\{x_t\}_{t=1}^T$  as the solution of the following minimization problem:

$$\min_{x_t^*} \sum_{t=1}^T (x_t - x_t^*)^2 + \lambda \sum_{t=2}^{T-1} [(x_{t+1}^* - x_t^*) - (x_t^* - x_{t-1}^*)]^2$$

<sup>4</sup> The cyclical component of output was multiplied by 100, to obtain percentual deviations from trend. In relation to the unemployment, the filter was applied directly to the raw series with no logarithmic transformation so, no multiplication was needed since we already have percentual deviations.



As we can see, indicator (6) is only relevant when the economy is in expansion and the second indicator in (7) is only relevant when the economy is in recession. In presence of asymmetry of this form, equation (2) can be written as:

$$U_t^c = \beta^+ I_t^+ y_t^c + \beta^- I_t^- y_t^c + \varepsilon_t \quad (8)$$

In this case, the Heaviside indicators take the form:

$$I_t^+ = \begin{cases} 1 & \text{if } y_t^c \geq 0 \\ 0 & \text{if } y_t^c < 0 \end{cases} \quad (9)$$

$$I_t^- = \begin{cases} 1 & \text{if } y_t^c < 0 \\ 0 & \text{if } y_t^c \geq 0 \end{cases} \quad (10)$$

In both cases, we test the asymmetry hypothesis through a typical F test for the null  $\beta^+ = \beta^-$ .

### 4.3. The Cointegration Hypothesis

In its most simple form, the cointegration analysis introduced by Engle and Granger (1987) states that two series are cointegrated if there is a long-run equilibrium between them. Technically, if two series are non-stationary and I(1) and if there is a stationary linear combination between them so, the two series are cointegrated in the form CI(1,1).

We do the cointegration analysis with the two-step method developed by Engle and Granger (1987). Let  $u_t$  be the logarithm of the unemployment rate and  $y_t$  the logarithm of real output, then, the univariate cointegration method estimates the following long-run equation:

$$u_t = \beta_0 + \beta_1 y_t + \varepsilon_t \quad (11)$$

Then it tests the stationarity of the residuals  $\varepsilon_t$ . The cointegration test applied is the conventional ADF test, which takes the form:

$$\Delta \hat{\varepsilon}_t = \rho \hat{\varepsilon}_{t-1} + \sum_{i=1}^p \Delta \hat{\varepsilon}_{t-i} + \mu_t \quad (12)$$

If the residuals are stationary we can assume the presence of a long-run equilibrium between real output and the unemployment rate, in some way validating “Okun’s law”.

Furthermore, if the two series are cointegrated, the *Granger Representation Theorem* says that there is a representation of the cointegrating equation in the form of an error correction model specified as follows:

$$\Delta u_t = \alpha_0 + \sum_{i=1}^p \beta_{1i} \Delta u_{t-i} + \sum_{j=1}^q \beta_{2j} \Delta y_{t-j} + \beta_3 \hat{\varepsilon}_{t-1} + \mu_{1t} \quad (13)$$

$$\Delta y_t = \alpha_0 + \sum_{i=1}^p \beta_{1i} \Delta y_{t-i} + \sum_{j=1}^q \beta_{2j} \Delta u_{t-j} + \beta_3 \hat{\varepsilon}_{t-1} + \mu_{2t} \quad (14)$$

Where  $\hat{\varepsilon}_{t-1}$  are the estimated residuals from the cointegrating equation (11), these are the estimated corrector of the disequilibrium observed in each quarter. The coefficient  $\beta_3$  is a measure of the speed of adjustment towards the equilibrium. Even if capturing a long-run equilibrium and correcting the short-run disequilibrium, the last specifications will not be correct if the adjustment to the long run is asymmetric. In that case, the dynamics introduced by equations (12), (13) and (14) will be misspecified. If in fact the unemployment rate behaves differently in each stage of the business cycle, there will be no reason to assume that the correction is made equally in the case of existing significantly different positive and negative deviations from the long run equilibrium.

Following the work of Enders and Granger (1998) and Enders and Siklos (2001), asymmetry can be introduced by a threshold variable that accounts for positive and negative deviations from equilibrium. After estimating the cointegrating equation (11), the method uses an asymmetric version of the ADF test that follows a Threshold Autoregressive Model (TAR) of the form:

$$\Delta \hat{\varepsilon}_t = I_t \rho_1 \hat{\varepsilon}_{t-1} + (1 - I_t) \rho_2 \hat{\varepsilon}_{t-1} + \sum_{i=1}^p \Delta \hat{\varepsilon}_{t-i} + \mu_t \quad (15)$$

The cointegration test is carried out by testing the null  $\rho_1 = \rho_2 = 0$  using a F test. Enders and Granger (1998) also point another test that although having lower power can be used at least informally to assess the cointegration hypothesis. This one, commonly called *t-max* takes the value of the most significant of the *t* ratios of the two coefficients  $\rho_1$  and  $\rho_2$ . Note that, since we have changed the dynamics of the ADF test, the two cointegration tests are non-standard and so, to proceed with them, we use the critical values simulated by Enders and Granger (1998), Enders and Siklos (2001) and Wane, Gilbert and Dibooglu (2007) that extended the simulations from the first two authors to include more lags in the asymmetric ADF equation. Any deviation from the presented structure should imply a new experiment simulation. The Heaviside

indicator  $I_t$  that is needed to include asymmetric dynamics in the cointegration test, is defined as follows:

$$I_t = \begin{cases} 1 & \text{if } \hat{\varepsilon}_{t-1} \geq \tau \\ 0 & \text{if } \hat{\varepsilon}_{t-1} < \tau \end{cases} \quad (16)$$

After testing for cointegration, asymmetry can be assessed through a standard F test for the null hypothesis  $\rho_1 = \rho_2$ . Regarding the threshold variable, we consider two hypotheses: first we consider  $\tau=0$  and second we estimate the consistent threshold through Chan's (1993) grid-search procedure. This algorithm can be described as follows: first, estimate the cointegrating equation (11) and then sort the residuals in ascending order. Second, eliminate the 15% lower and higher residuals and consider the rest 70% as possible thresholds. Third, the algorithm demands to estimate the asymmetric ADF equation (15) and the indicator (16) with each one of the residuals as possible thresholds, and, finally, choose the residual for threshold that held the lowest residual sum squares in equation (15). As shown in Enders and Granger (1998), a sufficient condition for stationarity of  $\hat{\varepsilon}_{t-1}$  is  $-2 < (\rho_1; \rho_2) < 0$ .

After detecting cointegration, the Error Correction Representation with asymmetric dynamics can be written as:

$$\Delta u_t = \alpha_0 + \sum_{i=1}^p \beta_{1i} \Delta u_{t-i} + \sum_{j=1}^q \beta_{2j} \Delta y_{t-j} + I_t \beta_3 \hat{\varepsilon}_{t-1} + (1-I_t) \beta_4 \hat{\varepsilon}_{t-1} + \mu_t \quad (17)$$

$$\Delta y_t = \alpha_0 + \sum_{i=1}^p \beta_{1i} \Delta y_{t-i} + \sum_{j=1}^q \beta_{2j} \Delta u_{t-j} + I_t \beta_3 \hat{\varepsilon}_{t-1} + (1-I_t) \beta_4 \hat{\varepsilon}_{t-1} + \mu_{2t} \quad (18)$$

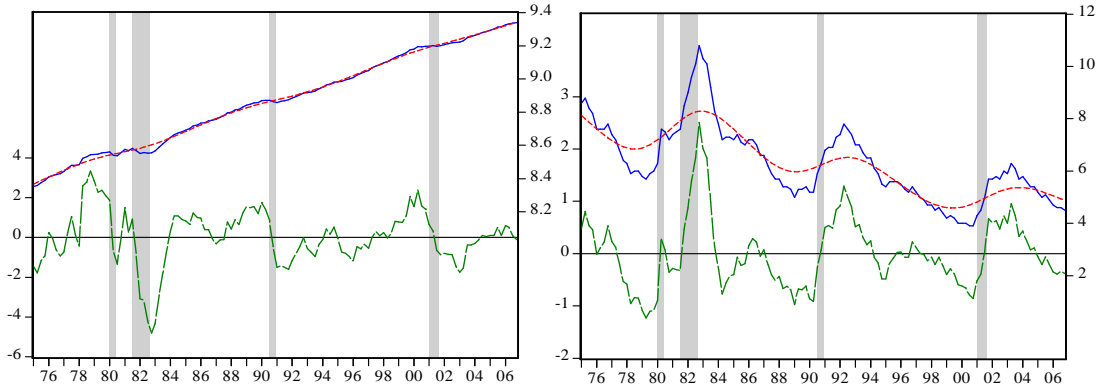
The use of this dynamic procedure is useful since we are able to know with higher accuracy the correction that is made by each one of the variables when subjected to shocks. Moreover, if we do not detect asymmetry in (15), i.e., if we do not reject the null hypothesis  $\rho_1 = \rho_2$  then we can see that the usual Engle and Granger procedure is a special case of the asymmetric specification.

## 5. Empirical Results

### 5.1. Preliminary Considerations

The results for the trend-cycle decomposition and the unit root tests are presented in the next tables and figures. The Figure 2 and the Table 1 show the descriptive analysis of the series obtained by the filtering process.

**Figure 2. Cyclical Components (HP  $\lambda=1600$ )**



**Note:** Cyclical Component of Real Output - Left and Cyclical Component of the Unemployment Rate – Right. Shaded Areas are NBER recessions.

**Table 1. Descriptive Statistics from Filtered Series (HP  $\lambda=1600$ )**

$X_j$	St. Dev.	St. Dev.(% $y_t - y_t^*$ )	Correlation of GDP with $X_j(t+i)$								
			X(t-4)	X(t-3)	X(t-2)	X(t-1)	X(t)	X(t+1)	X(t+2)	X(t+3)	X(t+4)
$y_t - y_t^*$	1.367	1	0.32	0.49	0.68	0.86	1	-	-	-	-
$U_t - U_t^*$	0.659	0.48	-0.30	-0.46	-0.63	-0.80	-0.90	-0.85	-0.73	-0.57	-0.39

**Note:** Maximum Correlation detached.

Table 1 gives the correlation of the unemployment rate with the output gap and the autocorrelation of the output gap. This analysis will enable us to obtain not only the degree of persistence of output but also the cyclical relation between the two variables, i.e., if the unemployment rate in fact lags real output. The criteria can be defined as in Dolado, Sebastian and Vallés(1993): let  $\rho_{y,U}$  be the correlation coefficient between the cyclical component of output and unemployment rate so, we say that the unemployment rate is a leading indicator if maximum correlation is obtained at  $t-i$  for  $i=1,2,3,4$  and a lagging indicator if maximum correlation is obtained at  $t+i$  for  $i=1,2,3,4$ . Furthermore, the unemployment rate is countercyclical if maximum correlation is negative and pro-cyclical if maximum correlation is positive.

The results presented in Table 1 suggest a high persistence of output, but it is also possible to observe a decrease after two quarters. The unemployment rate seems to be well synchronized with the real output since maximum correlation is obtained at  $t=0$ , which surprised us, although the correlation coefficient at  $t+1$  is somewhat high which is consistent with a lagged behavior. As we expected, the unemployment rate behaves as a countercyclical variable. In terms of volatility, the unemployment rate is clearly less volatile than output.

In the unit root analysis, we performed tests not only on the “raw” variables but also on the cyclical components, since we will use them to estimate the models (2), (3) and (8). As already said, we employ the commonly used ADF and the Phillips-Perron test. The results are presented in Tables 2 to 4.

**Table 2. Augmented Dickey-Fuller Unit Root Tests**

		Test Statistic					
		T <sub>c</sub>	lag's	t <sub>i</sub>	lag's	t	lag's
Akaike Pmax=6	Y	-0.944	1	-3.088	2	5.909	1
	u	-2.363	3	-3.469 **	3	-0.705	4
	Δy	-8.340 *	0	-8.356 *	0	-2.626 *	3
	Δu	-4.452 *	3	-4.426 *	3	-4.162 *	2
Akaike Pmax=12	Y	-0.595	12	-3.177***	12	3.656	12
	U	-1.763	8	-3.647 **	10	-0.754	8
	Δy	-4.041 *	11	-4.048 *	11	-1.978 **	12
	Δu	-4.204 *	7	-4.178 *	7	-4.178 *	7
Schwartz Pmax=12	Y	-0.944	1	-2.9	1	5.909	1
	U	-2.098	2	-3.469 **	3	-1.114	1
	Δy	-8.340 *	0	-8.356 *	0	-3.548 *	1
	Δu	-7.758 *	0	-7.728 *	0	-7.713 *	0
Mod. Akaike Pmax=6	u	-	-	-2.452	1	-	-
	Δu	-	-	-4.165 *	2	-	-

**Note:** \* Significant at 1%, \*\* Significant at 5%, \*\*\* Significant at 10%.

Pmax represents the maximum number of lags allowed.

t<sub>c</sub> is the test statistic with intercept, t<sub>i</sub> is the test statistic with intercept and trend, and t is the test statistic without intercept or trend.

**Table 3. Phillips-Perron Unit Root tests**

		Test Statistic		
		T <sub>c</sub>	t <sub>i</sub>	t
	y	-0.911	-2.892	8.519
	u	-1.904	-2.578	-1.010
	Δy	-8.410 *	-8.430 *	-5.303 *
	Δu	-8.019 *	-7.993 *	-7.973 *

**Note:** \* Significant at 1%.

t<sub>c</sub> is the test statistic with intercept, t<sub>i</sub> is the test statistic with intercept and trend, and t is the test statistic without intercept or trend.

**Table 4. Unit Root Tests for Cyclical Components**

		Test Statistic			
		t <sub>c</sub>	lag's	t	lag's
ADF Akaike Pmax=6	$y_t - y_t^*$	-4.005 *	2	-4.020 *	2
	$U_t - U_t^*$	-4.444 *	3	-4.462 *	3
Phillips-Perron	$y_t - y_t^*$	-3.473**	-	-3.484 *	-
	$U_t - U_t^*$	-3.262**	-	-3.272 *	-

**Note:** \* Significant at 1%, \*\* Significant at 5%, \*\*\*.

Pmax represents the maximum number of lags allowed.

t<sub>c</sub> is the test statistic with intercept and t is the test statistic without intercept or trend.

We start analyzing the results for the logarithm of output. Both tests confirm that GDP is well characterized by a unit root process. We can say that, when output is affected by a positive

shock, this leads to a revision of the forecasting for a long period. The results for the unemployment rate are not so strong (note that we are testing the log of the unemployment rate). In Table 2, the results of the ADF test points towards the stationarity along a linear trend. Changing the lag selection criteria doesn't seem to change the result, with exception of the modified Akaike criteria that chooses one lag and hence rejects this hypothesis. Looking now at the results of the Phillips-Perron test, used mainly to compare the results for the unemployment rate, it rejects the hypothesis of stationarity along a linear trend at the 1% level of significance. The results of the tests for the transitory components of output and unemployment rate produce the expected results, detecting stationarity in both cases.

## 5.2. Initial Specifications: Symmetry Versus Asymmetry

In this section we present the results of the estimation of equations (1) to (10). We start by presenting the results for the symmetric equations (1) to (4) in Table 5.

**Table 5. Results for Symmetric Models**

Eq.	$\alpha$	$\beta$	R-squared	AR(4)	LB(4)	White	JB	Reset	Dummies
Model (1), $\Delta U_t$	1.152 (10.472*)	-0.410 (-13.993*)	0.75	21.495*	61.211*	0.472	0.662	0.344	-
Model (2), $U_t - U_t^*$		-0.43 (-16.070*)	0.84	11.215*	45.128*	2.845	3.877	4.616**	3
Model (3)-(4), ADL(8,8)	-0.241 (-7.957*)	-0.395	0.92	0.325	0.259	34.160	2.773	0.588	-

**Note:** \* \*\* \*\*\* Rejection of the Null at 1%, 5% e 10% respectively.  
t ratios in parentheses.

For the ADL(8,8) model,  $\alpha$  represents the short-run coefficient and  $\beta$  the long-run coefficient.

AR(4) is the F version of LM test for the presence of serial Correlation up to fourth order and distributed as  $F(p;n-p-k)$ .

LB(4) is the Ljung-Box test for the presence of Autocorrelation up to fourth order.

White is the Heteroscedasticity test.

JB is the Jarque-Bera test for the Presence of Non-normality in the Residuals.

Reset is the Specification test.

Robust t ratios computed using the Newey-West Method when Autocorrelation or/and Heteroscedasticity is Present.

Lag Length in the ADL(p,q) selected through Akaike Information Criteria.

So, Table 5 shows that the estimated Okun's coefficient is very similar for models (1) and (2). Caution is needed in the interpretation of the results since they describe different things for the same dimension. Model (1) describes the effects of growth in the economy on the unemployment rate and model (2) describes the effects of output fluctuations. Overall the degree of adjustment is about 0.4. In the first model, we estimate that a 1% increase in the output in one year decreases the unemployment rate by 0.41 points, while in the second model, when real output grows 1% above the trend, the unemployment rate decreases by 0.43 points below its "natural" level. One problem with these models is the existence of autocorrelation, probably due to the omission of short-run dynamics. To correct this problem, we use the Newey and West (1987) method to estimate a robust covariance matrix. We also detect non-normality in the residuals of the second equation, so 3 dummies were introduced to correct the problem.

Bad specification was also detected by the RESET test in this equation. Since the estimations achieved by these two models are close, the problem may not be serious.

The estimation of the  $ADL(p,q)$  model, enables us to correct the lack of short-run dynamics in the last models and so account for autocorrelation. The lag length was selected using the Akaike criteria, but first we've tried to obtain an estimate without autocorrelation. Several estimations were performed imposing the restriction  $p=q$  for each lag length and the autocorrelation problem was only eliminated using an  $ADL(8,8)$ . The Akaike criterion, used to select the number of lags, also indicates that the model is appropriate despite the relatively high lag length. The estimated long-run coefficient is -0.395 which is close to the previous estimates and the short-run coefficient is -0.24, which is the short-run impact of output fluctuations on the unemployment rate.

The problem with these models is that they capture a combined effect of the evolution of output in the unemployment rate, disabling an evaluation of the effects of recessions and expansions separately. This problem can be solved through models (5) and (8), which produce the results presented in Table 6.

**Table 6. Results for Initial Asymmetric Models**

	$\beta^+$	$\beta^-$	$F(\beta^+=\beta^-)$	R-squared	AR(4)	LB(4)	White	JB	Reset	Dummies
Model (5), $\Delta U_t$	-0.403 (-9.051*)	-0.458 (-3.956*)	0.129	0.75	20.988*	60.252*	2.954	0.660	0.145	-
Model (5), $\Delta U_t^\Psi$	-0.224 (-6.096*)	-0.448 (-5.451*)	5.041**	0.44	1.853	6.762	1.685	1.437	1.312	-
Model (6), $U_t - U_t^*$	-0.403 (-11.809*)	-0.431 (-14.848*)	0.967	0.86	12.470*	46.898*	6.463	1.077	5.238**	4

**Note:** \* \*\* \*\*\* Rejection of the Null at 1%, 5% e 10% respectively.

t ratios in parentheses.

$F(\beta^+=\beta^-)$  is the Asymmetry test.

AR(4) is the F version of LM test for the presence of serial Correlation up to fourth order and distributed as  $F(p;n-p-k)$ .

LB(4) is the Ljung-Box test for the presence of Autocorrelation up to fourth order.

White is the Heteroscedasticity test.

JB is the Jarque-Bera test for the Presence of Non-normality in the Residuals.

Reset is the Specification test.

Robust t ratios computed using the Newey-West Method when Autocorrelation or/and Heteroscedasticity is Present.

$\Psi$  Quarterly Changes Regression.

It was included two estimations for equation (5). In the first one, we consider annual changes in the variables putting our attention more in the medium-run and eliminating the possibility of capturing the short-run adjustment, hence we estimated the same equation considering quarterly changes, which improved the results. We can see that the two estimates for each regime are different. The valid coefficient for recessions is higher than the one for expansions. Interestingly, the estimated expansions' coefficients for the first and third estimations are almost equal, taking the value -0.403, but the estimated coefficient considering quarterly changes is about 50% lower than these ones, specifically -0.224. The third equation continues to be misspecified as in the symmetric estimates and once again dummies had to be

incorporated to control for the non-normality in the residuals detected by the Jarque-Bera test. The question that we want to answer is: is asymmetry significant? The estimates gives the idea that, in fact, the unemployment rate seems to increase faster in recessions than decrease during expansions, which by itself would confirm the presence of an asymmetric behaviour. Considering the formal asymmetry test, denoted in the table by  $F(\beta^+ = \beta^-)$ , for the first and the third estimates, we are not able to reject the null, which was expected at least for the first estimate.

When we consider annual changes, we turn our attention to the medium run, so if asymmetry and disequilibrium existed, probably most of it is already corrected. So, the quarterly charges estimate, will probably capture this asymmetric nature of the unemployment rate since we are considering its short-run adjustment. Considering the underlying asymmetry test obtained with this estimate, we are able to reject the null at the 5% significance level and confirm the presence of asymmetry in the behaviour of the unemployment rate in the short-run. Once again we detach that in the short run, for each decrease in real output the unemployment rate increases faster than it decreases during output expansions.

### 5.3. Symmetry versus Asymmetry: Cointegration Analysis

Despite the apparent robustness of the estimates presented so far, they ignore the possibility of the existence of a long-run equilibrium, which if it really exists, implies that those findings are biased. The cointegration analysis not only accounts for this possibility but also makes possible to test for the presence of asymmetry. Having established that the logarithms of real output and unemployment rate are  $I(1)$  processes, we are able to test for cointegration using the Engle and Granger two-step procedure. The results are reported in Table 7.

**Table 7. Engle-Granger Cointegration Test**

	$\beta_0$	$\beta_1$	R-squared	AR(4)	LB(4)	White	JB	Reset
Coint. Eq. (11)	7.013 (7.948 *)	-0.586 (-5.912 *)	0.55	412.791 *	366.236 *	0.376	2.821	0.020
ADF - Akaike $P=8$	$t_p$ -3.160 *			0.509	0.407			

**Note:** \* \*\* \*\*\* Rejection of the Null at 1%, 5% e 10% respectively.  
t ratios in parentheses.

$t_p$  is the cointegration test without intercept or trend.

$P$  represents the number of lags used in the test.

AR(4) is the F version of LM test for the presence of serial Correlation up to fourth order and distributed as  $F(p;n-p-k)$ .

LB(4) is the Ljung-Box test for the presence of Autocorrelation up to fourth order.

White is the Heteroscedasticity test.

JB is the Jarque-Bera test for the Presence of Non-normality in the Residuals.

Reset is the Specification test.

Robust t ratios computed using the Newey-West Method when Autocorrelation or/and Heteroscedasticity is Present.



The obtained results suggest the presence of a long-run relation between real output and the unemployment rate in the U.S. economy. Since the two series are cointegrated, the estimate -0.586 is a “super-consistent” estimate for Okun’s coefficient, which is interesting since it is higher than our former estimates. Note however that we are assuming that the underlying adjustment is symmetric towards the equilibrium, which may not be true, and if not, the results from the symmetric cointegration are biased as well. So, we now test the possibility of cointegration with asymmetric adjustment, through equations (15) and (16), which will be performed in two ways. First we consider the case where the value of the threshold is  $\tau=0$  and second, we choose the optimal value of the threshold through Chan’s (1993) grid-search procedure already explained in section 4.3. The results of the several testes can be found in Table 8.

**Table 8. Asymmetric Cointegration Test**

Eq.	$\rho_1$	$\rho_2$	$\Phi_\epsilon$	$F(\rho_1=\rho_2)$	R-squared	AR(4)	LB(4)	White	JB	Reset	Lags	Dummies
$\tau=0$ <i>t-max</i> =-2.458	-0.087	-0.036	3.101	1.634	0.59	1.095	1.412	20.301	3.867	1.565	8	7
$\tau=0.1620$ <i>t-max</i> =-3.584*	-0.141	-0.057	6.785**	4.348 **	0.60	1.097	2.359	17.733	3.401	0.303	8	8

**Note:** \* \*\* \*\*\* Rejection of the Null at 1%, 5% e 10% respectively.  
t ratios in parentheses.

$\Phi_\epsilon$  and *t-max* are the Cointegration Tests.

$F(\rho_1=\rho_2)$  is the Asymmetry test.

AR(4) is the F version of LM test for the presence of serial Correlation up to fourth order and distributed as  $F(p;n-p-k)$ .

LB(4) is the Ljung-Box test for the presence of Autocorrelation up to fourth order.

White is the Heteroscedasticity test.

JB is the Jarque-Bera test for the Presence of Non-normality in the Residuals.

Reset is the Specification test.

Robust t ratios computed using the Newey-West Method when Autocorrelation or/and Heteroscedasticity is Present.

Lag Length selected using Akaike Criteria.

As for the previous models, the Akaike Information Criteria (AIC) was used to select the number of lags, with a maximum of 12. The Table 8 presents estimates for the two coefficients that determine the adjustment process  $\rho_1$  and  $\rho_2$ , the value of the F-statistic for the null of no cointegration,  $\Phi_\epsilon$ , the value of the statistic *t-max* for the null of no cointegration, the value of the F-statistic for the null of symmetric adjustment  $F(\rho_1=\rho_2)$  and the specification tests for each equation. For both equations, the AIC selected 8 lags which ensured an equation without autocorrelation. In the second estimate, the optimum threshold selected through the grid-search procedure was 0.1620. However, for both the estimations, dummies had to be used to control for non-normality in the residuals, seven for the first equation and eight dummies for the second. Efficient critical values for the tests were then computed through a Monte Carlo experiment with structures set by the two estimated equations. In the first case, we set a cointegrating equation with two variables with the unemployment rate and output substituted by two random-walks and an asymmetric ADF equation with eight lags, seven dummies and  $\tau=0$ . For the

second equation, the same procedure was used for the cointegrating equation but the asymmetric ADF equation included eight lags, eight dummies and  $\tau = 0.1620^5$ . The results from the simulations with 10 000 replications are presented in Table 9.

**Table 9. Simulated Critical Values**

Test Statistic	Threshold	1%	5%	10%
$\Phi_\varepsilon$	$\tau=0$	7.454	5.376	4.375
	$\tau=0.1620$	7.688	5.319	4.346
<i>t-max</i>	$\tau=0$	-3.424	-2.882	-2.601
	$\tau=0.1620$	-3.452	-2.882	-2.600

**Note:** Critical Values refer to 10 000 Replications with a Sample of 128 Observations. As example, for the *t-max* the values mean that 1% of the 10 000 replications exceeded -3.424 (for the zero threshold) and -3.452 (for the consistent threshold). The rest of the values were computed using the same process.

Using these simulated values, we are now able to perform the tests. For the first estimation, the value of the F-statistic is 3.101 which is not able to reject the null of no cointegration at any significance level and the *t-max* statistic takes the value -2.458 which again is not able to reject the null. So, we are not able to detect cointegration assuming that  $\tau=0$ . Since there is no reason to assume that the threshold is zero and as we've seen the results are not good in that situation, now we analyze the results for the case in which the threshold is consistently estimated. The value of the F-statistic is  $\Phi_\varepsilon = 6.785$  which is able to reject the null of no cointegration at the 5% level of significance. Using now the *t-max* statistic for the same purpose, we see that it takes the value -3.584 which rejects the null hypothesis at the 1% level of significance. After establishing cointegration in the asymmetric model, using a consistently estimated threshold, we test now the null of symmetric adjustment against the alternative of asymmetric adjustment. The statistic test takes the value  $F=4.348$ , which is able to reject the null of symmetry at the 5% level of significance, which means that we find cointegration with asymmetric adjustment between the unemployment rate and real output in the U.S. economy. Note that a positive deviation from equilibrium is eliminated at 14.1% each quarter and a positive deviation is eliminated only at 5.7%. A priori, this indicates that increases in the unemployment rate that cause deviations from equilibrium (during recessions), are eliminated faster than decreases. The adjustment in the case of a positive deviation is almost 4.5 times higher than the adjustment during a negative deviation.

<sup>5</sup> The procedure used is mainly the same as described in Enders and Granger (1998) and Dibooglu and Enders (2001) with the difference that we generated 10 000 random walks with standard deviation equal to unity from a standard normal distribution with 228 observations. In each replication the first 100 observations were discarded and the remaining 128 considered performing the estimations. We assume a pseudo random number with standard normal distribution for the first observation of each one of the simulated random-walks.

#### 5.4. Dynamic Adjustment and Error Correction Models

After establishing the presence of a long-run equilibrium, but with asymmetric adjustment towards it, we now turn to the underlying dynamic adjustment and the speed of adjustment that can be consistently estimated through equations (17) and (18). The idea behind the Error Correction Model (ECM) is quite appellative: if two variables exhibit a stable relation in the long run, but there is constant disequilibrium in the short run, then the ECM is able to determine and correct this disequilibrium and estimate the speed of adjustment towards the equilibrium.

In order to obtain a comparative platform, we present the estimates of the symmetric ECM in the equations (13) and (14). Note that, when the Engle and Granger method is used, the Error Correction Models can be estimated as a VAR in first differences incorporating the error corrector estimated by the cointegrating equation (11). The number of lags was chosen through the Multivariate Akaike Information Criteria.

**Table 10. Error Correction Models**

	Symmetric Model		Asymmetric Model		
<i>I</i>	$\beta_{3i}$	Lags	$\beta_{3i}$	$\beta_{4i}$	Lags
$\Delta u$	-0.093 (-3.486 *)	3	-0.109 (-2.391 **)	-0.083 (-2.375 **)	3
$\Delta y$	0.007 1.547		0.017 (2.211 **)	0.001 0.158	
AR(4)	5.900			5.811	
p-value	0.207			0.214	
White	39.03			50.405	
p-value	0.602			0.379	

**Note:** \* \*\* \*\*\* Rejection of the Null at 1%, 5% e 10% respectively.

t ratios in parentheses;

Lag Length selected using Akaike Criteria.

AR(4) is LM test for the presence of serial Correlation up to fourth order in the VAR.

White is the Heteroscedasticity test for VAR.

The Table 10 presents the estimates of the adjustment coefficients for each equation, and tests for the presence of autocorrelation and heteroscedasticity in the residuals. We start by the symmetric ECM. The Akaike criteria selects a model with three lags which gives the information that 9.3% of the disequilibrium verified in the unemployment rate is corrected each quarter, which corresponds to a total adjustment of 10.9 quarters or about 2.7 years and reveals a slow speed of adjustment in the economy. The output doesn't seem to be sensitive to the adjustment process, evaluating by the low speed of adjustment and the statistical insignificance of the coefficient at conventional levels which possibly mean that short-run disequilibrium can be persistent. Turning now to the results of the asymmetric ECM, the multivariate Akaike selects a model with three lags. The estimates confirm the presence of two different speeds of adjustment. In the case of the unemployment rate, when there is a positive deviation from

equilibrium, 10.9% of that disequilibrium is corrected each quarter, but in the presence of a negative deviation the speed of adjustment is only 8.3% in each quarter. In the case of real output, once again, our estimates show not sensitive in relation to the adjustment process. We estimate that a positive deviation from disequilibrium has an implicit speed of adjustment of 1.7%, although in the case of a negative deviation we estimate that the adjustment is not significant. These results are different from the one found by Harris and Silverstone (2001) that in the case of a positive deviation estimate an adjustment of 21.4% and in the case of a negative deviation obtain 2.2%. In the symmetric case they report a speed of adjustment of 11.6% for the unemployment rate, slightly higher than the one estimated obtained here.

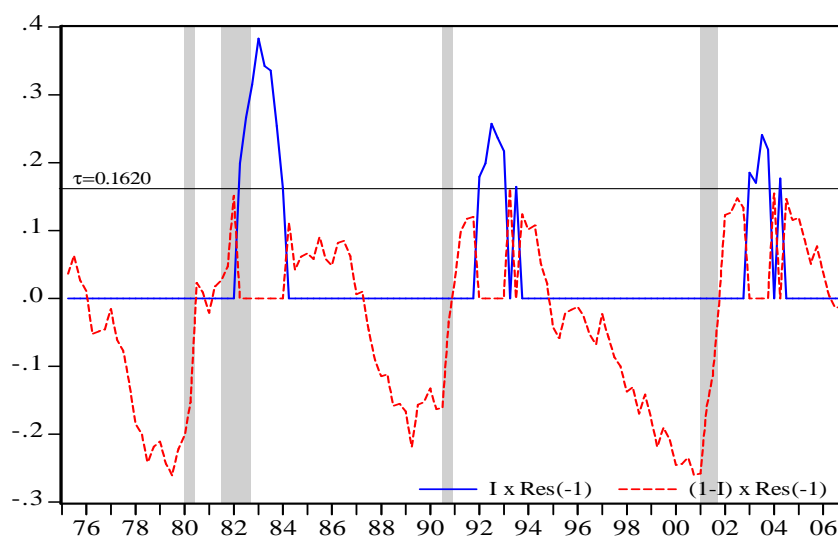
## **6. Discussion of Results**

The results presented in the previous section give a positive answer to our research objectives posed in the introduction. In fact, our results suggest that the dynamic adjustment between the unemployment rate and real output in the U.S. economy is asymmetric, but we need to shed some light on this subject, specifically, what do we mean by positive and negative deviations of the unemployment rate from disequilibrium and by asymmetric behavior of the unemployment rate. By positive deviations we mean increases in the unemployment rate from the long-run equilibrium and by negative deviations we mean decreases in the unemployment rate from the equilibrium. We believe that, positive deviations are connected with recessions and negative deviations are connected with expansions, so, both of these states push the economy away from equilibrium. That is to say, if disequilibrium is due to the different states of the economy, expansions and recessions, as well as their characteristics, depth and duration, then the threshold variable should be able to capture the effects of these different states of the cycle on the unemployment rate. If this is true, the estimated speeds of adjustment represent the underlying adjustment during those phases of the cycle.

The evidence presented in this paper, suggests that the unemployment rate adjusts quickly during recessions but the return to equilibrium may be slower during expansions. As a way of testing this thought, Figure 3 shows the asymmetric pattern in the error correction term, i.e., the error correction multiplied by the Heaviside indicator computed with the optimal threshold, which represents the short-run adjustment that push the economy back to equilibrium.

The graph in Figure 3 reveals that in fact, during recessions, which are represented by the shaded areas, occur positive deviations from equilibrium as predicted. For other side, the negative deviations seem to be longer than positive deviations and also deeper, with exception of the one correspondent with the second oil shock period. Moreover, adjustments in the case of positive deviations tend to be quick and with lower amplitude.

**Figure 3. Asymmetry in the Error Correction Term**



**Note:** Shaded Areas are NBER Recessions.

The central question is why do we observe these differences in the adjustment? In first place, we believe that this fact is intimately connected with the flows in the labor market. Probably the transitions employment→unemployment and employment→”out of the labor force” during recessions (which push the unemployment rate up) are quicker than the transitions unemployment→employment and “out of the labor force”→employment during expansions. As a consequence, real adjustments during recessions can be higher, what would justify a higher speed of adjustment in the presence of positive deviations of the unemployment rate from equilibrium. Furthermore, as Harris and Silverstone (2001) suggest, if prices are imperfectly flexible in the short run and nominal adjustments happen predominantly during expansions, then this would explain a slower adjustment during this phase since real adjustments may be conditioned by nominal adjustments.

Other explanations focus the fact that it takes time to train new workers and so, low adjustment is a direct consequence. For example, the model of McKay and Reis (2007) suggest that firms face asymmetric costs in adjusting labor in the sense that hiring new workers implies training them (subject to decreasing returns to scale) while firing costs are constant. Mismatch problems in the labor market can also exist, with a decrease in job creation and reduced flow of workers into employment.

## 7. Concluding Remarks

In the attempt of assessing the dynamic adjustment between the unemployment rate and real output in the U.S. economy, the majority of the literature assumes that the adjustment from the

short to the long run is symmetric, independently of the state of the economy. In this study, we depart from this probably bad assumption and show that it can lead to different results and hence policy recommendations.

The tests performed can be divided in two groups: the first stands for the assumption that the unemployment rate behaves differently in the different states of the business cycle, and another group that allows for the possibility that there is a stable equilibrium between the two aggregates, but where the short-run adjustment is made differently depending on the shock that caused the deviation from equilibrium. We believe that the two methods are strongly connected and in fact, test the same characteristic of the unemployment rate since we assume that deviations from equilibrium are caused by expansions and recessions. The cointegration analysis based on an Optimal Threshold Autoregressive model delivers consistent results.

The results suggest that positive deviations from equilibrium are not corrected with the same speed as negative deviations. We present evidence that the unemployment rate increases faster in recessions than it recovers during expansions. Using the threshold cointegration analysis we also find that positive deviations from equilibrium, which are associated with less prosperous phases of the economy are corrected at a higher speed than negative ones. We also believe that this asymmetry is connected with the flows within the labor market in which transitions during recessions can be faster than transitions during expansions and this can also be associated with nominal rigidities or imperfectly flexible prices in the U.S. economy that cause the adjustment during expansions to be slower. Future research should further address this and would also be interesting to relate the results here presented with new findings that suggest a possible asymmetric behavior of the business cycle.

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