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Faculty of Business and Economics

BACHELOR THESIS

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Relationship between rates of unemployment and inflation in the Czech Republic

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I would like to thank everyone, who helped me with this thesis – by advice, suggestion or critical remark. I would like to thank my supervisor Assoc. Prof. Václav Adamec, Ph.D. for his numerous advice during preparation of this thesis. Last, but not least, I want to thank my parents for supporting me during my studies.

I hereby declare, that I prepared this thesis myself according to instruction of my thesis supervisor and used the referenced resources in the attached list. I also agree with lending and publishing of this thesis.

Brno, May 21, 2012 ________________________

Abstract

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The goal of this thesis is to examine relationship between unemployment rate and inflation in the Czech Republic and Slovakia during years 1994-2011 and to construct static and expectations augmented Phillips curve. For expectations augmented model, expected inflation was detected by using two methods – adaptive expectations and the geometric lag model. Thesis also contains detection of natural rate of unemployment, short-term supply shocks and cyclical unemployment in both countries. For analysis annual data from the Czech Statistical Office, the Slovak Statistical Office and the International Monetary Fund were used.

Key Words

Phillips curve, natural rate of unemployment, cyclical unemployment, supply shocks.

Abstrakt

Slezarová, I. Vztah míry nezaměstnanosti a inflace v České republice. Bakalářská práce. Brno, 2012.

Cíl bakalářské práce je ověřit vztah mezi mírou nezaměstnanosti a inflace v České republice a na Slovensku v letech 1994-2011 a vykonstruovat statický a modifikovaný model Phillipsovy křivky. U modifikovaného modelu byla použita očekávaná inflace. Tato inflace byla určena dvěma způsoby – metodou adaptivního očekávání a nekonečným geometricky rozděleným zpožděním. Práce také obsahuje výpočet přirozené míry nezaměstnanosti, cyklické nezaměstnanosti a nabídkové šoky. Pro analýzu byly použity data z Českého Statistického Úřadu, Slovenského Statistického Úřadu a Mezinárodního Měnového fondu.

Klíčová slova

Phillipsova křivka, přirozená míra nezaměstnanosti, cyklická nezaměstnanost, nabídkové šoky

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1 Introduction

Economics become independent science since the second half of eighteen century. In that time the main goal of economists was to create wealth. People focused on microeconomics even though the division between microeconomics and macroeconomics did not exist. In thirties of twentieth century, the attention started to focus also on macroeconomics.

Macroeconomics deals with the economy globally. It studies the development and impact of aggregate variables. The main aggregate variables are the Gross Domestic Product (GDP), general price level (inflation), unemployment and the relationship with foreign countries described by difference of import and export (trade balance).

Macroeconomics gives to policymakers the manual how to avoid recession, high inflation, how to support economic growth and improve living standards. Macroeconomics also affects companies, entrepreneurs and general public. For example, a change of interest rates by the National Bank influences everyone's decision what to do with savings and investment activity of firms.

There are different opinions about functioning of the economy. Should people try to intervene? Liberalists believe that in economy is inner balancing mechanism that gets economy into equilibrium point. Others believe that there exists some unbalance which can be solved by action from the government. Policy of the government can be divided into four groups – Monetary, Fiscal, income and international trade policy. (Pavelka 2007)

Income policy is in control of government. It aims at inflation and it controls wage price setting process. International trade policy cares about trade balance. It controls tariffs, quotas and licenses.

Monetary policy is in control of the Central Bank. The main goal is stable price level (low inflation). Secondary goals are GDP growth and low unemployment. To achieve these goals it uses following tools – reserve ration, discount rate, open market operations and for open economy the exchange rate. These tools influence money supply, amount of commercial banks reserves and interest rates.

There are several policies of the Central Bank. The main ones are monetary expansion and monetary restriction. Monetary expansion is used only in crisis because it goes against the main goal of monetary policy – low inflation. Central bank increases bank reserves. This increases money supply. When money supply is high the interest rates go down. Low interest rates make aggregate demand go up and this rises GDP and decreases unemployment. On the other hand, the "second evil" – inflation rises. This policy was used in the current crises. The other policy is completely opposite and more often used. The main goal is to lower inflation.

Fiscal policy is in the hands of government and the main goals are growing GDP and low unemployment. The main tool of fiscal policy is the state budget (government expenditures and taxes).

Similarly as monetary policy there are two types of policies – expansionary and restrictive. Expansionary fiscal policy leads to higher GDP and lower inflation. To achieve these goals government either increases spending, decreases taxes or both. These actions lead to increased aggregate demand (in case of lowering taxes there is also increase in aggregate supply). Higher aggregate demand and supply increase GDP and lower unemployment. Restrictive fiscal policy is used mainly when economy is overheated and the goal is to lower inflation. The spending decreases, taxes increases; the goal is to lower aggregate demand but not supply. Decreasing aggregate supply would lead to stagflation (increasing both – unemployment and inflation). Due to this reason, it is better to decrease government spending; increasing taxes may lower aggregate supply. It is interesting that even though restrictive strategy is usually used when economy is overheated, the Czech government (and most of governments of European countries) is using it now.

Fiscal policy also uses automatic stabilizers that, as the term suggests, stabilizes economy and reduces fluctuations in business cycle. First stabilizer is progressive tax system. During recession, economy does not fall as quickly as with flat tax but in expansion the raise is slower. The second stabilizer is unemployment support – the consumption does not fall as deep and people have at least some money.

2 Objectives

The Phillips curve describes relationship between two macroeconomic indicators – unemployment rate and inflation. Both of these indicators are connected to economic growth. Usually, the growth of GDP leads to lower unemployment. From observations made in the United States in last century every decrease of output below potential output will increase unemployment rate by one percent above the natural rate of unemployment. This relationship is called as Okun's law.

Using data from the Czech Statistical Office, the Slovak Statistical Office and the International Monetary Fund the relationship between unemployment rate and inflation seems to be existing in the Czech Republic at the first glance. In this work, the relationship will be explored in detail. The main goal is to find, if there exists a tradeoff between two macroeconomic indicators mentioned above. The secondary goal is to find the natural rate of unemployment and to construct its confidence interval. The tertiary goal is to describe cyclical unemployment and short-term supply shocks in given time period. Then the results will be compared with the results in Slovakia, which are also included in this thesis.

3 Literature review

In literature review basic economic facts mainly about inflation, unemployment rate and Phillips curve are included. In this section was used literature by Rozmahel (2004), Mankiw (1999), Mankiw (2007), Salunke (2009) and Pavelka (2007).

3.1 Inflation

It can be said that inflation occurs when on average the price levels rise. This does not mean that prices of all goods rise – some may stay constant and some may even fall down. To express term inflation Greek letter π is used.

Generally, inflation is expressed in Equation [1].

$$\pi = \frac{P_t - P_{t-1}}{P_{t-1}} \qquad [1]$$

3.1.1 Measurement

Inflation is measured by price indexes, which measure increase in the price level. Every price index has weights that show how much the change of price of a commodity influences given indeces. The most important indexes are:

Consumer price index (CPI) – The consumer basket contains especially items used in households such as food, clothes, water, housing etc. CPI is an example of Laspeyres index (LI). This index is sometimes called “base weighted” because the prices are weighted by quantities in the base period. Simply – index is the goods in the basket times the price over the same goods times price in previous time period. Mathematically, it is described in Equation[2]. For the determination of inflation it is necessary to divide the change of indexes over the index in previous time period (see Equation [3]).

$$Laspeyres\ index = \frac{\sum P_t q_0}{\sum P_0 q_0} \qquad [2]$$

$$\pi_t = \frac{LI_t - LI_{t-1}}{LI_{t-1}} \qquad [3]$$

Producer price index (PPI) – In this basket, products important for producers such as commodity prices, mining products, prices of raw materials etc. are included. It measures prices at wholesale or at the producer level.

GDP Deflator – This is not like price indexes above, but it also helps measure inflation. It uses ratio of nominal and real GDP to estimate the rise of prices. Because GDP is changing every year, items in basket change too. Therefore, it is not possible to use Laspeyres index for computation as it deals with stable basket. There exist another index that deals with changing basket. It is called Paasche index. It can be formulated it – see Equation [4].

$$Paasche\ index = \frac{\sum P_t q_t}{\sum P_0 q_t} \quad [4]$$

The inflation rates measured by CPI and GDP Deflator are usually similar. The main difference is that deflator includes only products made in a given country and CPI measures the difference of prices in products bought by consumers.

3.1.2 Types of inflation

Inflation can be divided into three groups according to its size:

Moderate inflation – This inflation is in the majority of developed world. With this inflation people trust money and are not afraid that they will lose value. It represents slow rising prices in economy. Moderate inflation is very small – usually a single digit.

Galloping inflation – Galloping inflation (sometimes called hyperinflation) is when the inflation rate is two or more digits. So high rise of prices makes major problems in economy. People do not believe in money, it is very difficult to get a loan; people tend to buy fixed assets.

Inflation can be described according to origin

The origin of inflation may be supply side (cost push) or at demand side (demand pull inflation)
Demand pull inflation happens, when demand grows more rapidly than supply. Cost push is caused by increased price of production.

3.2 Unemployment

People can be divided into two groups – economically active (labor force) and economically inactive (students, children, pensioners, people, who do not seek job etc.). Economically active people can be divided in two groups – employed and unemployed. It is possible to illustrate this statement in Equation [5].

$$L^s = L + U \quad [5]$$

Rate of unemployment u can be expressed in Equation [6].

$$u = \frac{U}{L^s} \quad [6]$$

Involuntary unemployment may be shown graphically (Figure 1). Real wage *w'* is higher than wage *w* that causes no involuntary unemployment. This causes gap between household labor supply and labor demand. The difference between variables *L* and *L'* is called unemployment.

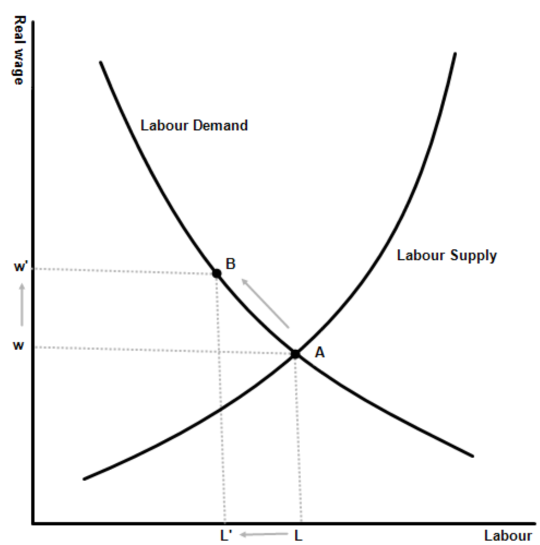

Figure 1: Labour market *(Source: Author's work)*

It is important to differentiate between voluntary unemployed and involuntary unemployed people. Voluntary unemployed people are not part of a labor force and therefore are not included in an unemployment rate. There are included only involuntary unemployed people.

3.2.1 Wage rigidity

Wage rigidity is sometimes called wage stickiness. The meaning of this term is that wages do not adjust very quickly. It explains Figure 1 why; it takes time for real wage w' to move to w with an effect of lowering the unemployment. There are several reasons for wage rigidity:

Collective bargaining – For firms it is very difficult to lower wages due to existence of trade unions. Even companies without trade unions will prefer to keep workers with higher salary because to fire this worker a hire a new one is very costly – firing, hiring, training costs. Even to force someone to accept lower salary than before may be dangerous, worker may not be as hard working and loyal as before.

Social minima – there exist a minimal wage that makes it more difficult for real wages to be lower.

Efficiency wages – companies believe that wages make workers more motivated. They will more likely keep workers with higher salary to ensure they will be working hard and they will be thankful for their good position.

Imperfect information – this expects that wages are fully flexible but they adjust slowly because of wrong expectations.

3.2.2 Types of unemployment

There are three types of unemployment –structural, frictional and cyclical.

Structural unemployment – there exist a mismatch between supply and demand of labor. For example there are no doctors on the market but there are a lot of teachers. There may also be a mismatch in location

Frictional unemployment – this is a short term natural unemployment. People are giving up jobs and looks for better ones but it takes some time to find suitable job.

Cyclical unemployment – is caused by fluctuations of business cycle. It usually occurs when economy is in recession. The main reason is decrease of spending. This causes unemployment.

When cyclical unemployment is zero we say there is full employment of labor force. Frictional and structural unemployment are unavoidable even if they are non-zero and cyclical unemployment is zero we speak about full employment. In this thesis cyclical unemployment for the Czech Republic is computed and it can be found in Figure 13 and Figure 17.

High unemployment has negative effect on economy. Main effect is on output that is lower than it could be. Long term unemployment may also cause social problems.

3.2.3 Natural rate of unemployment

In a long-run, unemployment is at the level of the natural rate of unemployment. But it is not constant over time and it does not have to be socially desirable. When unions win higher wages it causes a higher rate of unemployment. This rate is called a natural rate because monetary policy cannot change it. If there would be rapid money growth, it would not affect rate of unemployment. It would only cause higher inflation. Nature rate of unemployment can be affected by labor market policies (minimal wage, collective bargaining laws, job training programs etc.)

3.3 The Phillips curve

George Akerlof, Nobel Prize winner in 2001 once said "Probably the single most important macroeconomic relationship is the Phillips curve"[1]. What is this relationship about?

Phillips curve describes relationship between a rate of unemployment and inflation. The first one who discovered this was economist A. W. Phillips in 1958. He found out that in the United Kingdom there exist correlation between rate of change of money wages and unemployment. After that, economists P. Samuelson and R. Solow modified the curve and changed the rate of change of money wages for inflation. They believed that the Phillips curve is an important tool for policymakers – they can choose between high inflation and low unemployment or contrary wise. The logic behind this was movement of aggregate demand. When aggregate demand rose, the output increased (Figure 2) so unemployment decreased and inflation went up.

[1] Whole speech of George Akerlof is available at http://www.nobelprize.org/mediaplayer/index.php?id=501

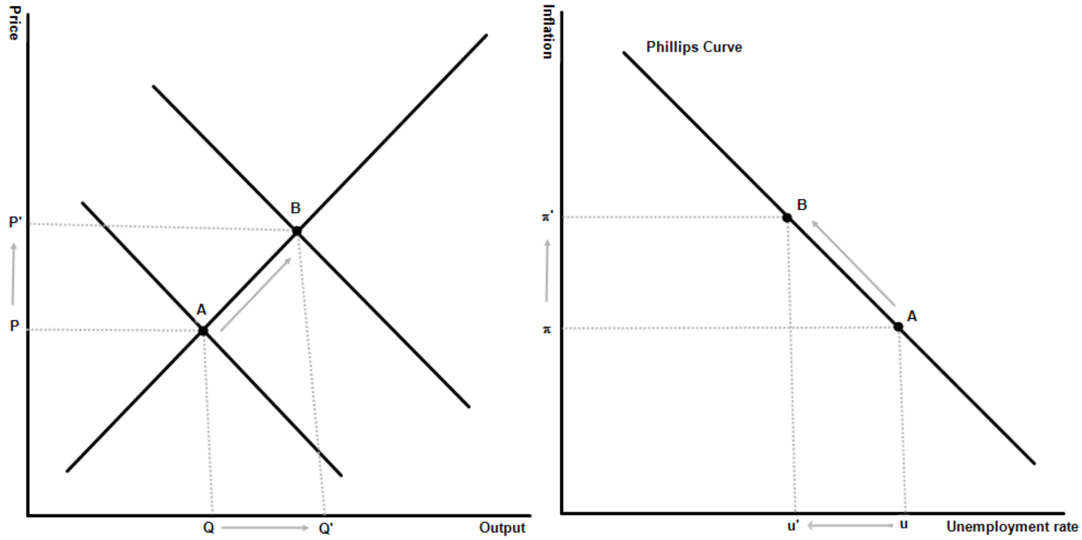

Figure 2: Shift in aggregate demand and reaction of Phillips curve *(Source: Author's work)*

In 1968 M. Friedman came with an idea that monetary policy cannot make tradeoff between unemployment and inflation in the long run. He believed that the changes will happen only in the short run. The idea was that growth of money supply does cause inflation but it does not affect real variables (output, unemployment). He concluded that in long-run inflation is not related to the rate of unemployment. This conclusion did mean that the long-run Phillips curve is vertical (Figure 3).

According to Friedman and Phelps it is possible to describe unemployment rate in Equation [7].

$$u = u^* - a * (\pi_a - \pi_e) \quad [7]$$

In the long-run, people believe whatever inflation the CNB produces. This means that actual inflation is equal to expected inflation. If this knowledge plugged in into equation, the result is that in long-run unemployment rate is the natural rate of unemployment. The Friedman's view of Phillips curve is dangerous for policy makers. The original Phillips curve implies that to lower unemployment it is necessary to raise money supply and raise inflation. According to Friedman this will have effect in short-term but in long-term unemployment rate return to its original value but inflation will stay higher. Not a nice scenario. (Figure 4)

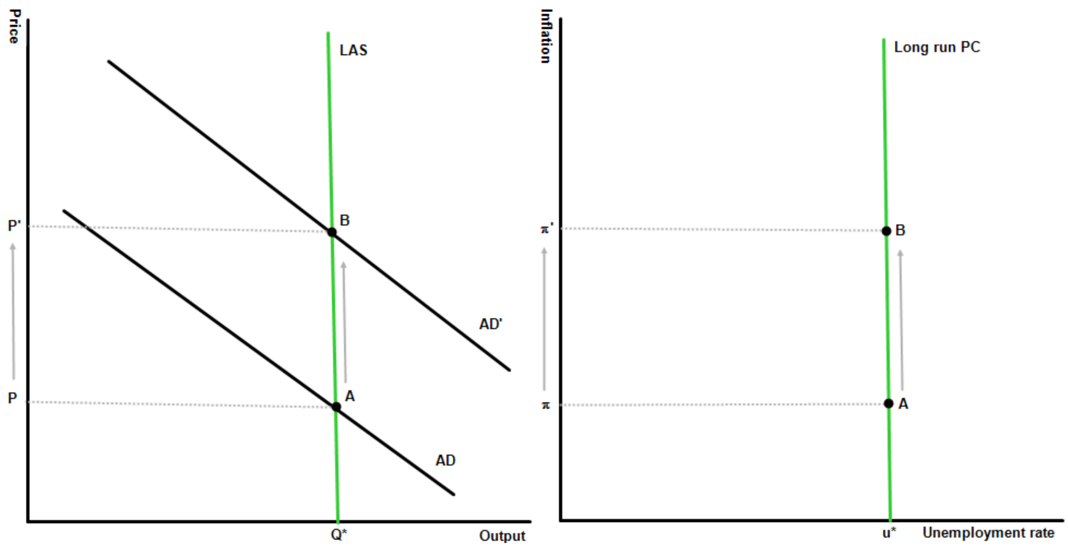

Figure 3: Long-run Phillips curve *(Source: Author's work)*

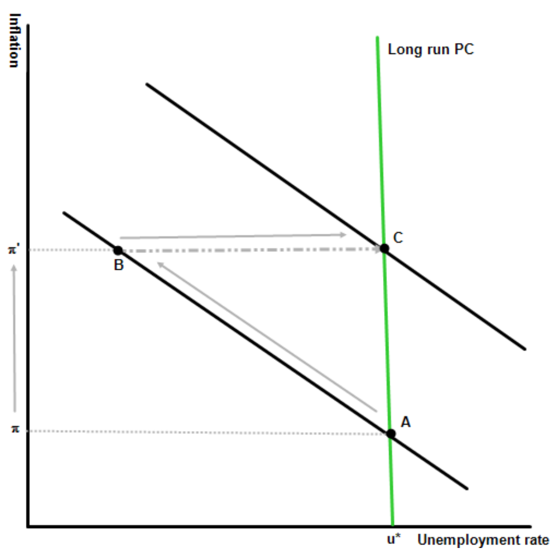

Figure 4: Return to u* *(Source: Author's work)*

In the past, there happened several experiments to influence unemployment rate or inflation. Here are several of them:

Vietnam War

Before the Vietnam War economist in U.S. could be observing almost perfect Phillips curve (Figure 5). When the war begun, the government expenditures rose and there was more money on the market (money supply rose by 13% in period 1970-1972). This in theory, it should cause lower unemployment. For one year unemployment really slowly declined. But as Friedman and Phelps predicted, it returned back to values of 1960s.

Oil supply shock

In 1974 OPEC used power of cartel and lowered supply of oil and therefore raised their prices to almost double. It caused increase of costs of firms' production. This lead to decrease of aggregate supply and the short run Phillips curve shifts to the right (Figure 6). Both inflation and unemployment rates were high and for policy makers it was difficult to decide whether the trade-off was favorable or not. The question was, if people view inflation as a reaction to supply shock and will expect that it is only temporary or if they think that an era of high inflation begun. The first expectation would lead to only temporally shift in Phillips curve contrary to the second expectation. In the U.S. Fed decided to increase money supply to lower unemployment with cost of high inflation. This treatment was pretty successful but in 1979 OPEC started again to raise prices of oil so the unemployment rose again. The whole situation is shown in Figure 7.

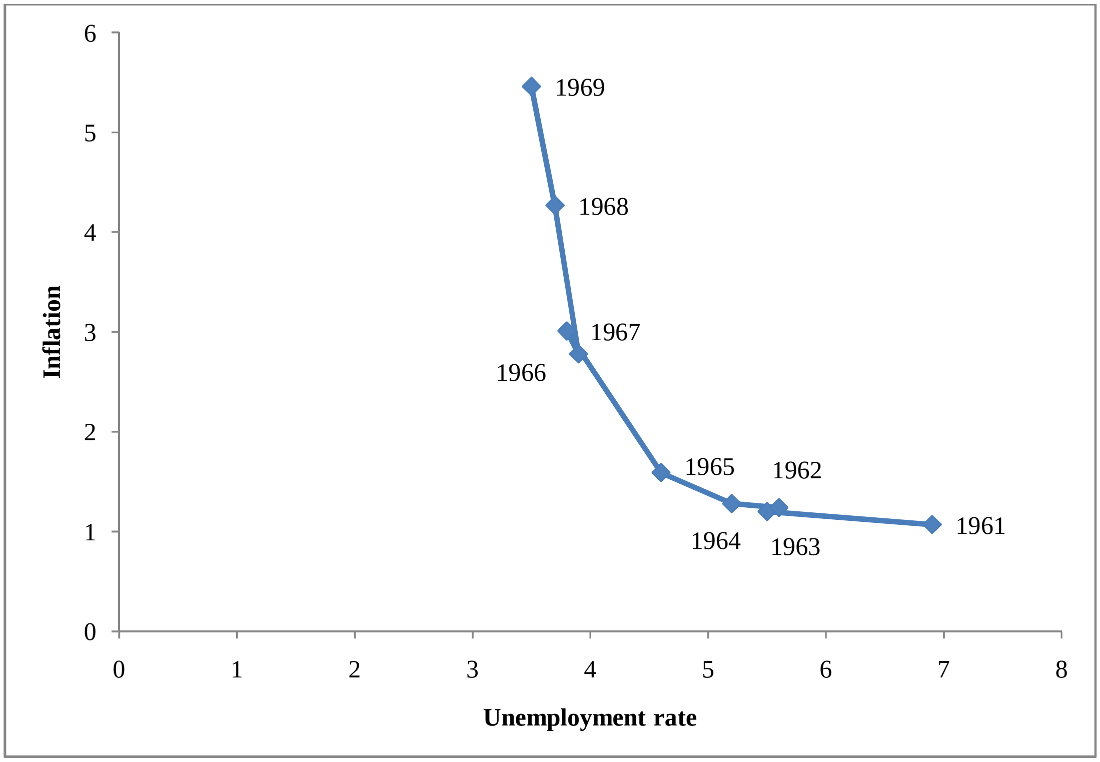

Figure 5: Phillips curve in the US in years 1961-1969 *(Source: Author's work)*[2]

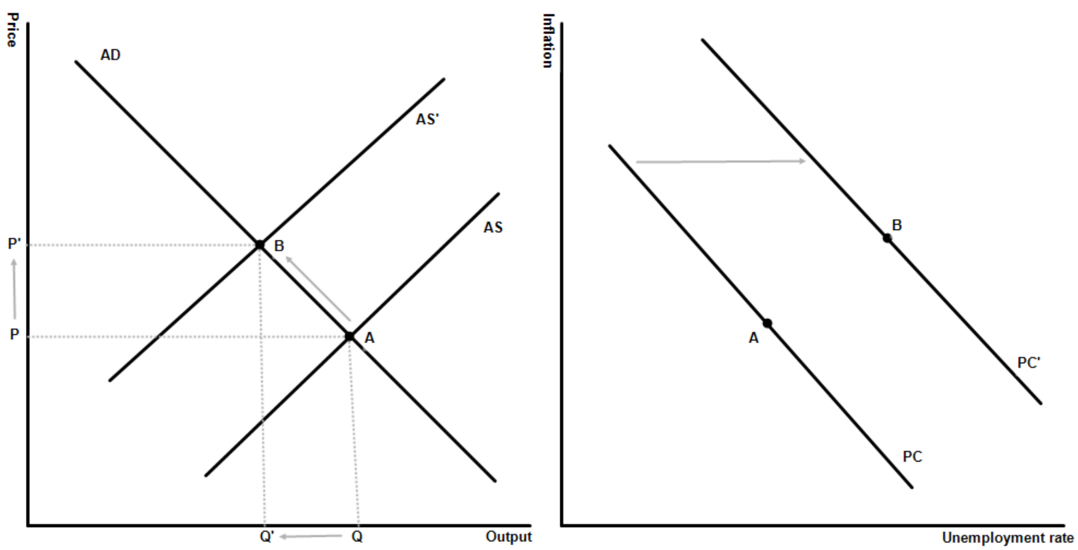

Figure 6: Phillips curve and Supply Shock *(Source: Author's work)*

[2] Author's execution, the data originates from Bureau of Labor Statistics

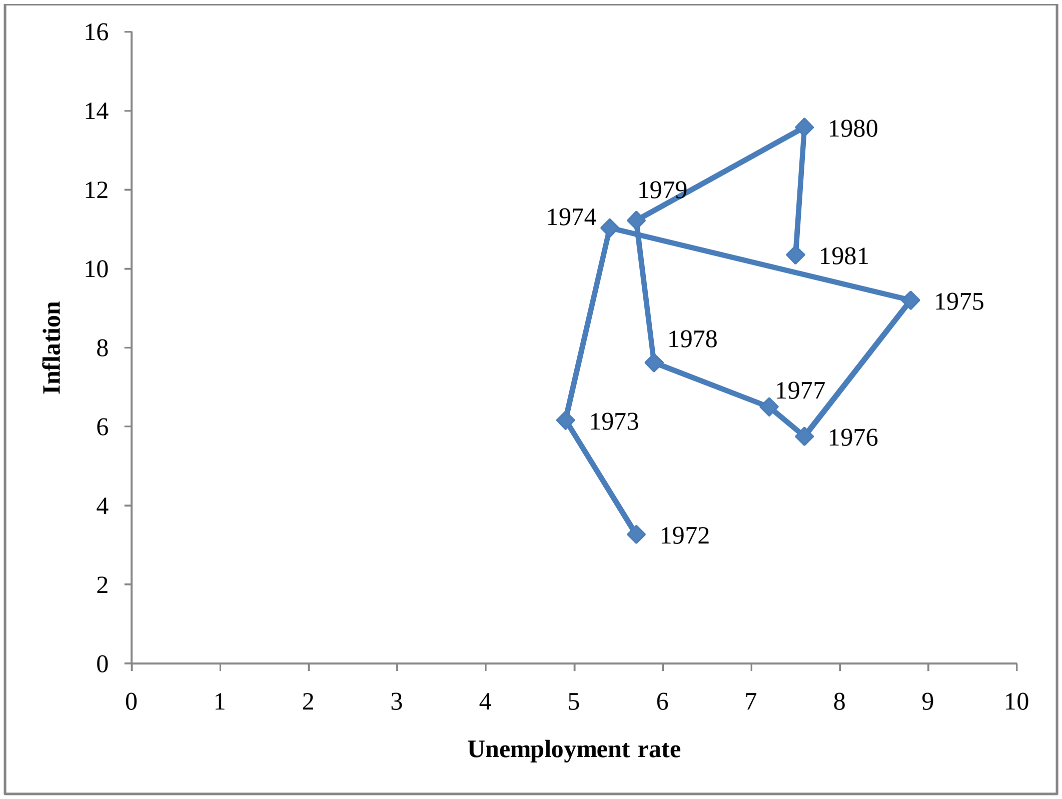

Figure 7: Phillips curve in the US in years 1972-1981 *(Source: Author's work)*[3]

New chairman of Fed Paul Volcker was appointed in 1979 and came with solution to these problems. According to Friedman, a natural rate of unemployment in long term was constant and could not be changed by monetary policy. So if rate of unemployment will increase in short-term as an effect to monetary policy, during time it will return back to its original value. Volcker used this theory and did exactly opposite policy of his ancestor. He lowered money supply. This led to lower inflation rate and higher unemployment. But during time unemployment went back to its original value (Figure 8 and Figure 9).

These problems and solutions show the usefulness of Phillips curve.

[3] Author's execution, the data originates from Bureau of Labor Statistics

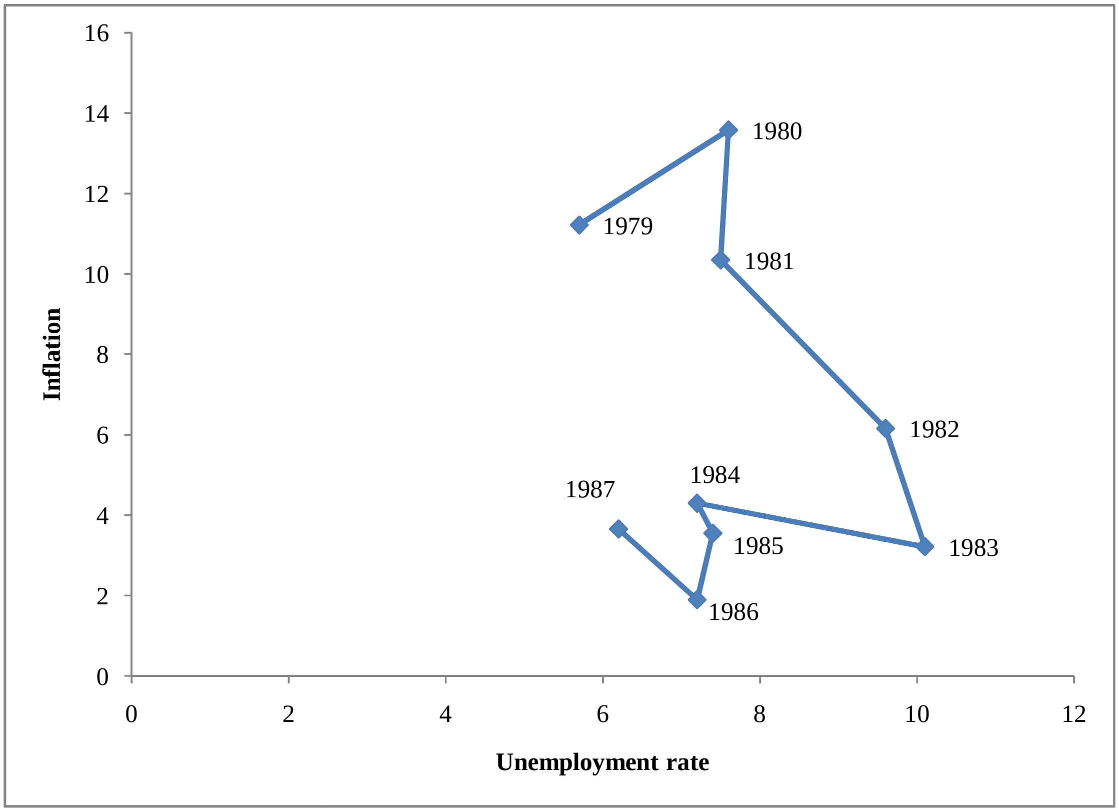

Figure 8: Phillips curve in the US in years 1979-1987 *(Source: Author's work)*[4]

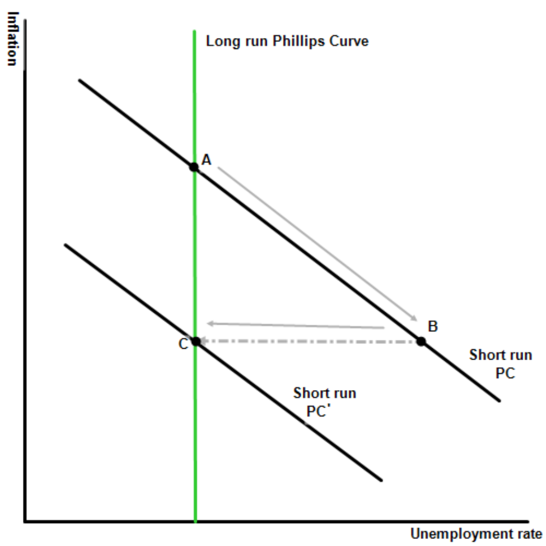

Figure 9: Disinflation by Volcker *(Source: Author's work)*

[4] Author's execution, the data originates from Bureau of Labor Statistics

4 Material and Methods

In this chapter data and their collection will be described, the method of adaptive expectations, the issue of accepting Euro in Slovakia, and briefly regression analysis, time series, detection of the natural rate of unemployment, delta method, geometric lag model will be described. There will also be a chapter about software application that was used for most of the calculations – Gretl.

4.1 Data

For research of the Phillips curve the following data were used – unemployment rate in the Czech Republic, inflation in the Czech Republic, unemployment rate in Slovakia and inflation in Slovakia (see Table 8).

4.1.1 Inflation

Inflation is measured as annual rate of change of consumer prices. The units are percentages. The data were collected yearly.

4.1.2 Unemployment rate

Unemployment rate shows the quotient of number of unemployed people and total labour force (in percentage). Unemployment rate is constructed according to EUROSTAT methodology and according to suggestions of International Labour Organization.

4.1.3 Data Collection

Data originated from different sources. For the Czech Republic both - inflation and unemployment rate were obtained from the Czech Statistical Office. The unemployment rate in Slovakia was obtained from the Slovak Statistical Office from their database SLOVSTAT. There is an issue with inflation; the Slovak Statistical Office offers only data since 1997 and so does EUROSTAT. Therefore, data were obtained by the International Monetary Fund from the World Economic Outlook Database (2012).

4.2 Slovak Crown and Euro

Slovak internal economic background changed very much with the change of currency. The average inflation in years 2000-2008 was 6.16% in comparison with 1.86% in years 2009-2011. This is significant difference and it brings questions if it would not be better to divide this series in two parts – one before year 2006 when Slovakia entered ERM II and after. To enter Eurozone, there are following conditions to be met:

- Restricted inflation rate
- Limited government debt and annual deficit
- At least 2 years in ERM II
- Limited long term interest rates

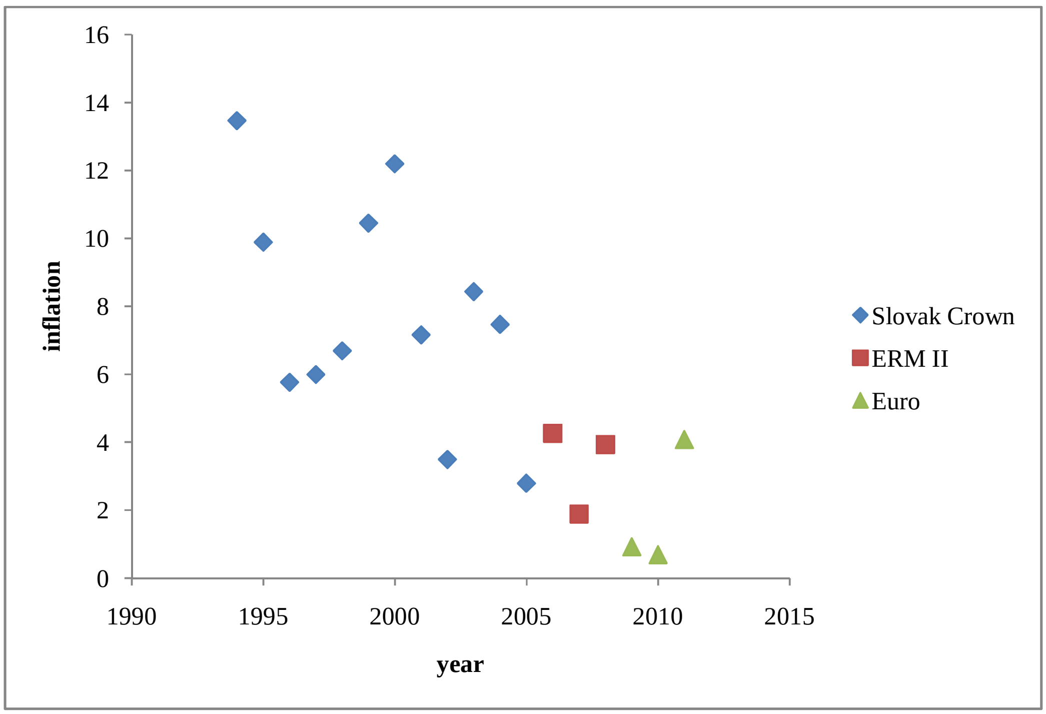

Figure 10: Inflation in Slovakia *(Source: Author's work)*[5]

For Slovakia, the most difficult requirement to fulfill was the strict inflation rule - the country cannot have inflation above than 1.5% plus the average of three countries in Eurozone with the lowest inflation. In years 2007 and 2008 Slovakia strongly regulated prices of electricity, natural gas and wages. Slovak crown was at that time joined to Exchange Rate Mechanism so it was closely tied to Euro. This caused lower

[5] Author's execution, the data originates from International Monetary Fund [20]

inflation. Figure 10 shows differences of inflation before entering ERM II and after entering Eurozone.

4.3 Regression analysis

In this part of work were used as sources Randall E. Schumacker and Richard G. Lomax (1996), Green (2002), Wooldridge (2002), Gujarati (2002), Studenmund (2001), In this work, a simple Ordinary Least Squares (OLS) regression will be used. The linear relationship is expected but it is not unusual to have a reciprocal relationship. The OLS method is based on minimal squares of residuals.

$$RSS = \sum \varepsilon^2 = \sum (Y_i - \hat{Y}_i)^2 = \sum (Y_i - \beta_0 - \beta_1 X_1)^2 \qquad [8]$$

Since the sum of residuals has to be minimal the final expression in Equation [8] has to be partially differentiated by β_0 and β_1. This gives us two equations with two unknowns (β_0, β_1) – Equation [9] and Equation [10]. By solving this system we get estimated regression equation in form $Y_i = \beta_0 + \beta_1 X_i$

$$\sum Y_i X_i - \beta_0 \sum X_i - \beta_1 \sum X_i^2 = 0 \qquad [9]$$

$$\sum Y_i - n\beta_0 - \beta_1 \sum X_i = 0 \qquad [10]$$

To get this estimated model is the easiest part. It may fit the data perfectly or it may be very different from them. There are several indicators that show if the estimated model actually does fit the data well. For all testing 95% confidence level is used.

T-test of parameters - This is used for testing the significance of a single regression coefficient. The null hypothesis says that the parameter is not significant; the alternative says the opposite – it is statistically different from zero. If parameters are not significant it means that they are probably not different from zero. This would mean that in a given model, the parameter is unimportant.

Goodness of fit – is showed by coefficient of determination R^2. It shows how well the regression fits the data. The value of R^2 is between 0 and 1. 0 means that the regression does not correspond to the data at all and 1 means the perfect fit. A low R^2 might well indicate that variables are poorly measured, exclusion of important variables, or mis-specification of model. But if model is correctly specified and variables are well measured and it still produces a small R^2, then it is not such a problem. There is no such a rule that some value of R^2 is too low and the model according to that should not be accepted.

R^2 adjusted – is similar to R^2 but it takes into account the number of variables and over specification of model. With addition of variable into the model, R^2 increases always but R^2 adjusted only, if this added variable improves the model.

In a model with more than one parameter F-test is often used. It tests an overall significance of a multiple regression. The null hypothesis says that all slope coefficients are simultaneously zero. Alternative hypothesis says that not all coefficients are zero.

4.3.1 Model specification criteria

Specification criteria compare residual sum of squares (RSS) with the number of observations and the number of variables. It creates an index that says how well the equation fits. In this category R^2 can be placed, but there are several other alternatives. For all of the criteria below applies the lower index the better fit.

Akaike's Information Criterion (AIC)

This criterion penalizes model for complexity but there is a tendency to overfit the model. It is computed by Equation [11].

$$AIC = \log\frac{RSS}{n} + \frac{2(p+1)}{n} \qquad [11]$$

Schwarz Criterion (SC)

This criterion also penalizes model for complexity and for sample size. It is more conservative and often used. It is showed in Equation [12].

$$SC = \log\frac{RSS}{n} + \log(n)\frac{p+1}{n} \qquad [12]$$

4.3.2 Normality assumptions

If the sole objective of regression is point estimation of the parameters then OLS method without any assumptions about the probability distribution of the error term ε_i will suffice. But because the point of this thesis is not just plain estimation of parameters but also inference then it is necessary to assume that ε_i fulfills some probability distributions.

Assumption 1

The model is linear in parameters and observations are stationary.

Assumption 2

The error terms have zero conditional mean. This assumption can be mathematically written as Equation [13].

$$E(\varepsilon_t|X) = 0, t = 1,2, \dots, n. \quad [13]$$

Assumption 3

There is no perfect collinearity. In other words no independent variable is constant or a perfect linear combination of others. Since the static Phillips curve does have only one parameter this assumption should not be taken into an account.

Assumption 4

The error terms are homoskedastic. The variance of the error terms is constant. Mathematically this assumption can be written as Equation [14].

$$Var(\varepsilon_t|X) = Var(\varepsilon_t) = \sigma^2, t = 1,2, \dots, n. \quad [14]$$

Heteroskedasticity can be detected by several tests, like White test, Park test, Breusch-Pagan test or Goldfeld-Quandt test. It can be also detected visually from the plots of by ACF and PACF plots.

Assumption 5

The error terms of two different time periods are not correlated (Equation [15]).

$$Corr(\varepsilon_t, \varepsilon_s|X) = 0, \text{for all } t \neq s. \quad [15]$$

When autocorrelation is present the consequences are the same as in presence of heteroskedasticity – OLS estimators are not efficient, we underestimate the true σ^2. Because of this it is likely that R^2 is also overestimated and t tests and F tests are no longer valid and may give misleading results in the statistical significance of the estimated regression coefficients. The serial correlation can be solved by using method Generalized Least Squares (GLS). GLS adjust equation for serial correlation. There are two variants – Cochrane-Orcutt (CO) and Prais-Winsten (PW). The main difference between these is that CO omits the first observation but PW uses it.

Assumption 6

The error terms are normally distributed as Normal $(0, \sigma^2)$. This implies assumptions 3, 4 and 5 but is even stronger because of the independence and normality assumptions.

If all of these assumptions are fulfilled we can use from Ordinary Least Squares standard errors, t-statistics and F-statistics. In other words, t-statistic has a t distribution and F-statistics have an F distribution.

4.4 Time series

Time series data is a set of observations taken in different times. They may be collected in different time intervals such as daily, weekly, annually etc. The data collected in short periods of time can be obtained continuously, such as stock prices. These data are used heavily in econometric studies.

Table 1: List of statistical tests

Type of test	**What it measures**	**Null hypothesis**	**Alternative hypothesis**
t-test of parameters	Significance of param.	$\beta = 0$	$\beta \neq 0$
F-test	Significance of model	All parameters are 0	H_0 not true
Breusch-Pagan test	Heteroskedasticity	ε_t is homoskedastic	ε_t is heteroskedastic
White test	Heteroskedasticity	ε_t is homoskedastic	ε_t is heteroskedastic
Durbin-Watson	Autocorrelation	No autocorrelation	Autocorrelation
Normality of residuals	Normality of residuals	ε_t is normally distributed	ε_t not normally distr.
Ramsey's RESET test	Specifications	Specification is right	Specification not right
Ljung-Box test	Autocorrelation	No autocorrelation	Autocorrelation
ADF	Stationarity	Is not Stationary	Stationarity

(Source: Author's work)

4.4.1 Stationarity

To be able to make time series regression it has to be stationary. It means that the time series has to have stable mean and variance and if the value of the covariance between the two time periods depends only on the distance between these periods and not on the time at which covariance is being computed. This is a definition of weak stationarity. There exists also a strict stationarity; it means that probabilistic behavior of values in time series is invariant to time.

To test stationarity, there are several options; in this work will be used Augmented Dickey-Fuller test (ADF). This test has a τ (tau) test statistics. The null hypothesis is that the observed variable is not stationary and the alternative says that it is stationary (see Table 1). When the test does not reject the null hypothesis it does not mean that the variable is not stationary. It means only that it cannot be proved in given confidence level that the variable is stationary. More information about ADF can be found in most econometrics textbooks or in article by Dickey and Fuller published in Journal of the American Statistical Association (1979).

4.5 Adaptive expectations

The adaptive expectation method states that people use recent data, such as inflation, to predict future data. In case of inflation, it can be mathematically written as Equation [16].

$$\pi_{e,t+1} = \pi_t \qquad [16]$$

This method is used for augmented Phillips curve for determination of expected inflation. Expected inflation can be also described by Geometric lag model – see chapter 4.8.

4.6 Delta Method

According to Casella, G. and Berger (2002), Delta method is based on Taylor series expansion. It finds the variance of functions of random variables. Generally, variance can be expressed as Equation [17]. In the second step of this approximation was used Equation [19].

$$Var(f(x)) \approx E([f(x) - f(a)]^2 \approx E\left(\left(\sum_{i=1}^{k} f_i'(a)(x_i - a_i)\right)^2\right)$$
$$= \sum_{i=1}^{k} [f_i'(a)]^2 Var(x_i) + 2\sum_{i>j} f_i'(a) f_j'(a) Cov(x_i, x_j) \quad [17]$$

It this work, it is important to find the standard error of natural rate of unemployment and therefore to find a variance of quotient (function form is in Equation [18]). For Taylor approximation partial derivations are expressed in Equation [20] and Equation [21]. It is important to realize that the variance is computed around the mean. Equation [22] express estimated variance for function in form of Equation [18].

$$f(x, y) = \frac{y}{x} \quad [18]$$

$$f(x) = f(a) + \sum_{i=1}^{k} f_i'(a)(x_i - a_i) \quad [19]$$

$$\frac{\partial f(x, y)}{\partial x} = -\frac{y}{x^2} \quad [20]$$

$$\frac{\partial f(x, y)}{\partial y} = \frac{1}{x} \quad [21]$$

$$Var\left(\frac{y}{x}\right) \approx \frac{\beta_0^2}{\beta_1^4} Var(x) - \frac{2\beta_0}{\beta_1^3} Cov(x, y) + \frac{1}{\beta_1^2} Var(y)$$
$$= \frac{1}{\beta_1^2}\left(\frac{\beta_0^2}{\beta_1^2} Var(x) - \frac{2\beta_0}{\beta_1} Cov(x, y) + Var(y)\right) \quad [22]$$

Variance and covariance can be found by coefficient covariance matrix (Equation [23]).

$$Var(\beta) = \begin{bmatrix} V_{11} & V_{12} \\ V_{21} & V_{22} \end{bmatrix} \quad [23]$$

In this matrix, values on main diagonal stands for variance and $V_{12} = V_{21}$ is covariance. When the way of computing the natural rate of unemployment form Equation [32] is considered then the result for standard errors is in Equation [24].

$$\sigma^2 = \frac{1}{\beta_1^2}\left(V_{11} - 2\frac{\beta_0}{\beta_1}V_{12} + \frac{\beta_0^2}{\beta_1^2}V_{22}\right) \quad [24]$$

The final confidence interval looks like Equation [25].

$$u^* \pm z_{1-\alpha/2}\sigma \quad [25]$$

Where quantile $z_{1-\alpha/2}$ is for 95% confidence level equal to 1.96.

4.7 The Natural rate of Unemployment

To get the natural rate of unemployment it is necessary to use a model, where the natural rate of unemployment is and to get it from it. For this is very useful to use the Phillips curve according to Friedman and Phelps. Then it can be adjusted into more useful form according to Wooldridge (2002).

$$u_t = u^* - a * (\pi_t - \pi_e) \quad [26]$$

π_e can be either estimated by adaptive expectations method as π_{t-1} or it can be obtained by geometric lag model (chapter 4.8). Either way $\Delta\pi_t$ stands for difference between actual and expected inflation.

$$u_t = u^* - a * \Delta\pi_t \quad [27]$$

By rearranging equation we get Equation [28].

$$\Delta\pi_t = -\frac{u_t}{a} + \frac{u^*}{a} \quad [28]$$

Because expressions $-\frac{1}{\beta_0}$ and $\frac{u^*}{\beta_1}$ are actually constants, it will be more simply written as β_0 and β_1. Therefore finally the equation is arranged as a simple linear model with one independent variable (see Equation [29]).

$$\Delta\pi_t = \beta_0 + \beta_1 u_t \quad [29]$$

Using ordinary least squares we get values for parameters of β_0 and β_1. Then from this information is subtracted a system of two equations (Equation [30] and [31]) with two variables.

$$\beta_0 = \frac{u^*}{a} \qquad [30]$$

and

$$\beta_1 = -\frac{1}{a} \qquad [31]$$

And from this system is separated Equation [32] - the natural rate of unemployment.

$$u^* = -\frac{\beta_0}{\beta_1} \qquad [32]$$

4.8 Geometric Lag model

According to Green (2002), Geometric Lag model is used when it is expected that the events in more recent past have higher influence and the importance of past fades with time. Equation [33] shows general geometric lag model.

$$y_t = \alpha + \beta \sum_{i=1}^{\infty} (1-\lambda)\lambda^i x_{t-1} + \varepsilon_{t,} \quad 0 < \lambda < 1 \qquad [33]$$

For expected inflation it can be simply put in Equation [34].

$$\pi_{e,t} = \lambda \pi_{e,t-1} + (1-\lambda)\pi_{t-1} \qquad [34]$$

4.8.1 Lambda

The lambda is a variable acquiring values from 0 to 1. When lambda is equal to 0 then the expected inflation is actually the value of inflation in last time period so the model is the same as the one using adaptive expectations. The “right” lambda value is a value which gives the least sum of the squared differences between observed and expected inflation.

The Lambda is found by optimization algorithm. There can be written simple algorithm to found it but in this work it was found with Microsoft Excel and solver function in it. Equation [35] shows the quantity that has to be minimized by changing lambda.

$$RSS = \sum_{t=1}^{n} (\pi_t - \pi_e)^2 \qquad [35]$$

4.9 Gretl

Gretl stands for *Gnu Regression, Econometrics and Time-series Library.* Gretl is software written in C programming language. The version 1.9.4. was used. It is targeted at econometric analysis. It is free and open-source and it can be downloaded from - http://gretl.sourceforge.net/. Because Gretl is under GNU General Public License (GPL) it can be modified or extended freely. The graphs that are also included in this thesis are done on the base of other free software – Gnuplot. The authors are Allin Cottrell and Riccardo "Jack" Lucchetti.

In this thesis, Gretl software was used for OLS, testing of stationarity, normality, homoskedasticity, autocorrelation, information criteria and other properties of regression. It was also used to construct regression graphs, descriptive statistics and coefficient covariance matrix.

4.10 Additional information

The regression output will be stated in tables. Tables will have the same format shown in Table 2.

Table 2 : Example of regression output

$y_t = \beta_0 + \beta_1 x_t$			
Standard error of β_1	Standard error of β_0	Number of observations	
t value of β_1	t value of β_0	R^2	
p value of β_1	p value of β_0	R^2 adjusted	
Darwin Watson statistics	Residual Sum of Squares	SC	AIC

(Source: Author's work)

5 Results and discussion

The goal of this chapter is to find out if there exists a statistically significant inverse relationship between unemployment rate and inflation in the Czech Republic and in Slovakia in years 1994-2011. Secondary goal is the determination of natural rate of unemployment, cyclical unemployment and supply shocks. Expectations augmented Phillips curve and geometric lag model of Phillips curve were used.

5.1 Czech Republic

5.1.1 Situation in the Czech Republic in years 1994-2011

Until mid-nineties there was no incidence of unemployment in the Czech Republic. The average unemployment rate was around 4%. In 1997, the unemployment rate went above 5% for the first time. During these times, strong, highly populated groups born in the 1970s entered the labor market. Also, problems with regions with ongoing major depression industry became stronger. In the second half of nineties, more companies went bankrupt than before. Another reason for growing unemployment rate was postponed retirement. Due to these reasons there was a high unemployment until 2004. The situation was getting better since 2004; the entrance to the European Union helped many companies to enter foreign markets. Even the strong Czech crown could not stop this trend. The situation was improving until 2009 when the world's financial crisis started.

In the examined period, the inflation did not go above 11%. At the beginning of transformation of the economy, there was high inflation in Czechoslovakia and later in the Czech Republic. Due to these reasons, the starting point of this analysis was a year 1994 when the inflation was relatively stable. The situation stabilized even more and after year 2000, it can be confirmed that the inflation time series is stationary. Since 2002, the inflation did not go over 3% with an exception of year 2008 when the Value Added Tax increased, excise duty on tobacco increased and the cost of energy increased.

5.1.2 Stationarity

To make a regression with time series data it is important to make sure the data are stationary. There were examined these variables: pure unemployment rate, reciprocal unemployment rate, pure inflation, the difference between inflation and delayed inflation and the difference between inflation and expected inflation which is described by geometric lag model (in Table 3 unanticipated inflation is described). All of these variables are stationary with an exception of non-differentiated inflation. But even pure inflation is stationary in sub-sample in years 2000-2011. For detection of stationarity augmented Dickey-Fuller test was used. The results are in Table 3.

Table 3: Results of stationarity test

Variable	Test statistics	P-value	Conclusion
Unemployment rate	-2.98	0.036	Stationary
Inflation (1994-2011)	-1.71	0.428	Non-stationary
Inflation (2000-2011)	-2.97	0.038	Stationary
First differences of inflation	-4.43	<0.001	Stationary
Unanticipated inflation	-3.26	0.017	Stationary

(Source: Author's work)

5.1.3 Simple model of Phillips curve

The simple model assumes tradeoff between unemployment rate and inflation in form $\pi_t = \beta_0 + \beta_1 u_t + \varepsilon_t$ or $\pi_t = \beta_0 + \beta_1 \frac{1}{u_t} + \varepsilon_t$. The coefficient β_1 is expected to be negative in the linear model and in the reciprocal model to be positive. These values of coefficients suggest existing tradeoff between unemployment rate and inflation. In the Table 4 basic statistics of both inflation and unemployment rate are provided.

In this work a simple reciprocal model of Phillips curve will be used because it shows better fit than the linear model – information criteria are better, R^2 is better and RSS are smaller. The Figure 11 shows the values and fitted reciprocal line. The expectation of positive slope was fulfilled. In the Regression 1, more detailed information about the regression is provided.

Table 4: General Statistics

	Unemployment rate	**Inflation**	**Inflation (1st differences)**	**Inflation (geo. lag**
Mean	6.55	4.47	-0.48	-0.81
Median	6.90	2.80	0.30	-0.45
Maximum	8.80	10.70	3.5	3.73
Minimum	3.90	0.10	-8.6	-7.74
Range	4.90	10.60	12.10	11.47
Variance	2.81	12.05	8.78	6.14
Standard deviation	1.68	3.47	2.96	2.48
Variation coefficient	0.26	0.78	6.21	3.08
Skewness	-0.36	0.62	-1.32	-0.98
Kurtosis	-1.28	-1.14	1.63	1.84

(Source: Author's work)

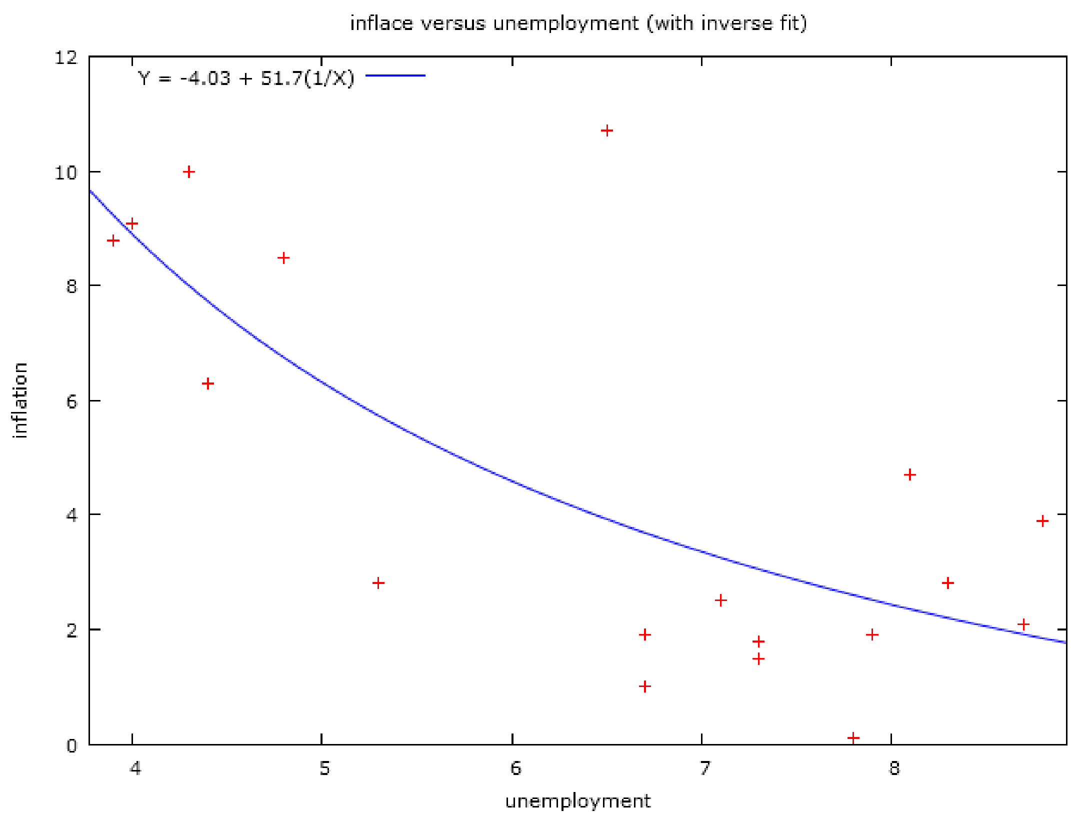

Figure 11: Scatterplot of the simple Phillips curve in the Czech Republic

Regression 1: Simple Phillips curve in the Czech Republic

$$\pi_t = -4.03 + 51.71\frac{1}{u_t}$$			
SE(β_1) = 12.08	SE(β_0) = 2.07	n = 18	
t value (β_1)= 4.28	t value (β_0) = -1.95	R^2 = 0.53	
p value (β_1) = 0.0006	p value (β_0) = 0.07	R^2 adj. = 0.50	
DW = 1.22	RSS = 95.53	SC = 86.91	AIC = 85.13

The regression shows very good results. It suggests that there exists tradeoff between unemployment rate and inflation. It is not usual to have such a nice fit for a static model of Phillips curve. In comparism with Wooldridge (2002) who worked with linear model the results of Czech model are with the right slope, significant and with high value of R^2. Only DW statistic suggests possible issues with autocorrelation.

In the next step will be checked, if there are any futher issues with model. The residuals do have mean very close to zero ($-1.35*10^{-16}$) and model is obviously linear in parameters. Next will be tested homoskedasticity, autocorrelation, correct specification of model and normality of residuals; the results are at Table 5. According to results by Wooldridge there is expected autocorrelation; data probably will not be heteroskedastic and according to theory the model should be correctly specified (even though the static Phillips curve is probably not the best model for determination of tradeoff between natural rate of unemployment and inflation; macroeconomists usually prefer the expectations augmented Phillips curve). This work will use this model for determination of the natural rate of unemployment.

Table 5: Tests of the Static Phillips curve model in the Czech Republic

Test	Test statistic	p-value	Conclusion
White's test	2.94	0.23	Homoskedasticity
Breusch-Pagan test	0.21	0.65	Homoskedasticity
Breusch-Pagan test (robust variant)	0.11	0.74	Homoskedasticity
Durbin-Watson	1.22	0.02	Autocorrelation
Ljung-Box (1. order)	2.30	0.15	No serial correlation
Ramsey’s RESET test	0.31	0.74	Specification OK
Test for normality	5.82	0.054	Residuals normally dist.

(Source: Author’s work)

Durbin Watson statistics suggest there is an autocorrelation. Autocorrelation causes higher variance. This causes no longer valid t-tests. The autocorrelation can be solved by GLS, Prais-Winsten variant as was used in analysis done by Wooldridge. The results of GLS are shown in Regression 2. Because the positive slope is backed up by strong significant t value, it is not expected that the GLS will change the result of this regression; in the Czech Republic, there is a significant tradeoff between unemployment rate and inflation in years 1994-2011. The test of normality is interesting. Test of normality implies homoskedasticity, no autocorrelation or serial correlation and no collinearity (collinearity is not present in this model, because there is only one parameter). Even though the normality test did not reject the null hypothesis that the residuals are normally distributed, the DW test indicates autocorrelation. Possible explanation may be that the test of normality did not accept that the residuals are normally distributed; the test only failed to prove on 95% confidence level that the residuals are not normally distributed.

Regression 2: GLS of the Static Phillips curve in the Czech Republic

$\pi_t = -3.80 + 50.35\frac{1}{u_t}$			
SE(β_1)= 14.64	SE(β_0) = 2.56	n = 18	
t value (β_1)= 3.44	t value (β_0) = -1.48	R^2 = 0.60	
p value (β_1) = 0.0034	p value (β_0) = 0.16	R^2 adj. = 0.57	
DW = 2.03	RSS = 82.52	ρ = -0.05	

The results were as expected; the autocorrelation effect was not very strong due to the low absolute value of ρ. On the other hand, the variance was probably really higher in Regression 1 because the significance of parameters decreased and the constant term became strongly insignificant. But the constant term is not the most important part of this regression.

5.1.4 Expectations augmented model of Phillips curve

The expectations augmented model can be written in form of Equation [7]. Using adaptive expectations, we can simplify it into Equation [29]. In the Table 4, are the basic statistics of both – unemployment rate and the first differences of inflation. Figure 12 shows the regression.

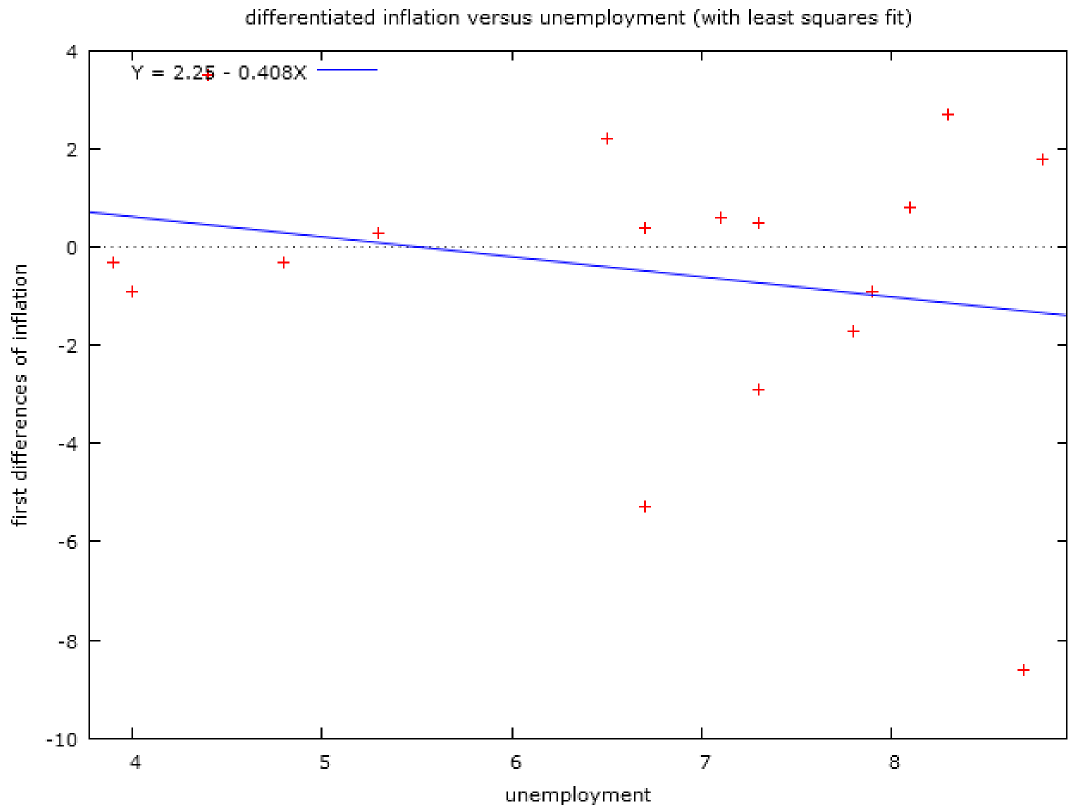

Figure 12: Scatterplot of unemployment rate vs. change in inflation

According to Figure 12, the negative slope the unemployment increases when unanticipated inflation decreases. This is also coherent with the theory. The relationship is not very strong as the results in Regression 3 suggest.

Regression 3: The change of inflation vs. unemployment rate in the Czech Republic

$\Delta\pi_t = 2.25 - 0.41u_t$			
SE(β_1) = 0.45	SE(β_0) = 3.14	n = 17	
t value (β_1) = -0.89	t value (β_0) = 0.72	R^2 = 0.05	
p value (β_1) = 0.39	p value (β_0) = 0.48	R^2 adj. = -0.01	
DW = 2.86	RSS = 133.33	SC = 88.92	AIC = 87.25

Our results have a worse fit than the ones done by Gujarati (2002), who used yearly data of US economy, who had statistically significant parameters. On the other hand, Green (2002), who also studied US economy, but with quarterly data and Wooldridge had worse fit than results in Regression 3. Under assumption that the assumptions from chapter 4.3.2 hold the natural rate of unemployment can be derived.

$$u^* = -\frac{\beta_0}{\beta_1} = -\frac{2.25}{-0.41} = 5.49 \quad [36]$$

Now a question arises: How much is the result from Equation [36] accurate? It was computed from statistically insignificant parameters. To answer this question the standard errors of the natural rate of unemployment will be calculated. That can be done by Delta method. Standard errors estimation is described in chapter 4.6. Equation [37] shows covariance matrix of regression coefficients of Regression 3.

$$Var(\beta) = \begin{bmatrix} 9.87 & -1.40 \\ -1.40 & 0.21 \end{bmatrix} \quad [37]$$

The results are shown in Equations [38], [39] and [40]. The variance of [36] is received.

$$\sigma^2 = \frac{1}{\beta_1^2}\left(V_{11} - 2\frac{\beta_0}{\beta_1}V_{12} + \frac{\beta_0^2}{\beta_1^2}V_{22}\right) = \frac{1}{(-0.41)^2}(9.87 - 2\frac{2.25}{-0.41}(-1.40) + \frac{2.25^2}{(-0.41)^2}0.21) = 4.84 \quad [38]$$

95% confidence interval is obtained.

$$u^* \pm 1.96 * \sqrt{\sigma^2} \quad [39]$$

$$5.49 \pm 1.96 * \sigma = 5.49 \pm 1.96 * \sqrt{4.84} = 5.49 \pm 4.31 \quad [40]$$

The final confidence interval is (1.18%, 9.8%) with 95% confidence level. This can seem as very wide interval. On the other hand, in comparing with Green the results are very similar. To compare – for the US economy in years 1950-2000 the predicted confidence interval also in 95% confidence level was (1.13%, 9.79%). Into account has to be taken the fact, that it is questionable, if the natural rate of unemployment is really parameter and if it is constant over time.

Cyclical unemployment and shocks

From computed natural rate of unemployment cyclical unemployment and shocks can be derived. Cyclical unemployment is actually the difference between observed unemployment and the natural rate of unemployment. In Figure 13, graphical view of cyclical unemployment is given.

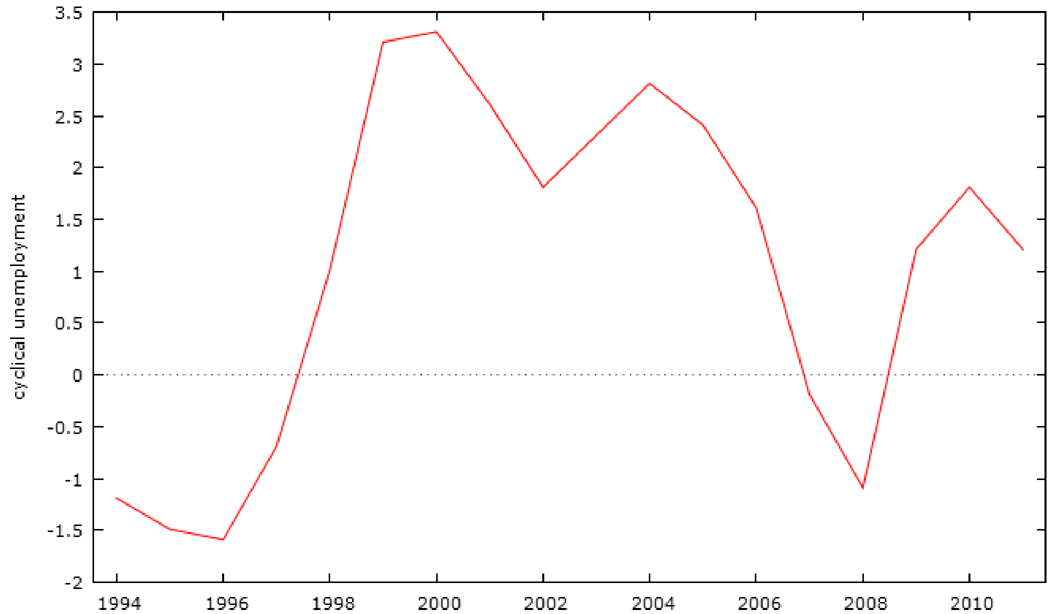

Figure 13: Cyclical unemployment

In model of Phillips curve $\pi_t - \pi_e = \beta(u_t - u^*) + \nu_t$ the left hand side stands for unanticipated inflation; first expression on right hand side shows the cyclical unemployment multiplied by constant and ν stands for supply shocks. ν can be expressed as residuals from model $\pi_t - \pi_e = \beta(u_t - u^*)$. Regression 4 shows this model estimation.

Regression 4: Phillips curve in the Czech Republic without constant term

$\Delta\pi_t = -0.41(u_t - 5.49)$			
SE(β) = 0.35		n = 17	
t value (β) = -1.15		R^2 = 0.08	
p value (β) = 0.27		R^2 adj. = 0.08	
DW = 2.86	RSS = 133.33	SC = 86.09	AIC = 85.26

The residuals of Regression 4 are the supply shocks. They are graphically shown in Figure 14.

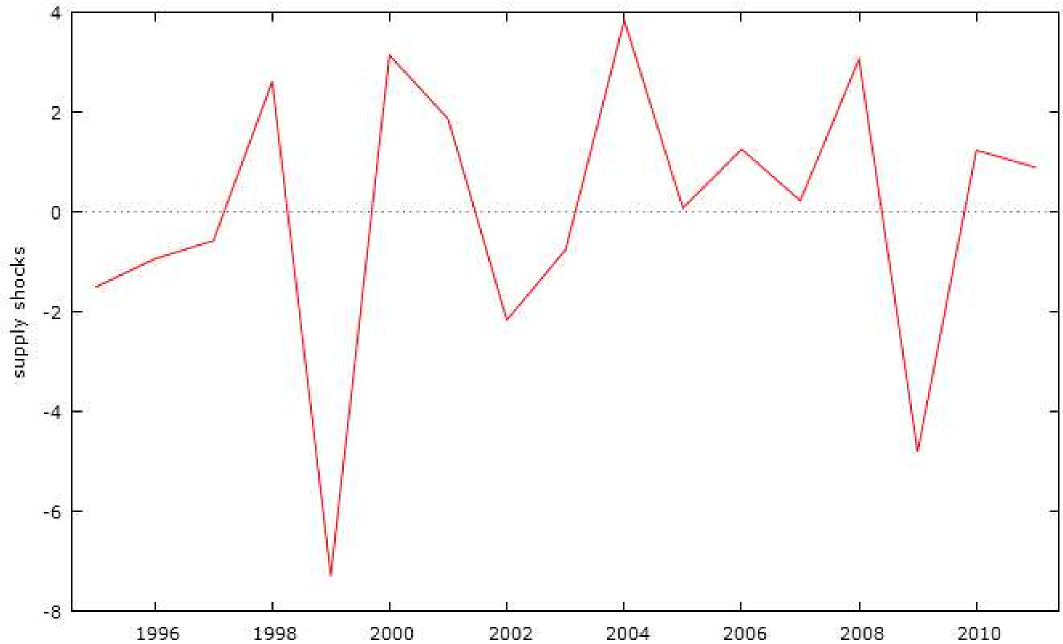

Figure 14: Supply shocks in the Czech Republic

5.1.5 Geometric Lag Model

Geometric lag model assumes that the people will not expect the values of given variable according to last observation only. It uses recursive technique to define the expected inflation. With inspiration in Green, research will be performed regression in form of Equation [29]; so the model is unchanged. The difference will be in the definition of expected inflation. According to geometric lag model with lag 1 the expected inflation is defined as Equation [41].

$$\pi_e = (1 - \lambda)\pi_{t-1} + \lambda\pi_{e(t-1)} \quad [41]$$

This model is described in chapter 4.8.

The tricky thing is to find the value of λ. The true λ lies in the place in which is the lowest value of residual sum of squares. In this work, the λ was found by Excel tables numerically by optimalization method. The Figure 15 shows the function of λ, the RSS sum of squares.

The minimal error sum of squares was recieved for $\lambda = 0.444$. The expected inflation was computed with this number and from this was obtained the unanticipated inflation. The basic statistics about unanticipated inflation obtained from geometric lag model as well as the unemployment rate statistics are at Table 4. The final result of regression is at Regression 5 and the scatterplot is in Figure 16.

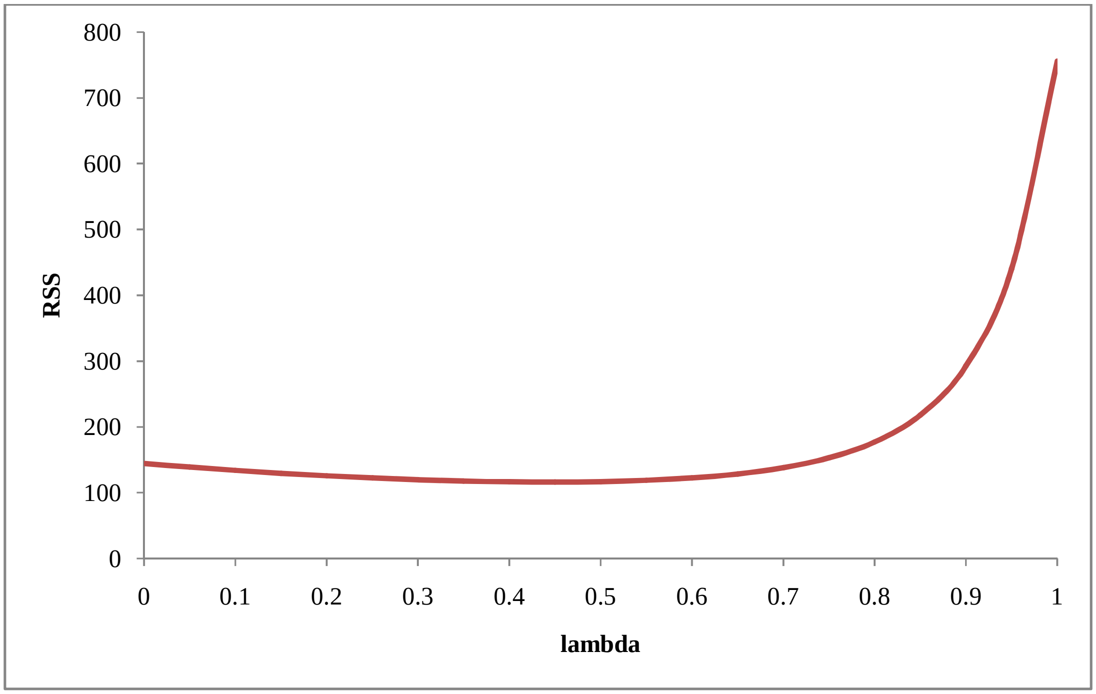

Figure 15: Searching for Lambda *(Source: Author's work)*

Regression 5: unemployment vs unanticipated inflation (expected inflation determined by geometric lag model)

$\Delta\pi_t = 3.13 - 0.60u_t$			
SE(β_1) = 0.34	SE(β_0) = 2.28	n = 18	
t value (β_1) = -1.78	t value (β_0) = 1.38	R^2 = 0.17	
p value (β_1) = 0.09	p value (β_0) = 0.19	R^2 adj. = 0.11	
DW = 2.45	RSS = 87.06	SC = 85.24	AIC = 83.45

Because different variables are used, the models expectations augmented Phillips curves cannot be compared according to R^2. But Regression 3 and Regression 5 can be compared by the values of residual sum of squares. The values of RSS are 133.33 and 94.56. Therefore, the second model fits much better. Results are similar to ones done by Green; only numbers are different, because Green had bigger sample size. The logic says that the second model should fit better; the λ is found according to smallest RSS. The second model cannot be worse; in can only be the same if the people expect inflation only according the last time period and not later past. In that case λ would be equal to zero.

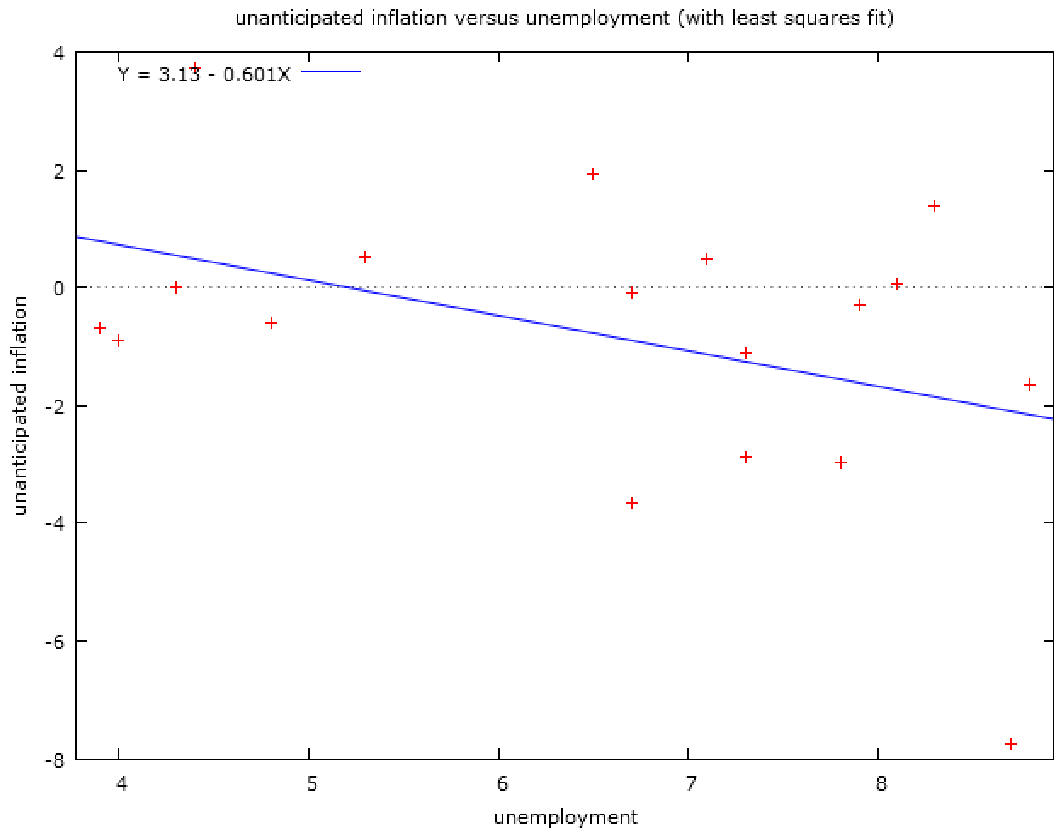

Figure 16: Scatterplot of unemployment vs. unanticipated inflation (expected inflation determinated by geometric lag model)

Natural rate of unemployment

The natural rate of unemployment was found the same way as before. The results are at Equation [42]. The natural rate of unemployment is received.

$$u^* = -\frac{\beta_0}{\beta_1} = -\frac{3.13}{-0.60} = 5.21 \quad [42]$$

The confidence interval is also found by the Delta method as before; covariance matrix of regression coefficients is shown in Equation [43], below are equations showing the arithmetical work.

$$Var(\beta) = \begin{bmatrix} 5.18 & -0.74 \\ -0.74 & 0.11 \end{bmatrix} \quad [43]$$

Variance of the natural rate of unemployment is received.

$$\sigma^2 = \frac{1}{\beta_1^2}\left(V_{11} - 2\frac{\beta_0}{\beta_1}V_{12} + \frac{\beta_0^2}{\beta_1^2}V_{22}\right) = \frac{1}{(-0.60)^2}(5.18 - 2\frac{3.13}{-0.60}(-0.74) + \frac{3.13^2}{(-0.60)^2}0.11) = 1.40 \quad [44]$$

95% confidence interval takes form

$$u^* \pm 1.96 * \sqrt{\sigma^2} \quad [45]$$

Then, the numbers are plugged in.

$$5.21 \pm 1.96 * \sigma = 5.21 \pm 1.96 * \sqrt{1.40} = 5.21 \pm 2.32 \quad [46]$$

The confidence interval (2.89, 7.53) confirms the previous results; there is no doubt the second model fits better. The residual sum of squares is smaller; the confidence interval is narrower. On the other hand, the results were not improved so much as in the case of Green research; his standard error was only 0.55. The model could be improved by further expansion; the cost would be lower number of observations.

Cyclical unemployment and Short-term Supply shocks

Cyclical unemployment and supply shocks were computed by the same method as previously. The graphical display of cyclical unemployment is in the Figure 17. The results are compared with ones obtained by model with first differences. The cyclical unemployment computed by geometric lag model is higher. The reason is that the natural rate of unemployment is smaller. Regression 6 shows results. Supply shocks are derived from these shocks.

Regression 6: Model of Phillips curve in the Czech Republic without constant term

$\Delta\pi_t = -0.60(u_t - 5.21)$			
SE(β) = 0.25		n = 18	
t value (β) = -2.38		R^2 = 0.25	
p value (β) = 0.03		R^2 adj. = 0.25	
DW = 2.45	RSS = 87.06	SC = 82.34	AIC = 81.45

The difference between Regression 6 and Regression 4 is in the way of calculating expected inflation. In Regression 6 was used geometric lag model for determination of expected inflation; Regression 4 used only simple model of expectations. In this model the expected inflation was actually the inflation in previous time period. This difference influenced results significantly. The Residual Sum of Squares is in Regression 6 lower by almost 35%.

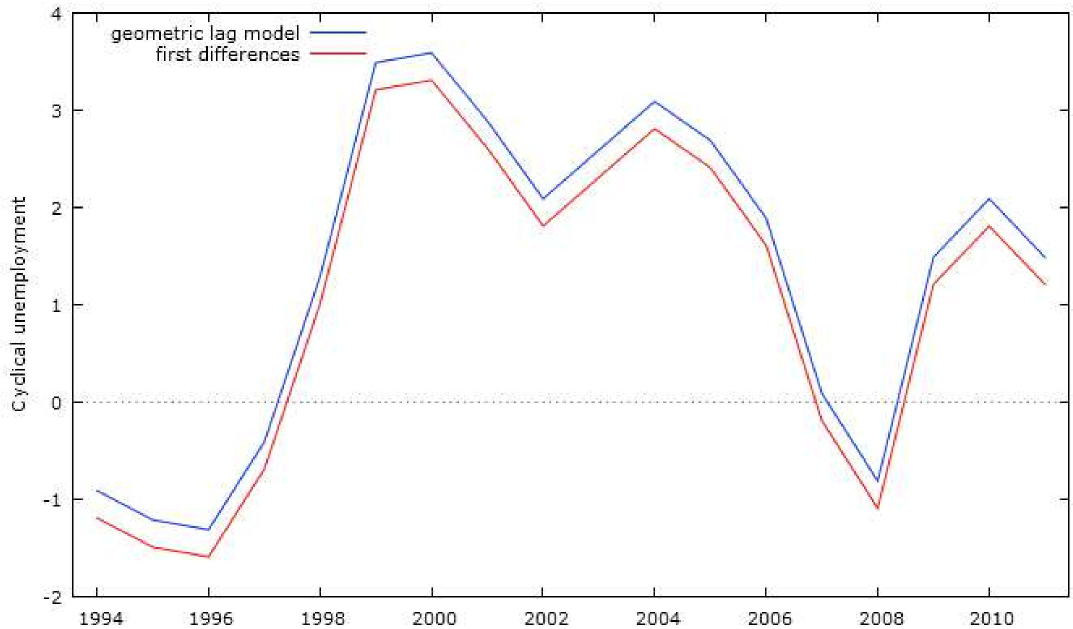

Figure 17: Cyclical unemployment in the Czech Republic

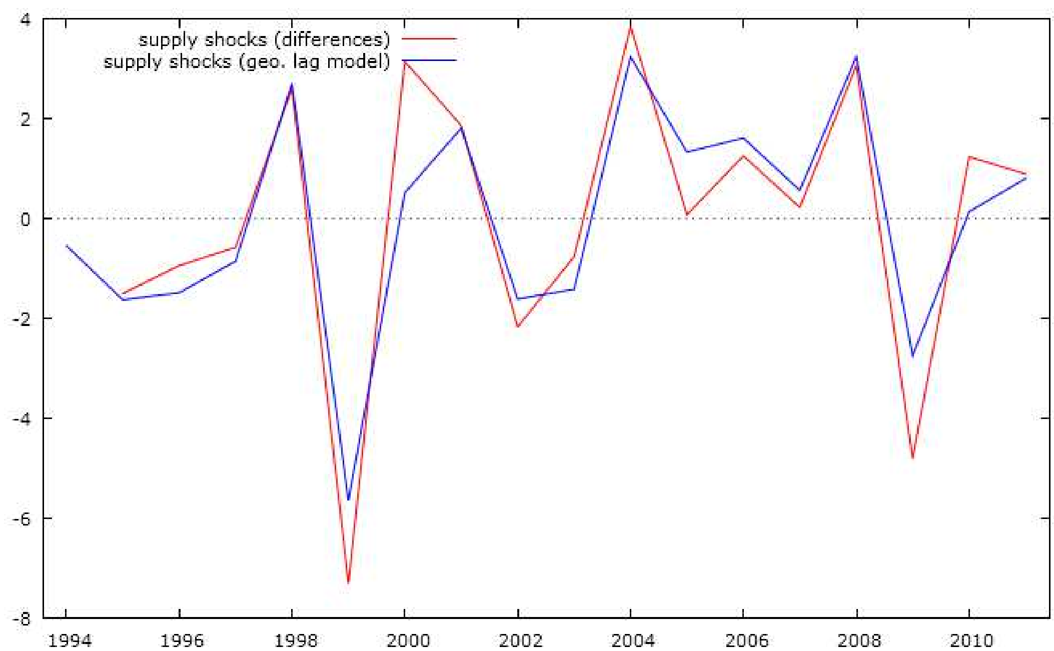

Figure 18: Supply shocks

Figure 18 shows the supply shocks. The results are also compared with results obtained by different method.

5.2 Slovakia

5.2.1 Situation in Slovakia in years 1994-2011

After division of Czechoslovakia the Slovak Central bank started to pursue independent monetary policy. Inflation in Slovakia was as well as in the Czech Republic relatively stable. At the end of nineties, inflation went up due to the increase of regulated rent and increase of VAT. In long term, the issue in Slovakia was high unemployment rate. Until 1996 there was over-employment. After 1994 long term unemployment started to be an issue. Almost 50% of unemployed people did not work for over a year. In 2000 unemployment rate increased over 18% and it stayed on this level over 2 years. Situation got better in 2002 – the improvement was caused by recovery of the economy and reforms of the government. Since 2000, the number of foreign investments was increasing and this also caused the improvement of unemployment rate. Since 2004 the unemployment rate was decreasing and it got to single digits in 2008. The issue of long term unemployment still exists. Over 75% of unemployed people are registered with employment bureau over a year. (Zeleznik, 2009)

5.2.2 Stationarity of variables

Situation in Slovakia was less stable than situation in the Czech Republic in years 1994-2011. This played a role in non-stationarity of some macroeconomic indicators. The Table 6 shows the results.

Table 6: Stationarity tests

Variable	Test statistic	P-value	Conclusion
Unemployment rate	-2.38	0.15	Non-stationary
Inflation (1994-2011)	-2.21	0.20	Non-stationary
First differences of inflation	-4.52	<0.01	Stationary
Unemployment rate (2006-2011)	-5.23	<0.01	Stationary
Inflation (2006-2011)	-1.12	0.71	Non-stationary

(Source: Author's work)

Non-stationary unemployment rate is something unusual but with problems in Slovakia in labour market, it is somehow understandable. It affects this study. Not only the static model but also expectations augmented model will be affected by the issue of non-stationarity of variable in regression.

5.2.3 Simple linear model of Phillips curve

Table 7 shows basic statistics of used data. In comparison with the Czech Republic both inflation and especially unemployment rates were significantly higher. The unemployment rate also has much higher variance.

Figure 19 suggests that in case of Slovakia, there will not be any statistically significant tradeoff between unemployment rate and inflation in years 1994-2011. This prediction confirms Regression 7.

According to Regression 7, there is no significant tradeoff. On the other hand the positive slope is not significant. To compare it with literature – the positive relationship is not something extraordinary. It is not usual, true, but for example, Wooldridge (2002) also found positive relationship in yearly data for US economy in years 1948-1996. The reasoning behind unexpected positive relationship was, that the Static Phillips curve is not the best model for detecting relationship between unemployment rate and inflation.

Table 7: General Statistics

	Unemployment rate (1994-2011)	Inflation (1994-2011)	Unemployment rate (2006-11)	Inflation (2006-11)	First differences of inflation
Mean	14.47	6.08	12.32	2.63	-0.55
Median	13.60	5.90	12.70	2.90	-0.20
Maximum	19.20	13.50	14.40	4.30	4.70
Minimum	9.60	0.70	9.60	0.70	-5.00
Range	9.60	12.80	4.80	3.60	9.70
Variance	8.86	13.91	3.17	2.76	9.88
Standard deviation	2.98	3.73	1.78	1.66	3.14
Variation coefficient	0.21	0.61	0.14	0.63	5.68
Skewness	0.21	0.40	-0.41	-0.14	0.08
Kurtosis	-1.23	-0.72	-1.11	-1.80	-1.30

(Source: Author's work)

Regression 7: Static Phillips curve in Slovakia

$\pi_t = -0.07 + 0.43u_t$			
SE(β_1) = 0.29	SE(β_0) = 4.35	n = 18	
t value (β_1)) = 1.44	t value (β_0)= -0.02	R^2 = 0.12	
p value (β_1)) = 0.17	p value (β_0) = 0.99	R^2 adj. = 0.06	
DW = 0.76	RSS = 209.27	SC = 101.02	AIC = 99.24

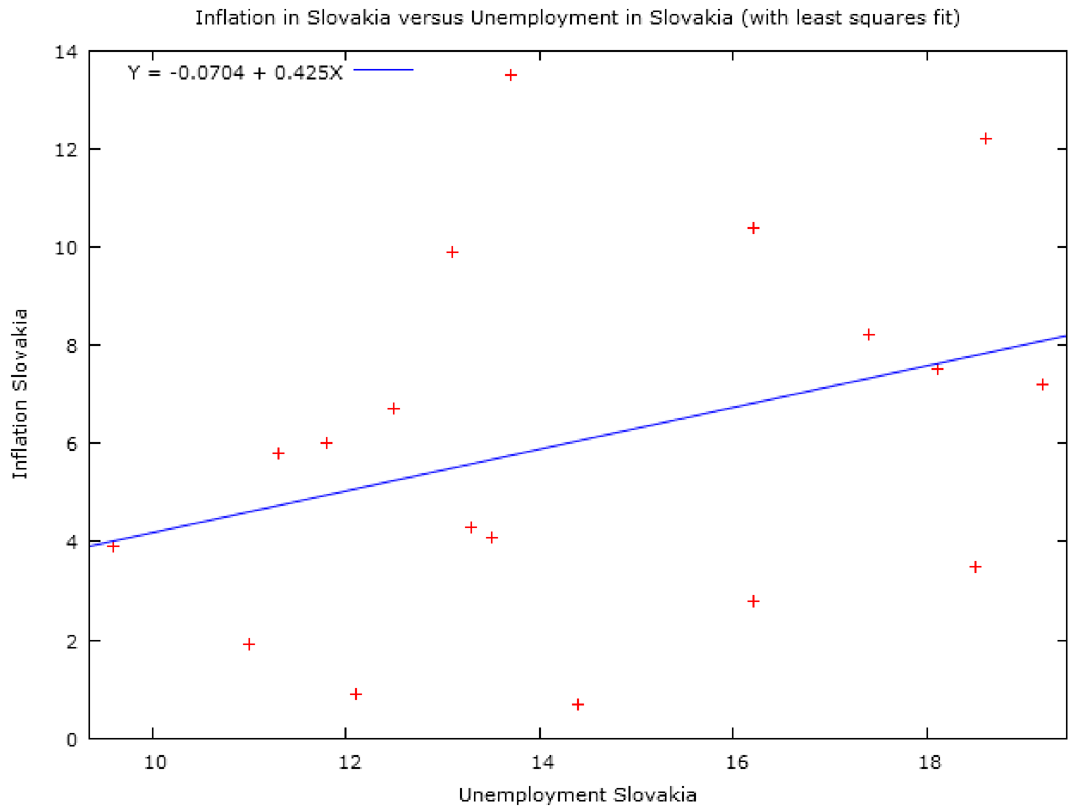

Figure 19: Static Phillips curve in Slovakia

5.2.4 Static Phillips curve in Slovakia in years 2006-2011

Slovakia accepted Euro in 1st of January 2009. One of the requirements on the list of Maastricht criteria is that the country has to be at least 2 years in ERM II. In other words, the exchange rate of Slovak Crown and Euro has to be tight (±15% of fluctuations). Slovakia entered into ERM II in November 2005. The static Phillips curve in years 2006-2011 is therefore the Phillips curve in Slovakia since the Euro was introduced.

The negative thing about this regression is low number of observations (only 6). The basic data statistics are in Table 7. The results (Regression 8) show that the slope is negative, as it should be. The results are strongly insignificant. But with Phillips curve, it is not usual to have a very good fit of data. It is important to stress out that the number of observations is only 6. Figure 20 shows the scatterplot of data and estimated regression line.

Regression 8: Simple Phillips curve in Slovakia 2006-2011

$\pi_t = 4.77 - 0.17u_t$			
SE(β_1) = 0.46	SE(β_0) = 5.69	n = 6	
t value (β_1)= -0.38	t value (β_0) = 0.84	R^2 = 0.03	
p value (β_1)= 0.72	p value (β_0) = 0.45	R^2 adj. = -0.21	
DW = 2.10	RSS = 13.34	SC = 25.40	AIC = 25.82

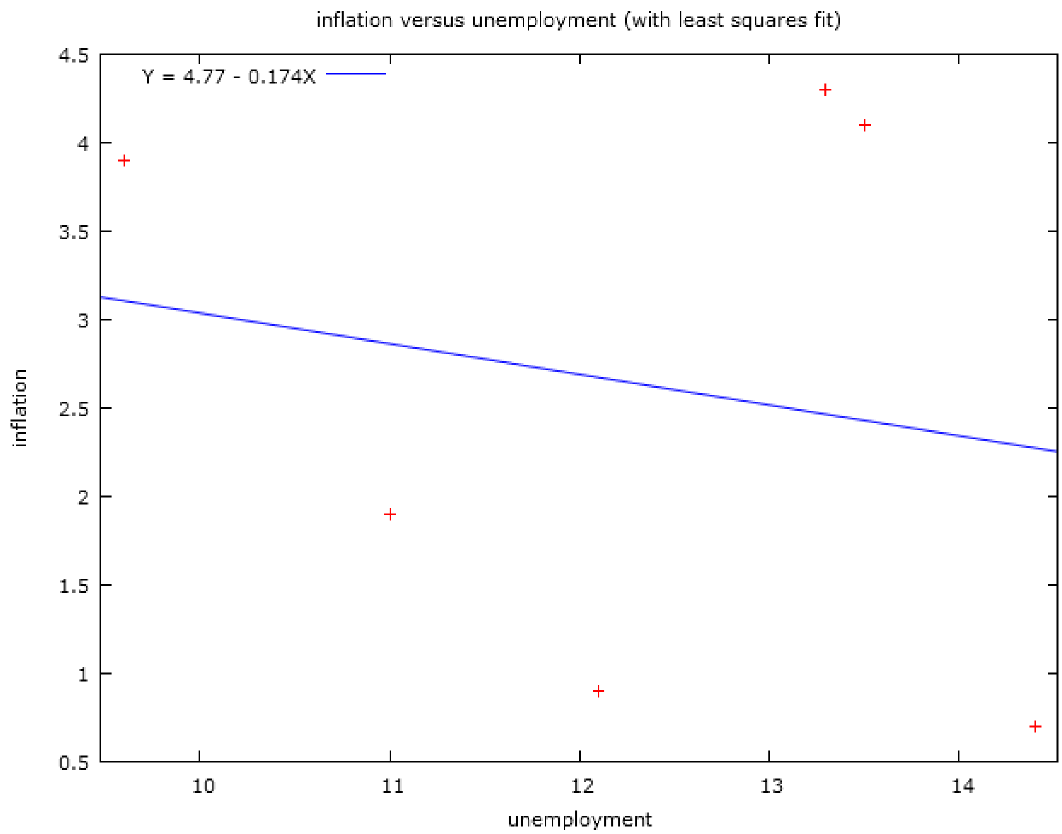

Figure 20: Static Phillips curve in Slovakia 2006-2011

The interesting fact about Regression 8 is the negative value of adjusted R^2. There are two reasons for it – too low number of observations and low R^2.

This regression does have negative slope but the goodness of fit and significance of parameters is very low. So even though there is a negative parameter it cannot be said that this model confirms tradeoff between unemployment rate and inflation in Slovakia in years 2006-2011. Furthermore, the inflation is non-stationary so it also affects negatively the regression.

5.2.5 *Expectations augmented model of Phillips curve*

From results in Figure 21 and Regression 9 it can be expected that the results of the natural rate of unemployment will be difficult to interpret. The problem is not really the low significance or extremely low value of R^2; these issues will be taken into an account in calculating standard errors of natural rate of unemployment and therefore the confidence interval would be wider. The actual problem is, that both β_0 and β_1, are negative numbers. This will lead to the negative value of natural rate of unemployment. This is not justifiable from the economic standpoint.

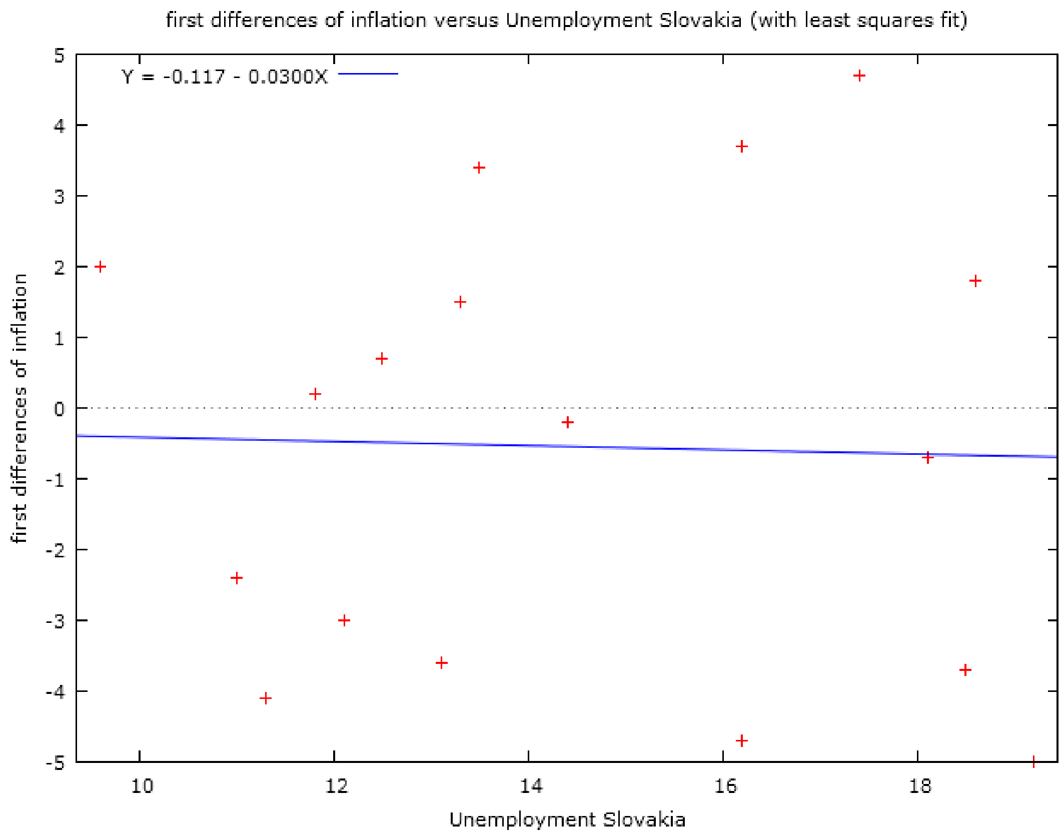

Figure 21: Augmented Phillips curve in Slovakia

Regression 9: Augmented Phillips curve in Slovakia

$\Delta\pi_t = -0.12 - 0.03u_t$			
SE(β_1) = 0.26	SE(β_0) = 3.93	n = 17	
t value (β_1)= -0.11	t value (β_0) = -0.03	R^2 = 0.0008	
p value (β_1) = 0.91	p value (β_0) = 0.98	R^2 adj. = -0.08	
DW = 1.98	RSS = 157.88	SC = 91.80	AIC = 90.13

Because of these issues it is useless to continue trying to find the natural rate of unemployment and its standard errors. The findings will not be accurate, because result -4% ± n% cannot be accepted no matter on the size of n.

The question now is if improvement on function of expected inflation will actually help the model. The observations in Regression 9 are statistically almost random. The static Phillips curve shows positive relationship between unemployment rate and inflation. Can these data produce reliable information about the natural rate of unemployment? It probably cannot. The results of relationship of unemployment rate and inflation in Slovakia are following: there is statistically evident no tradeoff between unemployment rate and inflation. From obtained data emerged negative natural rate of unemployment.

6 Conclusions

In the Czech Republic, the relationship between unemployment rate and inflation exists and is statistically significant. Even though the static model operates with non-stationary variable - inflation (non-stationarity was caused by higher inflation at beginning of transformation era) and therefore the results can be biased, there is no doubt that there exists a tradeoff between these two macroeconomic indicators. In a long term, the Phillips curve is expected to be vertical. The strong evidence of a tradeoff was surprising.

The expectations augmented Phillips curve shows that inflation lower than expected causes a rise in unemployment and vice versa. The model with expected inflation expressed as the inflation in previous time period did not give a strong evidence of this assertion. The model where expected inflation was expressed by geometric lag model shows better results even though the parameters are not statistically significant. From these models were computed the natural rates of unemployment with its confidence levels. The results differed by 0.2%. The more accurate model with expected inflation expressed by geometric lag model estimated the natural rate of unemployment as 5.21 ± 2.32. Cyclical unemployment was also estimated. The results suggests that between years 1998-2011 with an exception of year 2008 there existed cyclical unemployment in the Czech Republic and its peaks were in years 2000, 2004 and 2010. Supply shocks are oscillating around zero and there are not any significant time periods during which would be stable for longer period of time.

In Slovakia the situation was different. The simple linear regression showed positive slope. On the other hand, the relationship was very weak and the observations were almost random. This was not a main issue with the analysis of Slovak Phillips curve. The static model is not the best one and according to Wooldridge even the US economy shows positive trend in static model. The issue was the expectations augmented curve. Even though it is not usual to have a strong relationship in this model the value of R^2 equals to 0.0008 suggests almost random distribution. The resulting regression shows negative slope and also negative constant. This leads to negative natural rate of unemployment.

There can be several explanations of those problems. In Slovakia there was not such a stable development as in the Czech Republic. This assertion can be confirmed by basic statistic of data – both unemployment rate and inflation in Slovakia had bigger range and larger standard deviation. In case of unemployment rate these indicators were almost two times larger plus it was not stationary. The issue may be also the change of currency which may effected number of things. In the time period with Euro the results showed negative slope even though it was not a strong relationship. This time period did not differ from previous one only with currency. In this time the development of Slovakia is more stable. This was proved by basic statistics in Table 7 and also stationarity of unemployment rate.

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8 Appendix

8.1 List of Figures

8.2 List of Regression Models

8.3 List of Tables

8.4 List of Abbreviations

P_t	Price level in year t
P_{t-1}	Price level in year t-1
P_0	Prices in base year
q_0	Quantity of item purchased in base year
q_t	Quantity of item purchased in year t
L^s	Labor force
L	Employment
U	Unemployment
u	Unemployment rate
u^*	Natural rate of unemployment
π	Actual inflation
π_e	Expected inflation
ε	Error
β_0	Parameter
β_1	Parameter
Y_i	Observation i
$\hat{Y}_i$	Expected observation given the regression model

X_i	Explanatory variable
n	Number of observations
RSS	Residual (Error) sum of squares
p	Number of parameters
t	Time
E( )	Expected value
Var	Variance
σ	Standard deviation
Corr	Serial correlation
f(x)	Function
f(a)	Function at point a
f'	Derivation of function f
Cov	Covariance
$\partial f/\partial x$	Partial derivation of function with respect to x
μ	Mean
$V_{11,22}$	Variance
$V_{12,21}$	Covariance
a	Parameter
$\Delta\pi$	Difference between expected and actual inflation
λ	Lambda; parameter; $\lambda \in (0,1)$
ρ	Coefficient of correlation

8.5 Large Tables

Table 8: The original data

Year	Czech Inflation	Slovak Inflation	Czech Unemployment Rate	Slovak Unemployment Rate
1994	10	13.5	4.3	13.7
1995	9.1	9.9	4	13.1
1996	8.8	5.8	3.9	11.3
1997	8.5	6	4.8	11.8
1998	10.7	6.7	6.5	12.5
1999	2.1	10.4	8.7	16.2
2000	3.9	12.2	8.8	18.6
2001	4.7	7.2	8.1	19.2
2002	1.8	3.5	7.3	18.5
2003	0.1	8.2	7.8	17.4
2004	2.8	7.5	8.3	18.1
2005	1.9	2.8	7.9	16.2
2006	2.5	4.3	7.1	13.3
2007	2.8	1.9	5.3	11
2008	6.3	3.9	4.4	9.6
2009	1	0.9	6.7	12.1
2010	1.5	0.7	7.3	14.4
2011	1.9	4.1	6.7	13.5