Master Thesis

The Validity of Okun’s Law in the Swedish Economy

Submitted by:-

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Abstract

This thesis work examines the relationship between unemployment and GDP. Objective of this research is to investigate the presence of Okun’s (1962) relationship in the Swedish economy. The gap equation and technique of Hodrick-prescott filter (HP) is used for short run analysis to test Okun’s law, whereas co-integration model and the error correction model is used to test the relationship between unemployment and GDP in the short and long run. The study shows that the Okun’s law exists in the Swedish economy from the period 1993 quarter 1 to 2009 quarter 2. This research also proves that there exist a long run and short run relationship between unemployment and GDP.
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CHAPTER 01- Introduction

Swedish economy has faced a negative growth rate during the global financial crisis that started in autumn 2008 which resulted in a decrease of GDP by 4% but unemployment did not increase as expected. This scenario became a challenge for policy makers as they expected a strong increase in unemployment. Okun’s law is the most relevant method to analyze and describe the negative relationship between GDP and unemployment.

In the early period of Kennedy Administration, The council of Economic Advisers Washington DC asked Arhtur Okun to estimate relationship between GNP and level of unemployment in USA. Okun’s result stated that there will be a gain in GDP with decrease in unemployment from 7% to 4% of the labor force. These results led Okun to discover that an increase in unemployment by 1% will result in a reduction of GNP level by 3%. These results were challenging for the policy makers which indicate the decrease in output more significantly as compared to increase in unemployment. The main theme of the Okun’s findings is “increase in labor force size, increased working hours and more productivity” (Okun 1962).

This paper identifies ‘The Validity of Okun’s Law in the Swedish Economy’. In this research, I will study the relationship between the levels of unemployment to the output growth and check whether Okun’s (1962) historical relationship exists in the Swedish economy. Different versions of Okun’s law are used by Okun himself as the difference version, gap and dynamic version. In this thesis, the gap version is used to estimate Okun’s coefficient. The technique of Hodrick Prescott Filter Detrending Method (HP) is used for the smoothness of data. The main objective of the research is to study a long and short run relationship between unemployment and output. The Augmented Dickey-Fuller test (ADF) and the error correction model (ECM) are applied to check the stationary for long and short run as well. Quarterly time series data of unemployment and GDP from 1993 quarter 1 to 2009 quarter 2 is used to estimate the validity of Okun’s law in the Swedish economy. Statistics Sweden (SCB) and NIER (National Institute of Economic Research) are the sources of the data.

In this paper, the econometric model was taken from Silverstone (2001). This study was cross-country comparison. However, according to my knowledge, no previous work has been done in the analysis of the relationship between Swedish GDP and unemployment with this technique,
furthermore, by focusing on the period of 1993 quarter 1 to 2009 quarter 2. This study is more updated than earlier Swedish studies of Okun’s law.

The rest of this paper is organized as follows. The introduction is followed by a presentation of figures on GDP and unemployment in Sweden over the years. These figures are compared with similar data for other OECD countries. Chapter 3 comprises of literature review and Okun’s findings. In chapter 4, my econometric model and methodology is depicted. Chapter 5 includes results and discussion where as Chapter 6 contains conclusion. References and appendices for unemployment, GDP and ECM can be found in chapter 7 and 8 respectively.
CHAPTER 02

2.1 GDP and unemployment in Sweden

During 1990s, the home-made recession led to a slow-down in economic growth. GDP fell down in the 1990-1993 period as 4% decreased in GDP recorded in terms of volume. However, the growth rate paced up after 1993. Between the periods of 1998 to 2000, the volume growth rate was just over 4% annually which was higher than corresponding countries.

Figure1: Quarterly seasonally adjusted growth rate in Sweden 1993 quarter 2 to 2009 quarter 2

Source : OECD

In 2000, Swedish economy was affected by a strong economic downturn due to the crash of the IT industry in the early part of 2000 after the years of economic growth. This economic crisis was followed by the economic boom as world trade increased sharply which led to a rapid increase in the export growth of Sweden. In the 2004-2006 period, Swedish volume growth went up to 4%. However, in 2007, the economic growth slowed down again. In the later part of 2008, the financial crisis led to a deep recession. During 2009, GDP growth fell and recovered fairly in 2010.
In the period of 1990s, Swedish economy faced a deep economic recession due the enormous increase in unemployment and fast growing budget deficit as unemployment went up to 8%. By 1994, addition of students in the labor force resulted in an increase in the adjusted unemployment rate from 7.8% to 9.6%. In 1996, Swedish government revised the policies in order to reduce the unemployment from 8% to 4% by 2000. This rate was achieved in autumn 2000 which remain stable till 2002. However, in 2003, unemployment accelerated to 4.9%. In 2006, unemployment rate went up to 7.1% and fell down by 6.2% in 2007.

Figure 2 Quarterly unemployment rates in Sweden 1993 quarter 1 to 2009 quarter 2

![Graph of quarterly unemployment rates in Sweden 1993 to 2009](image)

*Source: SCB*

In the last period of 2008, unemployment rate began to increase from the third quarter to fourth quarter, seasonally adjusted. In 2009, unemployment rate reached to over 9% due to international financial crisis.

In the 1990-1993 periods, unemployment maintained a rate of 2-3% with gradually increasing GDP because of the lending in real estate and financial market which affected the price level. During the early 1990s unemployment rate reached the historically record rate 13% while GDP decreased dramatically due to home-made recession. In the 1996-2000 periods, government...
policies led to a fall in unemployment rate from 8% to 4% and GDP reached to 4% which was better than other comparable countries.

**Figure 3 Comparison of quarterly seasonal adjusted GDP and unemployment rate of Sweden (1993 quarter 1 to 2009 quarter 2)**

![GDP and Unemployment](image)

*Source: SCB*

In the 2004-2006 periods, unemployment accelerated again and maintained an average rate of around 7.5% in the whole period while GDP went up to 4%. During 2007, unemployment decreased to 6.2% and economic growth slowed down again. In 2008, unemployment started to increase in the fourth quarter and GDP fell down due to the international financial crisis.

### 2.2 Unemployment and growth rate in OECD countries

When the comparison of Swedish growth rate with other major economies is made, it is realized that the Swedish GDP Growth rate has been fewer than United States and OECD countries as well. Swedish GDP growth rate has been increased quite well in comparison to other countries since mid 1990s. Due to this, the gap has been narrowed in comparison to other countries. Figure 4 illustrates Swedish growth rate compares to other OECD countries from the period of 1993 quarter 2 to 2009 quarter 2.
Figure 4 seasonally adjusted growth rate comparison between Sweden and OECD countries from 1993 quarter 2 to 2009 quarter 2

From mid 1990s till 2009, average quarterly GDP growth was 0.65% and reached to maximum level of 2% in 2002 in Sweden. In 2004-2006 period, Swedish volume growth went up to 4%. However, in 2007, the economic growth slowed down again. In the later part of 2008, the global financial crisis led to a deep recession. During 2009 GDP growth fell down in Sweden. This growth rate showed its lowest GDP growth level in the fourth quarter of 2008 which is even lower than other OECD countries. However, Japan’s GDP growth fell more than any other OECD country’s growth rate during the first quarter of 2009.

Unemployment in OECD countries decreased in the 1993-2004 period but with different trends in each country. Figure 5 shows unemployment in OECD countries including Sweden from 1993 quarter 1 to 2009 quarter 2.

Source: OECD
Swedish economy experienced a relatively strong decrease in unemployment during 1993-2003. This decrease was even stronger than that in the United Kingdom, United States and New Zealand. However, a rapid increase in unemployment took place in Sweden in 2005 compared to other OECD countries. The fall in unemployment in Sweden during 2008 was relatively strong. But the level of unemployment in the same period was still higher than that in other OECD countries and the United States. In the year 2008, world economies were hard hit by recession which led to an increase in unemployment in Sweden as well as other OECD countries. However, Norway was the country which experienced the lowest unemployment level compared to other OECD countries in 2007 to 2009.

Source: OECD
CHAPTER 03

3.1 Okun’s formulation

Okun (1962) proposed two empirical relationships linking the rate of unemployment to real output. These relationships were two simple regression equations which have been used as rules of thumb since then. These equations extended by the economist to consider the elements which were neglected by Okun. These relationships came from the observations that more labor is required to produce more goods and services in the economy. In order to increase the production, additional labor can be achieved in various ways such as having more employees working longer hours or by recruiting more workers. Okuns estimated 3 to 1 relationship from three versions.

The difference version approach:

In Okun’s very first approach a relationship was established between quarterly changes in unemployment rate and the real output. This relationship can be written as

\[ \text{Change in unemployment rate} = c + d^* (real \ output \ growth) \]

This equation shows how the growth rate and unemployment rate change simultaneously, where \( d \) is the Okun’s coefficient having negative value. This means that an increase in growth rate would lead to a decrease in the unemployment level and a reduction in output is associated with rise in unemployment.

Okun used data from 1948 quarter 2 to 1960 quarter4 to derive the following equation:

\[ \text{Change in unemployment rate} = 0.30 – 0.07^* (real \ output \ growth) \]

The value of Okun’s negative coefficient is 0.07. This value explains that at every percentage point of real output growth over 4% is related with decrease in unemployment rate by 0.07 percentage point. Furthermore, with no increase in economic growth, unemployment will tend to increase by 3% from one quarter to another. Thus an annual growth of around 4% is mandatory to keep unemployment unchanged.
The gap version:

With the difference approach, Okun estimated the parameter values on the basis of quarterly unemployment and real GDP data. In the gap version approach, he focused on the gap between actual and potential output. Okun tried to identify the level of production under the condition of full employment. “Full of employment is a situation where everyone is able to get a job if they would like one”. Okun considered an unemployment level low enough to produce maximum without creating extra inflationary pressure.

Okun concludes that a high rate of unemployment will be related with idle resources. In such scenario, the actual rate of output is expected to be below its potential and vice versa in case of low unemployment rate. Okun’s relationship in the case of gap version can be written as follows:

\[
\text{Unemployment rate} = e + f^* (\text{gap between the actual and potential output})
\]

Where \(e\) is constant coefficient which shows the unemployment rate related to full employment and the positive value of ‘f’ explain the gap version approach.

Okun’s gap version equation was based on the assumption that full employment occurs when unemployment is at 4%. On the basis of this assumption, Okun constructed a series of potential output for the US. Different level of potential output can be found with change in the assumptions of full employment.

Dynamic version approach:

According to Okun’s observations, current level of unemployment can be affected by both current and past output. Okun’s analysis below indicates a relationship between past and current output on the one hand and current level of unemployment on the other.

A common form of the dynamic version of Okun’s law is

\[
\text{change in the unemployment rate} = a + b(\text{output growth})_t + c(\text{output growth})_{t-1} + d(\text{unemployment rate})_{t-1} + \mu_t
\]

Where \(a\), \(b\), \(c\) and \(d\) are the parameters.
With the common form of Dynamic version of Okun’s law, the right hand side of the equation has current output growth, previous output growth and the past changes in unemployment as variables. Equation explains the current change in unemployment with respect to the change in variables on the right side. The dynamic version of Okun’s law has some resemblances with original difference version of Okun’s law. The drawback of the dynamic version is that this version doesn’t have the simple interpretation compare to other versions of Okun’s law.

**Production-function version:**

Okun did not use the production-function version for his own formulations. Okun observed in his relationship that the unemployment rate is ideal when output is affected by idle resources. Economic theories indicate that the production of goods and services requires a combination of labor, capital and technology. Economist use other factors such as population, fraction of the population in the labor force and the number of hours with labor, capital and technology in order to have a clear picture for the analysis of elements that effects output. Hence, the production-function is a particular way in which labor, capital and technology is combined to produce output.

### 3.2 Literature review

In this thesis, our main focus is on empirical analysis. Several studies have been performed to examine the relationship between unemployment and growth rate using different versions of Okun’s law.

Knotek (2007) used three versions of Okun’s Law. First, he used the difference version and estimated unemployment rate from one quarter to the other. Second, Knotek also used the gap version to calculate the gap between the potential output and actual output. Third, in the dynamic version he analyzed the effects of unemployment on the past level of output, current level of output and past level unemployment.

Loria (2007) used three structural time series models and a Kalman filter on the data. Loria used Mexican quarterly data for the analysis. He compared the results from the related studies with the results from a study based on annual data. Loria based his study on Okun’s gap version, difference version and dynamic version approach to estimate the Okun’s coefficient which varied from 2.35 to 2.58.
Gylfason (1997) used a production function to calculate the output which is further used in Gap version. He used Swedish data for the analysis and found a 3 to 1 ratio relationship between output gap and unemployment exactly as in previous historical relationships. In early 1990s when Swedish economy experienced a deep crisis by home and discovered that the increase in unemployment was beyond the prediction of gap version of Okun’s law.

Silverstone (2001) assumed a symmetric relationship between changes in unemployment and output. This assumption means that expansions and compression in output have same absolute impact on unemployment, might not be always suitable. Okun used Gap version for short run analysis. He tested the co-integration in the long run and an error correction model in the short run. His study was based on data across countries.

Adanu (2002) estimated Okun’s coefficient using the gap version approach for ten Canadian provinces. He used two methods to estimate Okun’s coefficient with the Hodrick Prescott detrending method (HP) and under the quadratic detrending method (QT). He found relative stability of the coefficients for the two detrending methods.

Sinclair (2004) used the gap version to examine the bivariate correlation between unemployment and output. He divided the two macroeconomic variables in a permanent and a transitory component and then he estimated correlation of these components. By applying this model to the US economy, he noted that the fluctuation between output and unemployment is largely permanent and there is a presence of negative relationship between these permanent components.

Vougas (2003) used the dynamic version. He used non-accelerating rate of unemployment (NAIRU) to find the natural rate of unemployment. Vougas estimated (NAIRU) from a Philips curve taking account of hysteresis effect. With the hysteresis theory, the natural rate of unemployment can be determined from the previous rate of unemployment.

Petkov (2008) applied the Hodrick-Prescott filter into an autoregressive distributed lag model (ARDL) by combining both the economic and statistical approach. Petkov used the HP filter to capture the (NAIRU) which was furthered by error correction model (ECM) to estimate the Okun’s coefficient. He discovered a relationship between output growth and unemployment. The dynamic version of Okun is similar to that in Knotek (2007). Petkov used a regression method to explain the dynamic relationship.
To summaries the empirical studies, the empirical and economic approach is used in different scenarios. In almost every study, there have been two common variables namely unemployment and output. Gap, difference, dynamic and production-function versions have been applied to calculate Okun’s coefficient which shows the relationship between unemployment and output. The techniques of the HP filtering and the Kalmar have been used to smooth the data in accordance with the error correction model (ECM) and the co-integration method for analyzing the relationship between unemployment and output in short and long run.
CHAPTER 04

4.1 The Econometric Model

My econometric study of Okun’s law is based on the gap version. The argument for the gap version is that it provides a better explanation of unemployment and GDP relationship compared to the dynamic version. The gap version of Okun strives to show the difference between actual and potential output and assume that there will be maximum production level under full employment condition with no pressure of inflation.

The model is divided into two parts. The first part is about the estimation of a simple gap equation framework that establishes the short-run relationship between GDP and unemployment. The second part is about error correction model (ECM) and co-integration for the short and long run analysis between unemployment and GDP.

The simple gap equation framework

My gap equation is a clear representative for Okun’s law and it has direct correspondence in the empirical literature. This equation was used by Silver Stone (2001).

In regression framework or Okun’s gap version equation, unemployment gap is taken as dependent and GDP gap is taken as independent. After the use of natural logarithms the equation can be written as:

\[ U_t - U_t^* = b(Y_t - Y_t^*) + e_t, \text{where } b < 0 \]  

(1)

Where \( Y_t \) is actual real GDP level, \( Y_t^* \) is potential GDP level, \( U_t \) is the actual unemployment rate, \( U_t^* \) is the natural rate of unemployment. The values of \( Y_t^* \) and \( U_t^* \) can be obtained by estimating the corresponding trends of GDP and unemployment where \( e_t \) is random error term. The above equation (1) expresses the Okun’s law. The coefficient \( b \) shows the changes in unemployment that is accrued to change in GDP. Thus Okun’s coefficient can be estimated by taking the reciprocal of the coefficient \( b \) as below.

\[ \text{Okun’s coefficient} = 1/b \]  

(2)
The error correction model (ECM) and co-integration

The error correction model (ECM) is applied to get the information for short and long run relationship between GDP and unemployment. While co-integration used to check the existence of relationship between two variables in a long run.

4.2 Methodology

My regressions are constituted by two parts. In first part, I estimate simple gap equation and establish a short-run relationship between GDP and unemployment. The techniques of the Hedrick-Prescot (HP) filter are used to smooth the data.

In the second part, I used the error-correction model using the Engle-Granger two step method in order to test the relationship between unemployment and real output growth with quarterly data from 1993 quarter 1 to 2009 quarter 2 of Sweden.

The error-correction model using the Engle-Granger two step method

The co-integration error correction model (ECM) in economics is used to generate information about the short and long run dynamics of economic relationships. After regressing two variables of unemployment and GDP, I used the residuals of regress equation and applied the Augmented Dickey-Fuller test (ADF) test on those residuals for co-integration.

The long run regression equation is

\[ Y_t = \alpha_0 + \alpha_1 U_t + \alpha_2 T + \varepsilon_t \]  \hspace{1cm} (3)

Where \( \alpha_0 \), \( \alpha_1 \) and \( \alpha_2 \) are the parameters, \( \alpha_2 \) is the long run coefficient. Where time trend “\( T \)” is included to analyze a long-run relationship between GDP and unemployment. This regression analysis includes the concept of co-integration and the error correction model (ECM) (Haris and Silverstone, 1990).

By using co-integration, the relationship between these two variables has been figured out. According to this approach there is, at most, a single long-run relationship between \( Y_t \) and \( U_t \). This is mentioned in the following equation 3. Both \( Y_t \) and \( U_t \) are assumed to be integrated of the order 1or I(1).
The Engle and Granger equation is
\[ \Delta \epsilon_t^* = \gamma_0 + \gamma_1 \epsilon_{t-1}^* + \mu_t \]

According to Engle and Granger (1987) co-integration exists if
\[ \epsilon_t^* \sim I(0) \]

Null hypothesis: there is no co-integration between GDP and unemployment if \( \gamma_1 = 0 \) or \( \epsilon_t^* \sim I(1) \)
alternative hypothesis: there is co-integration between GDP and unemployment if \( \gamma_1 \neq 0 \) or \( \epsilon_t^* \sim I(0) \) where \( \epsilon_t^* \) is the residuals. The ADF test is applied to check for all above procedure.

The error correction model (ECM) is
\[ \Delta Y_t = \beta_0 + \beta_1 \Delta U_t + \beta_2 \epsilon_{t-1}^* + \omega \quad (4) \]

Where \( \epsilon_{t-1}^* \)
\[ \epsilon_{t-1}^* = Y_{t-1} - \alpha_0 - \alpha_1 U_{t-1} - \alpha_2 T \]

Where \( \Delta \) represents the first difference operator, \( \beta_1 \) is the short run coefficient and \( \epsilon_{t-1}^* \) is the lagged equilibrium error. \( \beta_2 \) is the coefficient of lagged equilibrium error where \( \omega \) is the random error term. Equilibrium error term comes from long run equation which is as follows:
\[ Y_t = \alpha_0 + \alpha_1 U_t + \alpha_2 T + \epsilon_t \quad (5) \]

As mentioned in eq.5 that unemployment and GDP are co-integrated since there is long term relationship or equilibrium between them. Certainly, there can be disequilibrium in the short run due to the error and this error term in the eq.5 can be termed as ‘equilibrium error’. This error term can be used to tie the short run behavior of the GDP to its long run value.
CHAPTER 05

Results and Discussion

I focused on quarterly data of unemployment and GDP of Sweden from 1993 quarter 1 to 2009 quarter 2. I found an inverse relationship between unemployment and GDP by using Okun’s gap version approach. Table.1 shows the estimated results.

Table. 1

<table>
<thead>
<tr>
<th>Output-Unemployment Relationship with gap version</th>
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<tbody>
<tr>
<td>Models</td>
</tr>
<tr>
<td>$U_t - U_t^* = b(Y_t - Y_t^*) + e_t$</td>
</tr>
</tbody>
</table>

Note: $\Delta y_t$ = Gap between actual and potential GDP level, $\Delta u_t$ = Gap between actual and potential unemployment level

The estimated regression equation as mentioned in econometric model shows that if there is one percent change in the unemployment gap, there will be 2.2% change in the GDP gap in the opposite direction.

I applied the error correction model (ECM) for the short run and long run. Before applying the ECM, I found the nature of the data as stationary at I (1) by using the ADF test. Since both unemployment and GDP are stationary at I (1).

The simple long run regression equation as mentioned in methodology chapter

$$Y_t = \alpha_0 + \alpha_1 U_t + \alpha_2 T + \epsilon_t$$

And the regression equation estimated form is

$$Y_t = -28.71 - 0.06U_t + 0.02T$$

(t-values) (-29.41) (-15.52) (42.69) Adjusted $R^2$=0.97
Now to check if the model is co-integrated, I first apply the ADF test in the residual of the above regress model to find if the data is stationary since we know that there is co-integration if the data is stationary. The ADF test results indicate that data is stationary which proves that there’s co-integration between unemployment and GDP.

The value of test statistic is -2.425, which is less than critical value of -1.95 with 66 observations and 5 % significant level. We can reject the null hypothesis of the unit root in the model. We know that both unemployment and GDP series is I (1) and the series of the residuals is I (0); hence, unemployment and GDP are co-integrated where -0.06 percent is the long run Okun’s coefficient which shows the inverse relationship between unemployment and GDP. The GDP level is positively related with time and statistically significant. The estimated coefficient shows that increase in one period result in the reduction of GDP by 0.02 percent.

The error correction (ECM) model is

\[ \Delta Y_t = \beta_0 + \beta_1 \Delta U_t + \beta_2 \epsilon^*_t - 1 + \omega \]

The estimated form of the error correction (ECM) model is

\[ \Delta Y_t = 0.005 - 0.06\Delta U_t - 0.89\epsilon^*_t - 1 \]

(t-values) (2.96) (-4.5) (-6.5)

The ECM model shows that GDP and unemployment have short run and negative relationship. The estimated ECM model shows -0.06 percent as the short run coefficients while the error correction term as negative and significant. The absolute error term suggests a fast adjustment process towards the equilibrium in the current quarter, the coefficient of the \( \epsilon^*_t - 1 \) shows the percentage of the disequilibrium of the previous quarter shock adjust back to the long run equilibrium in the current quarter which is very high.
CHAPTER 06

Conclusion

This paper traces out the significant short run and long run relationship between GDP and unemployment in the Swedish economy. I empirically conclude a significant negative relationship between GDP and unemployment which validates the famous Okun’s law (1962). The gap equation is estimated by using the HP filter which proves the short run significant negative relationship. The coefficient shows that if there is one percent change in the GDP gap, there will be 2.2 percent change in the unemployment gap in the opposite direction. It proves Okun’s law but the Okun’s coefficient decreased at 2.2 percent approximately. These results show the 2 to 1 relationship between unemployment and GDP which is contradict of the Okun’s (1962) results 3 to 1. Richard G. Sheehan mentioned in ‘The Variability of Okun’s coefficient’ that Tatam found a same 2.2 percent Okun’s coefficient which was the output loss linked with every one percent change in unemployment in surplus of the full employment level. Loria and Ramos (2007) found that the Okun’s coefficient ranges from 2.3 to 2.5 which are almost equal to the result derived in this paper.

The long run Okun’s coefficient -0.06 also proves the significant negativity of output unemployment relationship. The results show that the GDP and unemployment are co-integrated to each other in the long run since residuals of regressed variable are stationary at I(0). The study also analyzes the short run coefficient by using the error correction model (ECM) which proves the significant negative relationship between unemployment and GDP since the short run Okun’s coefficient is -0.06.

The result showed in the paper gives us a clear picture of effects of unemployment and GDP for the Swedish economy. The result supported by various authors for different time periods which helped us to use it as a good tool for analysis, forecasting of the business cycle and estimate the nature of the relationship between unemployment and GDP. Furthermore, economic policy should focus on increasing unemployment rate and at the same time avoid reduction in the growth rate.
**Acknowledge**

First and foremost I offer my sincere gratitude to my supervisor, Prof. Lennart Erixon who has supported me throughout my thesis with his knowledge and enthusiastic ideas. Without him this thesis would not have been completed or written. One could not wish for a better or friendly supervisor than him.

I got the opportunity to have very friendly and encouraging fellow students. They maintain a very healthy environment that was very productive and cheerful. I specially thanks to Ghalib Abbsar Minhas and Umair Akhtar for his valuable arguments regarding different aspects of the project.

Finally, I would like to say thanks to my parents and my wife who supported me throughout my studies in University.
References


21. Statistiska Centralbyrån (Statistics Sweden) (www.scb.se)
Appendices

Hodrick-Prescott Filter for Unemployment

Hodrick-Prescott Filter for GDP
### Gap version of Output-Unemployment Relationship

Regression

Dependent Variable: U  
Method: Least Squares

Sample(adjusted): 1993:2 2009:2  
Included observations: 65 after adjusting endpoints  
Convergence achieved after 59 iterations  
Backcast: 1992:2 1993:1

<table>
<thead>
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<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
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</table>

R-squared 0.795946  
Mean dependent var 0.003270  
Adjusted R-squared 0.785911  
S.D. dependent var 0.098528  
S.E. of regression 0.045588  
Akaike info criterion -3.278760  
Sum squared resid 0.126777  
Schwarz criterion -3.144952  
Log likelihood 110.5597  
Durbin-Watson stat 1.734415

Inverted AR Roots  
.73

Inverted MA Roots  
.54-.61i  .54+.61i  -.71+.60i  -.71-.60i
Augmented Dickey-Fuller test unit root for GDP

Call: lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
Residuals: Min 1Q Median 3Q Max
-0.030068 -0.012436 0.001507 0.009118 0.032808
Coefficients: Estimate Std. Error t value Pr(>|t|)
Z.lag.1 -0.0003578 0.0001691 2.116 0.03878 *
Z.diff.lag1 -0.1138537 0.1263876 -0.901 0.37154
Z.diff.lag2 -0.1154163 0.1215246 -0.950 0.34633
Z.diff.lag3 -0.1307326 0.1210598 -1.080 0.28482
Z.diff.lag4 0.2949383 0.1101100 2.679 0.00969 **
--- Signif. Codes: 0 ***, 0.001 **, 0.01 *, 0.05 , 0.1 , 1
Residual standard error: 0.014 on 56 degrees of freedom
Multiple R-squared: 0.2663, Adjusted R-squared: 0.2008
F-statistic: 4.065 on 5 and 56 DF, p-value: 0.003222

Augmented Dickey-Fuller Test Unit Root Test for GDP (Stationary data)

Test regression drift
Call: lm(formula = z.diff ~ z.lag.1 + 1 + z.diff.lag)
Residuals: Min 1Q Median 3Q Max
-0.030092 -0.012434 0.001532 0.009103 0.032779
Coefficients: Estimate Std. Error t value Pr(>|t|)
(Intercept) 0.004713 0.002216 2.127 0.037849 *
z.lag.1 -1.066420 0.305666 -3.489 0.000952 ***
z.diff.lag1 -0.447974 0.244819 -1.95 0.045925
z.diff.lag2 -0.163457 0.192568 -0.849 0.399590
z.diff.lag3 -0.294632 0.110058 -2.677 0.009726 **
Signif. codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1 1
Residual standard error: 0.01399 on 56 degrees of freedom
Multiple R-squared: 0.667, Adjusted R-squared: 0.6432
F-statistic: 28.04 on 4 and 56 DF, p-value: 8.387e-13

Value of test-statistic is: 2.1162
Critical values for test statistics:
  1pct 5pct 10pct
tau1 -2.6 -1.95 -1.61

The test-statistics is 2.11 which is greater than the critical value of tau1 which is -1.95 at 5% significant level. Hence, GDP follows random walk (without drift and trend), it has a unit root.

The autocorrelation (acf) and partial autocorrelation (pacf) show there is no autocorrelation in the residuals from this ADF model with 4 lags since the spikes of the acf and pacf are below the confidence interval blue line.

Augmented Dickey-Fuller Test Unit Root Test for GDP (Stationary data)

Value of test-statistic is: -3.4888 6.0906
Critical values for test statistics:
  1pct 5pct 10pct
tau2 -3.51 -2.89 -2.58
phi1 6.70 4.71 3.86

The value of test statistic is -3.48 which less than the critical value of tau2 which is -2.89 (at 5% significant level), so we can reject the null hypothesis. Hence GDP is stationary at I (1). The first difference of GDP is stationary.
Augmented Dickey-Fuller test unit root for unemployment

Call: lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
Residuals: Min 1Q Median 3Q Max
-0.155306 -0.049231 -0.001195 0.039052 0.246962

Coefficients: Estimate Std. Error t value Pr(>|t|)
z.lag.1 0.0003893 0.0015848 0.246 0.807
z.diff.lag1 -0.0292118 0.0897478 -0.325 0.746
z.diff.lag2 0.0566919 0.0887699 0.639 0.526
z.diff.lag3 0.0165728 0.0888651 0.186 0.853
z.diff.lag4 0.7354344 0.0880872 8.349 2.07e-11 ***
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
Residual standard error: 0.08756 on 56 degrees of freedom
Multiple R-squared: 0.5815, Adjusted R-squared: 0.5442
F-statistic: 15.56 on 5 and 56 DF, p-value: 1.397e-09

Value of test-statistic is: 0.2457

Critical values for test statistics:
1pct 5pct 10pct
tau1 -2.60 -1.950 -1.613

The test-statistics is 0.24 which is greater than the critical value of tau1 which is -1.95 at 5% significant level. Hence, unemployment follows random walk (without drift and trend), it has a unit root.

Augmented Dickey-Fuller Test Unit Root Test for unemployment (Stationary data)

Call: lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
Residuals: Min 1Q Median 3Q Max
-0.149511 -0.040908 0.001074 0.051824 0.213786

Coefficients: Estimate Std. Error t value Pr(>|t|)
z.lag.1 -0.3438 0.1594 -2.156 0.03580 *
z.diff.lag1 -0.5382 0.1838 -2.929 0.00507 **
z.diff.lag2 -0.4183 0.1967 -2.127 0.03830 *
z.diff.lag3 -0.2666 0.2054 -1.298 0.20010
z.diff.lag4 0.4394 0.1920 2.289 0.02626 *
z.diff.lag5 0.2534 0.1693 1.496 0.14077
z.diff.lag6 0.1885 0.1278 1.474 0.14660
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
Residual standard error: 0.082 on 51 degrees of freedom
Multiple R-squared: 0.819, Adjusted R-squared: 0.7942
F-statistic: 32.98 on 7 and 51 DF, p-value: < 2.2e-16

Value of test-statistic is: -2.1563

Critical values for test statistics:
1pct 5pct 10pct
tau1 -2.60 -1.950 -1.613

The value of test statistic is -2.15 which less than the critical value of tau1 which is -1.95 (at 5% significant level), so we can reject the null hypothesis. Hence unemployment is stationary at I (1). The first difference of unemployment is stationary.
The error-correction model using the Engle-Granger two step method

The simple long run regression equation results

Time series regression with "ts" data:
Start = 1993(1), End = 2009(2)
Call: dynlm(formula = lgdp ~ lunp + time(lunp) + D1)
Residuals: Min 1Q Median 3Q Max
-0.037006 -0.009020 0.001558 0.008395 0.031544

Coefficients: Estimate Std. Error t value Pr(>|t|)
(Intercept) -28.710123 0.976117 -29.413 < 2e-16 ***
lunp -0.063205 0.004071 -15.524 < 2e-16 ***
time(lunp) 0.021135 0.000495 42.693 < 2e-16 ***
D1 0.020816 0.007558 2.754 0.00771 **
--- Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.01458 on 62 degrees of freedom
Multiple R-squared: 0.9736, Adjusted R-squared: 0.9723
F-statistic: 760.7 on 3 and 62 DF, p-value: < 2.2e-16

Augmented Dickey-Fuller Test Unit Root Test for Co-integration

Call: lm(formula = z.diff ~ z.lag.1 - 1 + z.diff.lag)
Residuals: Min 1Q Median 3Q Max
-0.030587 -0.006978 0.001050 0.005559 0.030215

Coefficients: Estimate Std. Error t value Pr(>|t|)
z.lag.1 -0.4482 0.1841 -2.435 0.01799 1
z.diff.lag1 -0.1341 0.1572 -0.853 0.39693
z.diff.lag2 -0.2681 0.1370 -1.957 0.05522
z.diff.lag3 -0.3999 0.0995 -4.019 0.00017 ***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
Residual standard error: 0.01113 on 58 degrees of freedom
Multiple R-squared: 0.503, Adjusted R-squared: 0.4687
F-statistic: 14.67 on 4 and 58 DF, p-value: 2.44e-08

Value of test-statistic is: -2.435
Critical values for test statistics:
1pct 5pct 10pct
tau1 -2.6 -1.95 -1.61

The value of test statistic is -2.435 which is less than critical value of -1.95 and significant at 5% level. We can reject the null hypothesis of the unit root in the model. We know that both unemployment and GDP series is I (1) and the series of the residuals is I (0); hence, unemployment and GDP are co-integrated.
The error correction model

Time series regression with "ts" data:

Start = 1993(2), End = 2009(2)

Call: dynlm(formula = diff(lgdp) ~ diff(lunp) + L(res, 1))

Residuals: Min        1Q    Median        3Q       Max
-0.040987 -0.007846   0.002676 0.009446 0.029835

Coefficients: Estimate      Std. Error  t value         Pr(>|t|)
(Intercept)  0.005267    0.001779                    2.960        0.00435 **
diff(lunp)  -0.069400    0.015424                  -4.500        3.06e-05 ***
L(res, 1)   -0.890783    0.136526                   -6.525        1.42e-08 ***

Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.01401 on 62 degrees of freedom
Multiple R-squared: 0.4245, Adjusted R-squared: 0.4059
F-statistic: 22.86 on 2 and 62 DF,  p-value: 3.646e-08