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Hysteresis in unemployment in Slovakia

diplomová práce

Autor: Mgr. Magdaléna Řeháková

Vedoucí práce: Ing. Pavel Potužák, Ph.D.

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Prehlasujem na svoju česť, že som diplomovú prácu vypracovala samostatne a s použitím uvedenej literatúry.

Mgr. Magdaléna Řeháková

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Poďakovanie

V prvom rade patrí moja vďaka mojim rodičom, ktorí ma vždy podporovali, bez ohľadu na neštandardnosť mojich životných rozhodnutí alebo nepríjemností s tým spojených. Vždy mi boli vzorom ako osobnostným, tak pracovným a dúfam, že niekedy budem tak dobrým človekom a rodičom ako sú oni. Bez nich by táto práca nikdy nevznikla.

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ZADÁNÍ DIPLOMOVÉ PRÁCE

Zpracovatelka: **Mgr. Magdaléna Řeháková**

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Název tématu: **Hysteresis in unemployment in Slovakia**

Zásady pro vypracování:

1. The hysteresis effect in unemployment rate became the object of interest already in the 1980´s, when it first became apparent that a high unemployment rate does not always adapt fast to improving health of the economy. After the Great Recession the hysteresis topic has been revived and economists are trying to gain deeper understanding of the process in order to provide better policy answers to future crises – policy answers that would take into
account the specific features of each economy. Though there are studies that concentrate on transition countries and their comparisons, to my knowledge there is no study having at its center of attention solely Slovakia and its regions.
In my thesis I will begin with economic model of hysteresis in unemployment along with
literature review on the reasons for the existence of hysteresis and the possible methodology of its detection. I will continue with the empirical analysis of existence of hysteresis in Slovakia using various unit root tests and analysis of its regional presence. The analysis will be conducted on the data beginning at the end of the 1990´s until the most recent available data. I will therefore analyze hysteresis in unemployment in business cycles throughout
modern history of Slovakia. I will try to provide reasons for possibly different levels of hysteresis throughout regions. The discussion of the impact of hysteresis on the economy and on the options of mitigating the negative effects of hysteresis will conclude my thesis. The data will be obtained from the Central Office of Labour, Social Affairs and Family in Slovakia.

Rozsah práce: 65

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Mgr. Magdaléna Řeháková

Řešitelka

Ing. Pavel Potužák, Ph.D.

Vedoucí práce

prof. Ing. Robert Holman, CSc.

Vedoucí katedry

prof. Ing. Zdeněk Chytil, CSc.

Děkan NF VŠE

Abstract

In this thesis I present the theoretical background for the study of hysteresis in unemployment and its various potential sources and mechanisms through which hysteresis works with emphasis on the Slovak labor market context. I provide a review of available literature on hysteresis concerning Slovakia and regional analysis of this topic. I study the presence of hysteresis in Slovak unemployment rates at the country level as well as at the regional level. At the country level I use the unit root test with two endogenously determined breaks. Regions are being analyzed by univariate unit root tests and by the second-generation panel unit root tests. I cannot reject the hysteresis hypothesis neither at country-wide nor at the regional level. In the end, I present a discussion on policy implications.

Keywords: unemployment, hysteresis, unit root, region, factor analysis
JEL classification: E24, R2

Abstrakt

V této diplomové práci představuji teoretický základ teorie hystereze v nezaměstnanosti a různé potenciální zdroje a mechanismy, prostřednictvím kterých hystereze působí. Hysterezi v nezaměstnanosti studuji v kontextu Slovenska. Uvádím přehled dostupné literatury zabývající se hysterezi v nezaměstnanosti na Slovensku a literatury zabývající se regionální analýzou hystereze. Přítomnost hystereze v nezaměstnanosti na Slovensku analyzuji jak z hlediska celostátního, tak z hlediska regionálního. Na celostátní úrovni používám test jednotkového kořene se dvěma endogenně určenými zlomy. Data z krajů zkoumám prostřednictvím jednorozměrných testů jednotkového kořene a panelových testů jednotkového kořene druhé generace. Hypotézu o přítomnosti hystereze na celostátní úrovni i regionálních úrovních nemůžu zamítnout. Závěrem shrnuji možné implikace přítomnosti hystereze v nezaměstnanosti.

Klíčová slova: nezaměstnanost, hystereze, jednotkový kořen, region, faktorová analýza
JEL klasifikace: E24, R2

Content

Introduction

The topic of hysteresis in unemployment gained its importance during the 1980's when unemployment rates in Europe rose and remained high without any plausible explanation based on the contemporary economic theory (Blanchard and Summers 1986b). Blanchard and Summers brought to light the theory of hysteresis, which explained that temporary shocks - downturns of demand - could have permanent effects. During the years, the validity of the hysteresis theory was tested on the unemployment data of many countries. The European unemployment rate has consistently shown hysteretic features. Yellen claims that when *"persistent shortfalls in aggregate demand … adversely affect the supply side of the economy - an effect commonly referred to as hysteresis"* (Yellen 2016). Policy implications in case of the presence of hysteresis are to adopt more accommodative monetary and fiscal policy that would work counter-cyclically and would focus more on unemployment stabilization. On the other hand, if no hysteresis is present, these policies are not an adequate solution to recessions (Engler and Tervala 2018). Information on whether hysteresis is present in the economy has therefore very practical future application.

There are more studies analyzing the presence of hysteresis in unemployment that include also Slovakia. I will present them later in the thesis. To my knowledge there are no studies yet that would focus also on Slovak regions or that would use PANIC test as a panel unit root test "resistant" to interregional correlation.

In the theoretical part I will first introduce the general concept of hysteresis and original theory that used to be accepted as universal rule the unemployment rate follows in the long run – the natural rate of unemployment and NAIRU concept. Then I will introduce various meanings and approaches to hysteresis in unemployment. Available knowledge on the potential sources of hysteresis will follow. Within the review of the origins of hysteresis I will try to discuss them also from the Slovak perspective and provide a brief introduction to the problems Slovak labor market faces that could possibly invoke or exacerbate hysteresis. Part 2 consists of literature review divided into two thematical segments. Due to a very large available repository of literature I chose to present only hysteresis literature concerning Slovakia and literature that focused on studying the regional presence of hysteresis.

Empirical part will begin with description of data that constitute the source of my own calculations. I will continue with methodology presentation along with the background on the unit root testing with endogenously determined breaks. To study unemployment data in Slovakia, I chose Lee and Strazicich (2003) univariate unit root test with two endogenously determined breaks. Breaks are included both under the null and under the alternative hypothesis, not only under the alternative, which was the standard until Lee and Strazicich. This construction of the test guarantees that when we reject the null of a unit root, we reject it in behalf of the stationarity hypothesis, not in behalf of the existence of statistically significant breaks. Lee and Strazicich test answers the question whether there are possibly multiple equilibria (bordered by two structural breaks) within which the natural unemployment rate theory is valid. If the null of a unit root is not rejected, even taking account of the breaks does not provide a satisfactory proof that unemployment rate is a linear unit root process. I tried to provide a follow-up on the equations that constitute the theoretical and statistical basis of the test. To study unemployment hysteresis in regional data, I used univariate tests (ADF, KPSS, Ng-Perron) as well as panel unit root tests of the second generation that do not assume cross-sectional correlation among studied series. Out of the second-generation tests, I employ Pesaran panel unit root test (2007) and Panel Analysis of Non-Stationarity in Idiosyncratic and Common Components (PANIC) unit root test (2004). Both these tests assume factor structure of the series under scrutiny. Pesaran's assumption is that there is only one common factor that is the source of cross-sectional correlation and can be proxied by adding averages of first differences and first lags of the observed series. Pesaran then tests for a unit root in de-factored series. PANIC test, on the other hand, does not assume only one common component, and it tests for a unit root both in the common factor and idiosyncratic component series. In this manner, it can determine the source of the unit root process behind the unemployment rate data (Gengenbach et al., 2008).

All of the above-mentioned methods test for linear hysteresis defined as a unit root process. These tests will therefore give the answer whether a temporary shock to the unemployment rate in Slovakia and its regions would result in a permanent change in the equilibrium unemployment rate, either within some endogenously defined time range (Lee and Strazicich) or on the whole data sample (univariate unit roots, Pesaran, PANIC). These tests may provide some arguments on behalf of the opposite, that the fluctuations of the unemployment rate attributable to the business cycle are only temporary and unemployment rate will converge to its natural rate in a short time (again either within a certain time range – Lee and Strazicich, or in the whole data sample - other tests).

1. Hysteresis and natural rate hypothesis

1.1 The term “hysteresis”

The observation of hysteretic behavior in economic variables is not new. Roed (1997) mentions that since the times of Schumpeter, there were economists describing hysteretic behavior of economic variables, though they did not use the exact word yet.

The term ‘hysteresis’ was first used in physics in the nineteenth century (ibid.). The term hysteresis in physics describes the phenomenon of lagged magnetization:

“When a ferromagnetic material is magnetized in one direction, it will not relax back to zero magnetization when the imposed magnetizing field is removed. It must be driven back to zero by a field in the opposite direction.“[1]

Hysteresis therefore generally describes a situation in which some transitory shock has permanent effects. In economics, this theory is studied mainly within the fields of consumption, international trade and labour market theory (ibid., p. 393).

In the labor market theory, economists study whether there is any prevailing increase in equilibrium unemployment even after the source of this increase has ceased to impact. Intense research of unemployment hysteresis began especially at the end of the 1980’s. In the 1970’s and 1980’s economists were trying to find the answer on the steadily rising European unemployment rates. Most macroeconomic theories until then alleged that *“there exists some “natural rate” or “non-accelerating-inflation rate of unemployment” (NAIRU) towards which the economy tends to gravitate and at which the level of inflation remains constant”* (Blanchard and Summers 1986a, p.1). According to this theory unemployment fluctuations are only cyclical deviations from the natural rate or NAIRU. If the cyclical deviations have permanent effects, the natural rate (or NAIRU) hypothesis cannot be valid.

[1] http://hyperphysics.phy-astr.gsu.edu/hbase/Solids/hyst.html

1.2 Natural rate of unemployment

Until Friedman (1968) and Phelps (1967, 1968) Phillips curve was widely understood as a menu of outcomes for policymakers between different degrees of unemployment and price stability, as Samuelson and Solow (1960) put it, both in the short run and in the long run (Mankiw Reis 2018, p.83). Friedman and Phelps proposed modified Phillips curve that comprised the effect of expectations (Vane Mulhearn 2009, p.113).

In Friedman's presidential address published in 1968 he named equilibrium rate of unemployment "natural" as a counterpart to the Wicksell's term "natural rate of interest". According to Friedman

"the 'natural rate of unemployment', in other words, is the level that would be ground out by the Walrasian system of general equilibrium equations, provided there is embedded in them the actual structural characteristics of the labor and commodity markets, including market imperfections, stochastic variability in demands and supplies, the cost of gathering information about job vacancies and labor availabilities, the costs of mobility and so on". (Friedman 1968, p. 8)

A certain level of the unemployment rate is therefore natural if it is a result of market imperfections, rigidities, and the structure of labor market institutions in the economy. Since these are real variables, monetary policy cannot influence the unemployment rate in the long run. In the short run, the monetary authority can target a certain unemployment rate at the cost of inflation. Friedman explains the process by which expansionary policy would enable a lower unemployment rate during some transitory period through slow expectation updating. Lowered interest rates due to expansionary monetary policy would first stimulate income and spending. Higher demand would lead to increased production and employment. Since selling prices respond to the unexpected rise in nominal demand faster than factor prices, real wages will decrease. Since increase in nominal demand leading to increase in prices was unanticipated, people must update their expectations about the price level. It takes some time for employees to evaluate their wages at a new price level. When employees begin to demand higher nominal wages that would correspond to the increased price level to keep the real wage at the previous level, unemployment rate will adjust to the same natural rate.

In order for the monetary authority to maintain targeted unemployment rate lower than natural unemployment rate by using expansionary policy, economy would have to suffer from accelerating inflation (Friedman 1968, pp.9-10).

In Phelps' 1968 paper he defines an equilibrium unemployment rate as *"the rate at which the actual and expected price increases (or wage increases) are equal"* and *"is independent of the rate of inflation"* (Phelps 1968, p.682)

Phelps sums up: *„…a more inflationary policy permits a transitory increase of the employment level* ***in the present*** *at the expense of a (permanently) higher inflation and higher interest rates* ***in the future*** *steady state. Optimal aggregate demand therefore depends upon society's time preference"* (Phelps 1967, p.256).

Phelps' as well as Friedman's work was based on adaptive expectations hypothesis (Phelps 1968, p.682) that later was replaced by rational expectations theory. Recent research has though again focused on sluggish updating of expectations with the goal of finding better understanding of how expectations work. These might be a combination of adaptive and rational expectations. Researchers are trying to model them with the help of behavioral economics and new micro data that pay particularly attention to expectations (Mankiw and Reis 2018, p.85,92).

1.3 NAIRU

The NAIRU, originally labelled as non-inflationary rate of unemployment (NIRU), was first used by Papademos and Modigliani (1975). Tobin presumes the change to "non-accelerating" was possibly made in order to reflect the necessary inflation acceleration to maintain unemployment rate level target (Tobin 1997, p.7). Tobin provides his own interpretation of NAIRU and its difference with the natural rate. According to him NAIRU *"assumes an economy at which at anytime most markets are characterized by excess demand or excess supply at prevailing prices… The NAIRU is the unemployment rate at which inflation-increasing effects of the excess demand markets just balances the inflation-decreasing impacts of the excess supply markets. Unlike the natural rate, this is a balance among disequilibrium markets…Unlike the natural rate, the NAIRU could not be modelled as a single economy-wide market…"* (Tobin 1997, p.8).

Mankiw and Ball (2002) define NAIRU simply as an unemployment rate consistent with stable inflation, and they see NAIRU as an approximate synonym of the natural rate of unemployment.

1.4 Various approaches to hysteresis

1.4.1 Path dependence

Roed (1997, pp. 393-394) uses following discrete time dynamic model for description of the unemployment hysteresis:

$$u_t = f(u_{t-1}, \ldots, u_{t-k}, x_t, x_{t-1}, \ldots, x_{t-k}, y_t) \qquad (1)$$

u_t represents unemployment at time *t*, u_{t-k} are past realizations of *u* with *k* being the number of realizations that is deemed appropriate, x_t represents vector of exogeneous variables at time *t*, x_{t-k} is a vector of past realizations of exogeneous variables and y_t is a vector that captures the possible structural changes assumed to be invariant to the history of unemployment. The model without hysteresis would exist if:

$$\lim_{t \to \infty} u_t \mid u_{t-1}, \ldots, u_{t-k}, x_{t-1}, \ldots, x_{t-k} = u(x, y) \qquad (2)$$

meaning that in case there is no hysteresis, *"the rate of unemployment will converge to a number that does not depend on the past behavior of the system. "In that case, the model generates a path independent (but not necessarily constant) equilibrium rate of unemployment (attractor). If on the other hand equation (2) is violated, the model exhibits hysteresis and it yields at best a path dependent equilibrium rate of unemployment. In that case, even transitory shocks may have permanent effect on unemployment."(Roed 1997, p.394)*

According to Roed (1997), change in the equilibrium rate of unemployment can therefore happen either as a cause of the exogeneous structural break (change in y_t) or by some change *"within the system itself"* (hysteresis case). Roed continues: *"...in terms of standard behavioral equations, hysteresis may sometimes be interpreted as endogenous structural changes. For example, we may observe that some institutional features of the labor market have changed in a way that can account for the increased level of equilibrium unemployment. The big question is then: Is it the structural change that has caused the increase in the unemployment rate or is it the increase in the* *unemployment rate that has caused the structural change?... The potential power of the natural rate hypothesis emanates from the proposition that all these structural characteristics are exogenous. If that proposition turns out to be invalid, i.e. if cyclical deviations from the natural rate embody the seeds of destruction of the structural characteristics underlying that same natural rate, then there is not much natural about the natural rate at all."(ibid., pp.395-396)*

Lanzafame (2012, p. 416) formally defines hysteresis as a situation in which unemployment rate is linearly dependent on a combination of its past values, with coefficients summing up to one. This is a pure version of linear hysteresis which is econometrically equivalent to a unit root process.

León-Ledesma and McAdam (2003, p.11) provide an example of AR(k) process with no intercept shifts:

$$y_t = \beta_0 + \sum_{k=1}^{K} \beta_k y_{t-k} + \varepsilon_t \qquad (3)$$

León-Ledesma and McAdam explain that in this equation 'natural', mean, or equilibrium rate to which unemployment reverts over time is $\bar{y} = (\frac{\beta_0}{1-\sum \beta_k})$ if $\sum \beta_k < 1$. If on the other hand $\sum \beta_k = 1$, unemployment follows a random walk, displays path dependence, and it is defined as pure hysteresis.

Early studies focused on testing pure hysteresis by univariate unit root tests. This pure version of linear hysteresis was later relaxed. Situations in which unemployment rate though depended to a large extent on its past values were also considered hysteretic, and hysteresis was defined rather as "persistence" or "partial hysteresis" (Lanzafame 2012, p. 417). To capture possible non-linearities in the persistence model (for example due to different hiring and firing costs in the economy's upturns and downturns respectively), the definition of hysteresis as a multiple equilibria model was developed.

1.4.2 Structuralist approach

Multiple equilibria approach was backed by Edmund Phelps (1994). This model predicts that *"most shocks cause temporary movements of unemployment around the natural rate, but occasional shocks cause permanent changes in the natural rate itself*" (Papell et al. 2000, p.309). The reason is that some of the shocks will permanently change the equilibrium values of economic variables (Roed 1997) Unemployment should be therefore *"stationary around a process that is subject to structural breaks"* (Papell et al. 2000, p.309). The potential of the natural rate of unemployment to change when labour market structure/institutions change was expected also by Friedman: *"I do not mean to suggest that it is immutable or unchangeable. On the contrary, many of the market characteristics that determine its level are man-made and policy-made."* (Friedman 1968, p.9)

Phelps (1995) named a couple of shocks or inherent structural changes that could cause permanent increase in the natural rate of unemployment. One of them could be interventions in the labor market like taxation or barriers to firing a worker. Another reason Phelps mentions that could permanently shift the natural rate of unemployment is wealth and social capital. The richer the person is, the more financial entitlements the person has in the case of unemployment, the more he is prone to quitting or shirking the job. With such employees, employers would tend to increase their wages to incentivize them to stay. Increased wages would probably bring along also increased natural unemployment rate (Phelps 1995).

1.5 Possible hysteresis-producing mechanisms

Many mechanisms were suggested through which a lagged increase in unemployment may occur and prevail for longer time periods. Sources of hysteresis are not mutually excludable. Two frequently presented models of hysteresis based on its source are *insider-outsider model* and models based on *depreciation of skills, search effectiveness, and social stigma.*

1.5.1 Insider-Outsider Model

Blanchard and Summers (1986b) present the membership and duration theories. The core of the membership theories is in the asymmetry in the wage setting process between insiders, who are employed, and outsiders looking for jobs (Blanchard Summers 1986a). Blanchard and Summers distinguish pure insider case – when the wage is set only by insiders with no pressure from outsiders, and the case when outsiders exert pressure in the wage bargaining (Blanchard Summers 1986b).

In the **pure insider case,** only interests of insiders are taken care of in the wage bargaining, and they have priority in employment. In this simplified setting, insiders would set wages so as to keep the employment equal to membership. *“... after an adverse shock to aggregate demand which reduces employment, workers who are still employed have no desire to cut the nominal wage so as to increase employment.”* (Blanchard Summers 1986b, p.5). In reality, it might last a couple of periods until insiders lose their status and are considered outsiders with no wage bargaining power (and for newly employed it might take a couple of periods to be considered insiders with full wage bargaining power). For this reason, new unemployment rate equilibrium would appear only in cases of the sequence of shocks of the same sign. This extreme case will almost never happen, since adverse shocks will often be replaced by positive shocks, and insiders who lost jobs after the adverse shock will not lose their bargaining power before becoming insiders again (ibid. p.5-6).

More realistic is the case when **outsiders can exert some pressure on wages**. First, in the case of the adverse shock and higher unemployment rate, insiders might feel better off when accepting lower wage. Lowering their wage would give them higher probability of continuation of their employment, which they prefer, since with high unemployment rate it would be more difficult for them to find new employment. Furthermore, if insiders do not accept lower wages, the firm may be motivated to lay off groups of insiders if group of outsiders would accept wages that are low enough to cover hiring and firing costs. In such a case, the stronger is the effect of increased unemployment on the behavior of insiders and firms, the lower is the persistence of augmented unemployment rate (ibid. p.7-8).

Blanchard and Summers conclude that *“membership effects become important in bad times and are not crucially dependent on the presence of unions”* (Blanchard Summers 1986a, p.60). Roed (1997) adds that in the case of the adverse shock older workers whose wage exceeded their productivity might become unemployed. Since they won’t be able to find as financially satisfactory job as before due to their lower productivity, many of them will rather accept unemployment benefit system until their pension age. This would create another potential source of persistence in increased unemployment rate due to the adverse demand shock (Roed 1997).

On the contrary, Ball (2009) alleges that there is not much empirical evidence for the insider-outsider model and the behavior of the long-term unemployed seems to be a more promising source of hysteresis (Ball 2009, pp.22-23).

1.5.2 Depreciation of skills

Blanchard and Summers (1986b) continue with presentation of the duration theory. They explain that only outsiders who are short-term unemployed are able to exert some downward pressure on wages. The reason is that long-term unemployed lose their technical and possibly social skills, self-esteem, and habits needed to keep them competitive and productive. Lowered self-esteem may lead to acceptance of lower living standards, eventually leading to lowering their reservation wage but also their job search intensity. Consequently, many long-term unemployed may end up being dependent on social allowances and may become practically unemployable. Blanchard and Summers conclude that if the long-term unemployed exert little or no pressure on wages, a high fraction of the long-term unemployed in the society may turn into increased equilibrium unemployment rate.

Pissarides (1992) adds that although the duration of unemployment contributes to the persistence of high unemployment lasting some time, this period only equals to the time the respective people remain unemployed. This period may last several years, but it is not long enough to lead to a different equilibrium unemployment rate. He suggests that it's the firm's reaction to depreciation of skills of long term unemployed that might create new higher unemployment rate equilibrium. Firms that observe decreased skills of certain workers in certain locality or production domain may choose to offer less jobs in the next period even after the shock has ceased to effect. Since less jobs are available, old unemployed are left unemployed, their unemployment becomes the new norm, and new equilibrium unemployment rate is created.

Edin and Gustavsson (2005) find statistically significant evidence of a negative relationship between work interruptions and skills. They find out that one year out of work would move individual 5 percentile points down the skill distribution. Since recessions last a few years, depreciation of skills, subsequent wage drop and unemployment implication are of considerable importance. Pissarides (1992) remarks that intensity of search may fall down with duration of unemployment. He also adds that employers may prefer to hire short-term unemployed rather than long-term unemployed. Long-term unemployment raises doubts about the applicant's personality (due to possibly lost work habits, work attitude and so on), but also raises probability of lost skills during long unemployment time. The longer is therefore the person unemployed, the more skills he could have lost and more costly training the employer would have to provide to the worker. According to the European Centre for the Development of Vocational Training (further ECDVT) the depreciation of skills of lower-skilled workers is the greatest. Around 1/3 did not develop their skills in their present career compared to around 19% of highly educated people. ECDVT alleges that lower-skilled workers have suffered most from job losses in the current economic downturn (ECDVT 2012, p.2).

Roed (1997) comments that hysteresis may arise especially if depreciation of skills is unevenly distributed in the society; for example, if low-skilled workers are more affected by downturn of the economy and at the same time if relative wages are prevented from adapting by minimum wages, social security contributions, or strong egalitarian unions.

Ljungqvist and Sargent (1998) claim that people being laid-off are most probably already people with most depreciated skills. If unemployment compensation is based on previous earnings, they could get more out of unemployment compensation than if their wage adjusted to their present skills. Since unemployment compensation is better than their potential new earning, they might be less active in searching for a new job, which would contribute to the long-term unemployment. They also mention another factor that could be partly responsible for long-term unemployment. When the unemployment rate is low, social regulation offices can more easily monitor the unemployed. On the other hand, with unemployment high, it is more costly and complicated to closely monitor all unemployed, which also helps maintaining unemployment high (Ljungqvist and Sargent 1995).

1.5.3 Other reasons for hysteresis

Roed (1997) mentions other reasons for hysteresis. Social stigma may also produce different unemployment rate equilibria. During times of low unemployment being unemployed may be understood in the society as a negative sign and is believed to be self-inflicted. On the other hand, during recessions, when unemployment can hit anyone, it does not produce social stigma anymore, and it is excused by the society. Affected person then does not reduce his reservation wage as much and together with lower labor demand the situation may result in new unemployment equilibrium rate (Roed 1997).

Unemployment, and especially long-term unemployment, has also a very negative effect on mental health. This line of thought was analyzed by Farré, Fasani, and Mueller (2018) on Spanish unemployment rate data, whose numbers largely increased after the breakdown of construction sector during the Great Recession. Highlighted personal insecurity about his/her own value in the society definitely does not help good labor matching, and especially right skills matching, which are assumptions of an efficient and more productive economy.

Hiring and firing costs may lead to reinforcing unemployment problem as well. When it is difficult to find new workers, employers practice labor hoarding. After strong enough negative shocks, labor hoarding disappears, and the new equilibrium comes (Roed 1997).

Other factors reinforcing hysteresis could be capital scrapping during recessions. When recession is over, it takes very long time for capital accumulation to reach its previous levels, which prolongs high unemployment rate or could even lead to the new unemployment equilibrium (Roed 1997). Along with the capital scrapping and deterioration of skills, also lower innovation, diffusion, investment rates and entry rates could be the source of the hysteresis producing mechanism (Dosi et al. 2018).

Craighead (2016) specifically talks about decreased labor matching efficiency as a hysteresis producing mechanism. This is due to the protracted unemployment of many people. Employers and employees during this time lose many informal connections that help better labor matching.

1.6 The Slovak case

Union density is already very low in Slovakia (Habrman and Rybák 2016, p.22). According to Štefánik et al. (2019), the long-term unemployment along with the unemployment of the low skilled are very problematic areas of the Slovak labor market. A specific problem that Slovakia has to tackle are concentrated Roma communities. These are affected by high fraction of the long-term unemployed and low-skilled workers.

According to Figure 1 and Figure 2, Slovakia is one of the countries with the highest long-term unemployment in the European Union along with Greece, Italy, and Bulgaria. Many other countries, for example Croatia, Portugal, and Ireland, managed to decrease the fraction of long-term unemployed over the last years. Slovakia leads in the fraction of long-term unemployed also among the V4 countries with more than 20 percentage points difference to Hungary and 15 percentage points difference to the EU 28 mean.

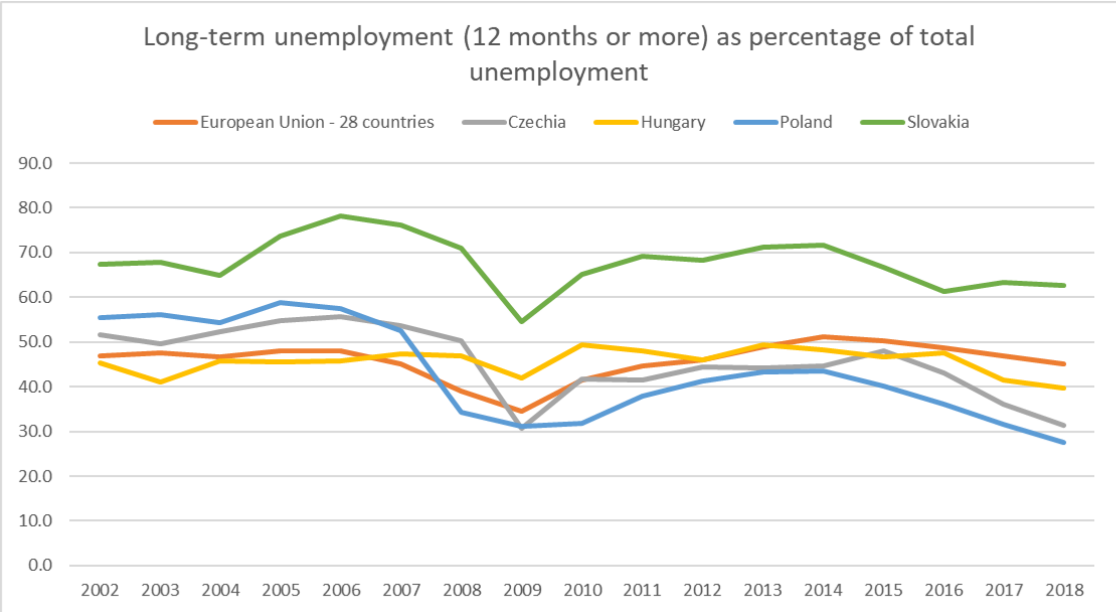

Figure 1. Long-term unemployment rate Visegrad 4 + EU average (20-64 years), source of data: Eurostat, own elaboration

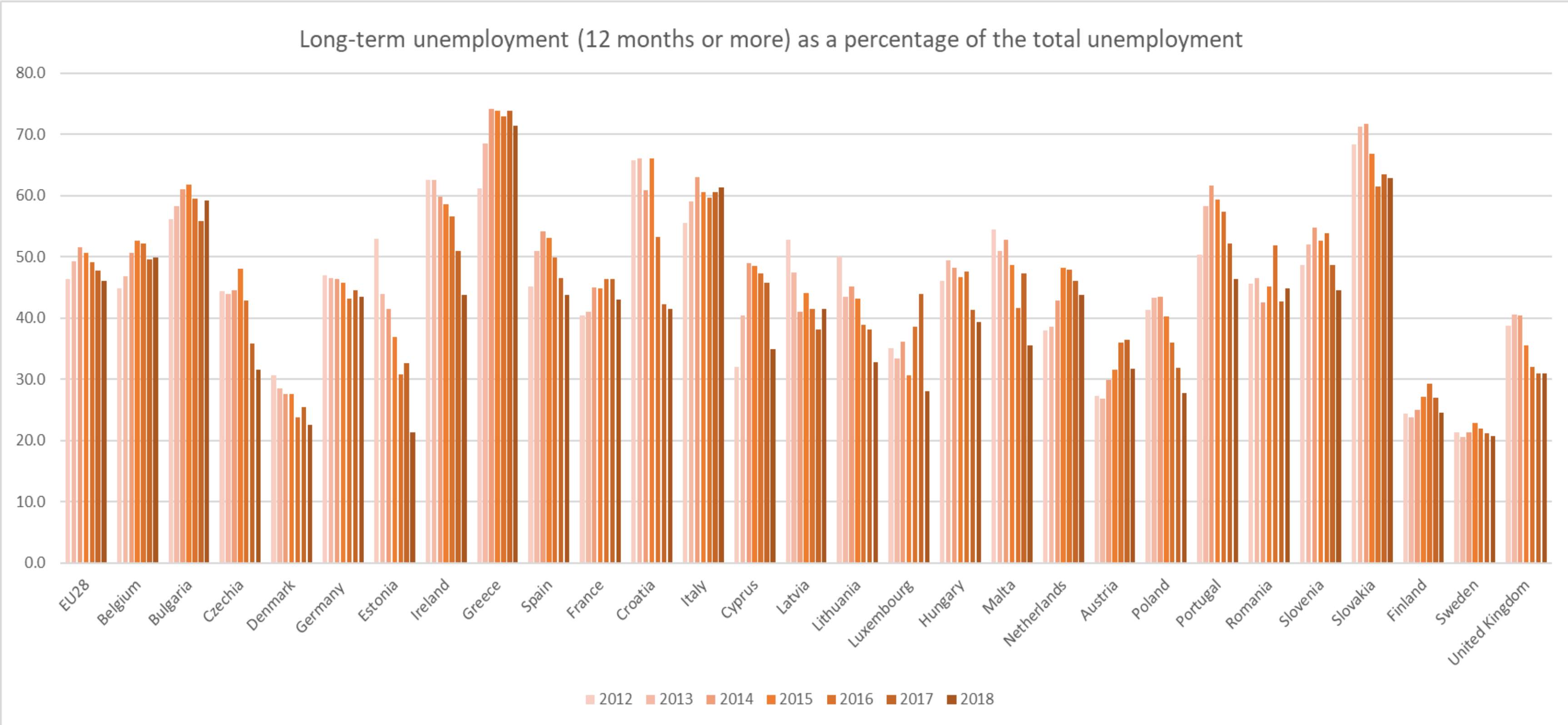

Figure 2: **Long-term unemployment** (12 months or more) as a percentage of the total unemployment, age: 20-64 years, data: Eurostat, own elaboration

Slovakia leads also in the unemployment rate of the low-skilled people as visible from Figure 3 and Figure 4. Slovakia again leads not only in the European union as a whole but differs also substantially from the V4 countries. In 2019Q1 the difference between Slovak unemployment of the low-skilled and the rest of the V4 was 20 percentage points and this gap has unfortunately been fairly stable over the years.

Štefánik et al. (2019, p.16-17) notes that *"impact of the social background on initial educational outcomes and on skills levels is one of the largest in Slovakia among the EU and OECD countries in recent years. This indicates that new generations will be increasingly confronted with unequal positions on the labor market."*

According to the report of the European Comission on Slovakia from February 27, 2019 three quarters of the total long-term unemployed are in three regions: Banská Bystrica, Prešov, and Košice (EC 2019). Measured by Gini coefficient, Slovakia has also the highest regional disparities of the EU countries (Sivaev et al. 2019, p. 24).

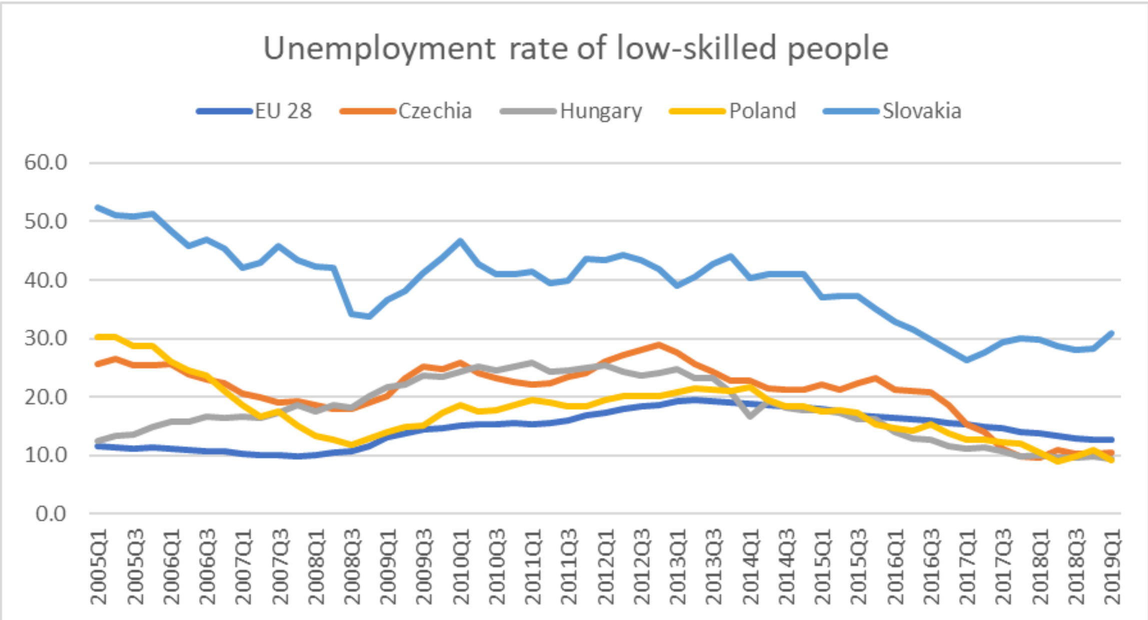

Figure 3. Unemployment rate of low-skilled people in Visegrad 4. As low-skilled are understood people with less than primary, primary, and lower secondary education, age 20-64 years, source of data: Eurostat, own elaboration

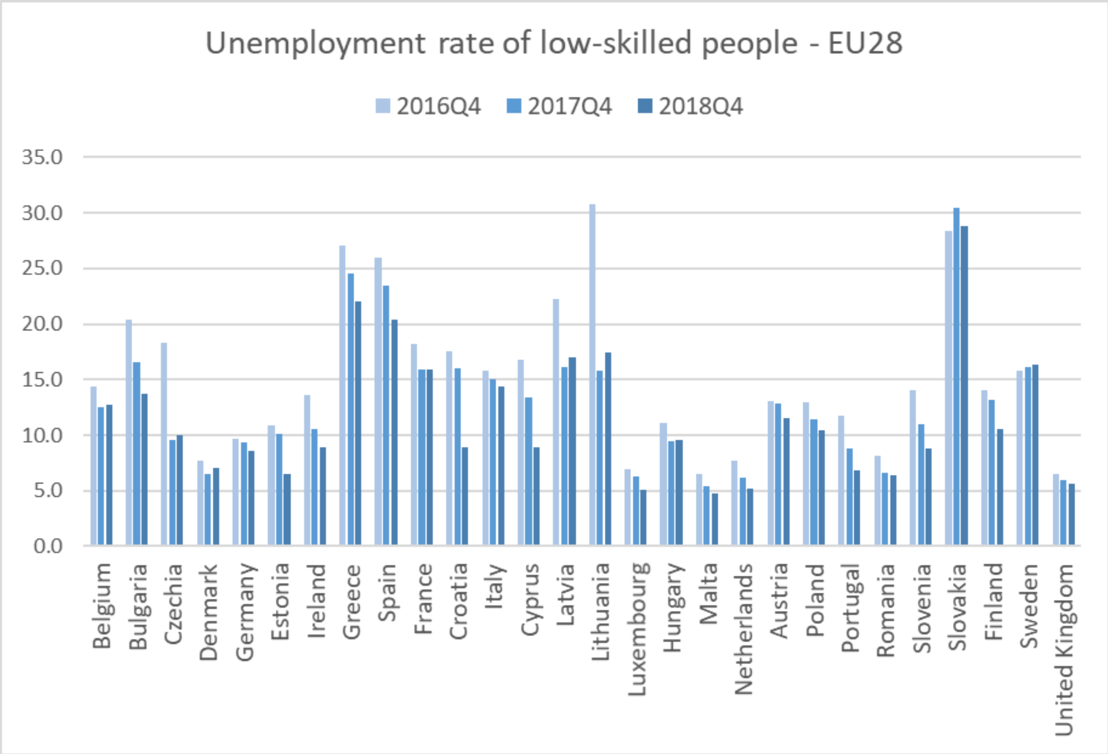

Figure 4. Unemployment rate of the low skilled people in the EU. As low-skilled are understood people with less than primary, primary and lower secondary education, age 20-64 years, source of data: Eurostat, own elaboration

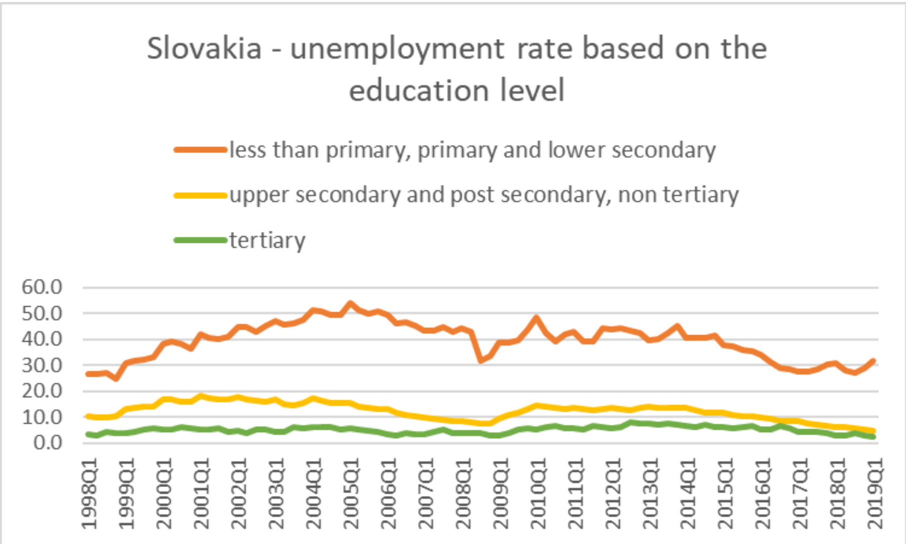

Figure 5. Unemployment rate based on the education level, source of data: Eurostat, own elaboration

As is obvious from Figure 4, many of the European countries managed to lower their low-skilled unemployment rate in the recent year. Slovakian low-skilled unemployment rate is stagnating around the same level in the last years, with females being worse-off than the males (Štefánik et al. 2019).

Participation in life-long learning programs that aim at counteracting depreciation of skills in time and at improving them is very low in Slovakia. From the unemployed only 0.4% took part in any training program in 2014 even though training improves skills and labor market matching (Machlica et al. 2017).

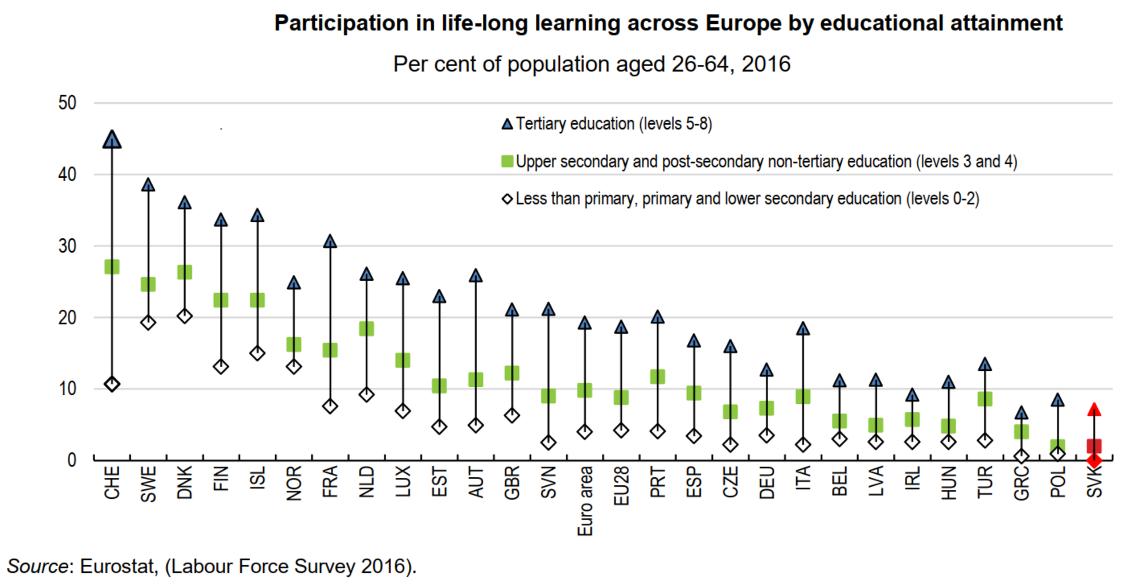

Figure 6. Participation in life-long learning across Europe, source Machlica et al. (2017, p.32)

1.6.1 Emigration

Another factor to provide a better description of the Slovak labor market is emigration. Emigration can be viewed as a solution to the high and persistent unemployment problem, but I believe from the long-term perspective especially emigration of high-skilled individuals poses a problem. High-skilled people are more productive and could be the source of innovation for companies that employ them and raise their competitiveness, which could lead to more jobs available in future. More qualified healthcare workers in the deprived regions could improve health of its population leading to increased productivity. More competitive firms could contribute to higher wages, lowering incentives for further emigration and increasing incentives to work.

Škuflić and Vučković (2018) state that there are few studies there that focus on the effect of emigration on the sending countries' economy and the labor market. These do not provide a priori clear-cut answers,[2] rather some ex post empirical assessments. In their analysis including Slovakia, Škuflić and Vučković (2018) find out that emigration actually increases unemployment in the emigrant countries. The reason is that there are differences between skills of emigrants and stayers, with emigrants being generally more skilled and proactive. If the emigrants were those who already were employed (or likely to be employed), but they search better quality of employment elsewhere, stayers may not be able to replace the emigrants, and mismatch between labor demand and supply may increase (Škuflić and Vučković 2018, pp.1832-1833).

Docquier et al. (2019) finds that *„positive correlation between the impact on the wages of the low-skilled and changes in quantities of high-skilled labor means wage losses among the low-skilled are more pronounced in high-skilled emigrant sending countries like Ireland and Eastern European countries... Because the low-skilled workers account for a larger share of the total wage bill and the wage losses they experience dominate the wage gains of the high-skilled, emigration ends up having negative average wage effects on the labor force.“* (Docquier et al. 2019, p.315)

Finally, Atoyan et al. (2016) claim that "*emigration can have adverse effects on per capita income growth and convergence, largely because of externalities"* (Atoyan et al. 2016, p.7), especially human capital externalities. Atoyan mentions that "*the emigration of the young and skilled could also have non- economic externalities—it leads to the exit of those who could have been agents of change in improving the quality of institutions"* (Atoyan et al. 2016, p.7).

Haluš et al. (2017) of the Institute for Financial Policy (IFP) studied Slovak emigration on the data from the register of the public health insurance company. After the crisis year 2009, the total emigration stabilized at approximately 15.000 people (0.3% of total population) per year. From people who left Slovakia during the period 2010-2015, more than half were less than 30 years old with the peak of people around 25 years old. Since public insurance covers Slovak students studying university abroad until they graduate and find work, this means that this data covers also students already studying abroad who decided to stay abroad. Around half of the people who left since 2009 did not come back until 2015 (the end year of the data for study). From graduates studying in Slovakia, every one out of ten recent graduates decides to move abroad, mostly

[2] Škuflić and Vučković (2018) provide also some literature review on the topic.

graduates from medicine (every one of five), or technical studies. (Haluš et al. 2017, pp.1-5). Vagač (2018) on behalf of the European Centre of Expertise in the field of labour law, employment and labour market policy though states that there are no consistent data on return migration. For this reason, it is difficult to draw clear-cut conclusions on the magnitude of the actual brain drain (Vagač 2018, p.7). However he claims that the average level of skills of immigrant workers is below that of domestic non-migrant population (Vagač 2018, p.13). Since people largely emigrate especially from regions with higher unemployment rate, emigration of high-skilled individuals also exacerbates regional disparities (Vagač 2018, p.10).

1.6.2 Roma community

Issue specific for Slovakia is the Roma community consisting of around 400.000 people. The employment rate of the Roma increased to almost 21% in 2017 of Roma living in settlements with at least one concentrated Roma settling. 21% employment rate of Roma people is nowhere near 51% for the non-Roma population living in the same settlements (Hidas et al. 2018). This is partly caused and aggravated by the low education levels of Roma. According to Machlica et al. (2014) 8 out of 10 Roma have no more than primary education. This is due to many reasons, for example high dropout ratio in secondary schools, higher stream of Roma students to special schools, insufficient command of Slovak language, low share of preschool attendance, and others. Education and employment prospects especially for women are then worsened by social pressure to start family very soon. Facing discrimination on the open labor market and dealing with psychosocial issues coming from living in poverty for prolonged period of time also generate barriers to employment. Researchers studied intergenerational mobility of the Roma population in Slovakia. They concluded that

"the probability to become unemployed or earn less than the minimum wage in irregular work is almost 70%, which is much higher compared to general population and even higher than the poorest non-Roma population" (Bednarik et al. 2019, p.9).

1.6.3 Deterioration of skills as a cause of hysteresis in Slovakia

To sum up, hysteresis can be caused by prolonged deterioration of skills in a considerable part of the population. This is due to the firm's reaction when they create a “thin” market offering less jobs than in the previous period and also due to psycho-social factors that lower the person’s employability during prolonged period of unemployment or low education level. Since education and social status of parents largely influences the social status of children, we may add that prolonged unemployment and low skills may impact the (change of the) equilibrium unemployment also indirectly through effects on children. Slovakia fails in substantially lowering the long-term unemployment rate and in unemployment rate of the low-skilled. This problem is extremely highlighted in the Roma communities. Based on the above-mentioned, I suggest deterioration of skills is presumably very feasible reason for the existence of hysteresis in unemployment in Slovakia.

2. Literature Review

Literature focused on hysteresis phenomenon in unemployment rate is vast.[3] Hence, I chose to list here only the literature concerning analysis of the unemployment hysteresis in Slovakia or the literature that concentrates on studying unemployment hysteresis in the regional context. In the end of literature review with respect to Slovakia, I present the brief table version of the following text.

2.1 Review of the hysteresis hypothesis testing with respect to Slovakia

One of the first tries to estimate the degree of persistence in unemployment in Slovakia was a paper by León-Ledesma and McAdam (2003) (LLM). They analyzed monthly unemployment rate data in the period from 1991 to 2001 for 12 Central and Eastern-European transition countries. When testing for the presence of linear hysteresis, they use univariate unit root tests (ADF, KPSS, ERS, Elliott). Most of the univariate unit root results pointed to the hysteresis hypothesis for the case of Slovakia. In order to control for the presence of structural breaks, they used Perron's (1997) unit root test with endogenous search for structural break. Perron's structural breakpoint unit root test looks for the biggest change in mean. The structural break is where the t-statistic of the coefficient of the change-in-mean dummy is the biggest in absolute terms. Even Perron's statistic could not reject the null of a unit root for Slovakia. When applying panel unit root tests (Im Pesaran and Shin (IPS) (1997), Chang (2002), Tayler and Sarno (1998)), they had to reject the null hypothesis at 5% significance level for all of the panel unit root tests in favor of the alternative. The null of IPS, Chang and Taylor and Sarno states that each individual process is a unit root process. Since they rejected the null for all panel unit root tests, they arrived at the conclusion that at least one of the individual series is stationary, although that did not prove the stationary series is Slovakia. The null of a unit root for all individuals in the unit root test of the mix of Levin Lin panel test with Perron's structural break test was also rejected. In order to test for existence of multiple equilibria in unemployment rate and study the behavior of unemployment rate within these equilibria, LLM applied Markov Switching regressions. Markov Switching regressions are based on the idea that the level of unemployment rate may change not only suddenly (structural breaks-absorbing state) but also gradually (business cycles – non-absorbing state). They found out that the

[3] For example O'Shaughnessy (2011), Jaeger and Parkinson (1994), Jump and Stockhammer (2018).

Slovak unemployment rate (in the data range analyzed) could be characterized by two states, out of which Slovakia spent most of the time in the low unemployment state, and since 1998 it moved to the high unemployment state. They concluded that within both states, unemployment rate can be defined as a stationary process, although with a high persistence parameter.

Camarero et al. (2008) studied monthly data from 1991 to 2003. First, they used panel unit root/stationarity tests (IPS, Maddala and Wu – unit root, Hadri – stationarity test). These tests pointed to the presence of hysteresis. Authors tried to create critical values in Maddala and Wu test by bootstrapping in order to account for possible cross-sectional dependence, but also this test did not reject hysteresis hypothesis. Then they performed Carrion-i-Silvestre (2005) test (that is an augmentation of Hadri test with structural breaks) and augmented Hadri test with critical values drawn from bootstrapped distribution to take into consideration cross-correlation of residuals. Neither individual KPSS test with breaks, nor Carrion-i-Silvestre test statistics could reject the null of stationarity of data. Camarero et al. therefore conclude that taking account of structural breaks, Slovak unemployment rate is stationary.

Cuestas and Gil-Alana (2011) use data from 1998 to 2007. They apply Ng and Perron unit root test, and Lee and Strazicich (2003) unit root test with endogenous search for structural breaks. Lee and Strazicich test is explained in detail in another part of the thesis. Then they used KSS test that assumes non-linearities in the speed of adjustment to the equilibrium natural rate. KSS' test (ESTAR-Exponential Smooth Transition Autoregressive) main idea is that autoregressive parameter varies depending on the "degree of misalignment from the equilibrium". In the "inner regime" it defines a unit root process, in the "outer regime" the variable may be stationary (Cuestas and Gil-Alana 2011, p.8). Transition between these two regimes is smooth due to heterogeneity in hiring and firing costs across firms (Akdogan 2016, p.4). As elaborations of KSS test, authors use Kruse test and Bec, Ben Salem, and Carrasco's tests (BBC, three regime Self Exciting Threshold Autoregressive Process – SETAR). In the end they test for the possibility that the series is integrated of non-integer order of integration. If the root of fractionally integrated series is smaller than 0.5, it indicates that the natural rate hypothesis is valid (in case that also structural breaks are present, then the structural hypothesis is valid). When order of integration is bigger than 0.5, but smaller than 1, it is a sign of persistence, and if it equals 1, then there is hysteresis. KSS, Ng Perron, Kruse, BBC, and Lee and Strazicich test could not reject the null of a unit root in case of Slovakia. On the other hand, using fractional integration the authors proved that unemployment rate in Slovakia is a mean reverting process (including intercept or intercept and trend in the model and when error term is an AR process – therefore model ARFIMA (1, d, 0)) with high degree of persistence after the shock (due to high autoregressive coefficients).

Cuestas and Ordonez (2011) analyzed monthly seasonally-adjusted data from 1998 to 2007 in 8 CEE states. They adopted the view that "some macroeconomic variables, such as unemployment, may shift smoothly rather than suddenly between different equilibrium values". They applied the logistic smooth transition autoregressive test of Leybourne et al. (1998), where the null of a unit root is tested against the alternative of logistic smooth non-linear trend, that drives the unemployment rate shift between two regimes. The result of this test was in accordance with the hysteresis hypothesis for the Slovak data. Afterwards they applied the already mentioned KSS (ESTAR) test, and by applying Anderson and Vahid's approach (1998) they tested for the common logistic smooth transition autoregressive non-linearities among countries. Their KSS (ESTAR) results suggested that the Slovak unemployment rate is a globally stationary process around a non-linear trend. The authors asserted that there is a common force that generates non-linear behavior of the unemployment rate for Latvia, Poland, Slovakia, and Slovenia. They proposed this common force may be the economic convergence. In Cuestas et al. (2015) they found evidence that the common driver for cyclical behavior of unemployment rates in Central and Eastern European countries may be rather the German business cycle.

Gozgor (2013) studied monthly data from January 1998 to January 2012 from 10 CEE countries. Applying panel unit root tests of Pesaran (2007) test and already mentioned Maddala and Wu (1999) test with bootstrapped critical values, he came to the conclusion that there is no mean-reversion tendency in the unemployment rate data for these CEE countries.

Marjanovic and Mihajlovic (2014) tested unemployment rates of certain OECD and transition countries on monthly data from January 2000 to January 2013 by means of univariate unit root tests (ADF, PP, KPSS), the first-generation panel unit root tests (Levin Lin Chu, IPS, Fisher-ADF, Fisher-PP). They also performed Quandt-Andrews structural breakpoint tests and the above-mentioned panel unit root tests on sample series divided by estimated breaks. Unit root tests gave evidence of non-stationarity of unemployment rate series as well as panel unit root tests for the first two periods. These researchers though did not perform cross-sectional dependence tests.

Furuoka (2014a) studied Visegrad group quarterly unemployment data from 1998Q3 to 2013Q4. He tested for hysteresis using linear unit root tests (ADF, PP, KPSS, ERS), Seemingly Unrelated Regressions ADF (SURADF) test and Fourier ADF test (FADF). FADF test is an ADF test augmented with Fourier trigonometric approximation parameters that should capture the potential non-linearities arising from structural breaks or business cycle fluctuations. SURADF test is again an ADF test statistic, but to address the possible correlation structure of residuals from each regression the critical values for each regression are calculated via Monte Carlo simulation. SURADF therefore provides test statistic with higher power than individual ADF regression, but also – since it is based on individual regressions – it allows to detect which of the panel unit series is stationary. In other words, the results of SURADF regression are not dependent on restrictive null hypothesis of “all processes are unit roots” vs. “at least one of the processes is stationary” (Holmes 2007, p. 6-7). None of the linear unit root tests gave evidence of hysteresis in Slovakia. FADF test statistic, on the contrary, rejected the null of a unit root at the 5% level of significance and demonstrated Slovakian unemployment rate to be rather characterized by the stationary process.

Bolat et al. (2014) analyzed unemployment data from 17 Eurozone countries over the period 2000-2013. They used panel KSS (Panel ESTAR) test of Ucar and Omay (2009) and sequential KSS test of Chortareas and Kapetanios (2009) with and without a Fourier function that introduces non-linearities. Sequential KSS test is based on removing panel units with the lowest KSS statistic from the panel and recalculating KSS statistic until we cannot reject the null of non-stationarity for the remaining panel. With this method the authors can take advantage of the higher power of panel unit root tests, with Fourier function take account of non-linearities and distinguish which panel members’ data is defined by the unit root process. Bolat et al. (2014) ascertained that both with and without using Fourier function in the panel KSS sequential test, test statistics for Slovak data cannot reject the null of hysteretic behavior of unemployment rate over the observed period.

Marjanovic, Maksimovic, and Stanisic (2015) analyzed the quarterly unemployment rate data from time range 2000-2012 on 8 transition countries, including Slovakia. They define hysteresis as changing NAIRU in time. They used the method of Kalman filter to estimate the NAIRU. Afterwards they tested for the existence of statistically significant time trend in the estimated NAIRU and conducted KPSS test on the NAIRU to see whether the time changing pattern is not caused by a unit root process. They claimed the hysteresis – as defined by Marjanovic, Maksimovic and Stanisic – is present in the Slovak unemployment data due to the statistically significant time trend in NAIRU and rejected stationarity in NAIRU at 1% level of significance.

Akdogan (2016) studied the presence of hysteresis in 31 European countries. He used Slovak data that begin in 1998Q1 and finish in 2014Q3. He employed the usual linear unit root tests (ADF, PP, ERS) and the KSS ESTAR model along with Asymmetric ESTAR (AESTAR) model. They also performed Christopoulos and Leon-Ledesma (2010) test (CLL) that takes into account non-linearities as well as possible structural breaks (found by LS test). Linear unit root test statistics did not reject the null of a unit root. LS one-break test[4] statistics rejected the null of a unit root with structural break at the 10% level of significance. ESTAR and CLL non-linear unit root tests rejected the null of a unit root on 5% level of significance. AESTAR did not reject the null. Akdogan claimed these results show that unemployment in Slovakia is stationary process, subject to the regime changes (Akdogan 2016, p.16).

In April 2016 the Institute for Financial Policy published a report by Habrman and Rybák (2016), that focused on estimating NAIRU and its drivers using the Kalman filter. They analyzed 19 countries including Slovakia using data from 2001-2013. They find out a strong hysteresis, when a 1 percentage point change in the actual unemployment leads to a 0.25 percentage point change of NAIRU.

Di Bella, Grigoli, and Ramirez (2018) analyzed quarterly data for 23 advanced economies, for Slovakia they used data from 1998Q3 to 2016Q3. They performed ADF test and Johansen trace test based on vector autoregression in levels. Johansen VAR test was specified by including real wages, real output, unemployment, and a linear trend. To reconcile their (for some countries) slightly ambiguous results, they performed Maddala and Wu (1999) and IPS (2003) panel unit root tests. Slovakia showed signs of

[4] They applied model C “Break” test – break in level and trend.

non-stationarity based on all four tests. They conducted a panel structural vector autoregressive test comprising two stage regression equations. Their aim was mainly to evaluate how certain defining variables of institutional setting (e.g. union density, length of job protected maternity leave etc.) influence magnitude of the response of unemployment to aggregate demand shock (which they found out to be “large, negative and persistent, suggesting strong hysteretic effects”).

As visible, there hasn’t yet been any unequivocal conclusion to the question whether there is hysteresis present in the Slovak unemployment rate.

Author	Year	Test	Panel?	Result	Data used
León-Ledesma and McAdam	2003	univariate unit root tests		mostly hysteresis	1991-2001
		Perron		hysteresis	
		IPS	x	at least one series stationary	
		Chang	x	at least one series stationary	
		Tayler and Sarno	x	at least one series stationary	
		Levin Lin + Perron structural break	x	at least one series stationary	
		Markov Switching		stationary with two states	
Camarero et al.	2008	IPS	x	hysteresis	1991-2003
		Maddala and Wu	x	hysteresis	
		Hadri	x	hysteresis	
		Maddala and Wu (bootstrapped c.values)	x	hystersis	
		KPSS		stationarity	
		Carrion-i-Silvestre	x	stationarity	
Cuestas and Gil-Alana	2011	Ng Perron		hysteresis	1998-2007
		Lee and Strazicich		hysteresis	
		ESTAR - KSS		hysteresis	
		Kruse		hysteresis	
		BBC-SETAR		hysteresis	
		fractional integration		stationarity	
Cuestas and Ordonez	2011	Leybourne et al.		hysteresis	1998-2007
		ESTAR - KSS		stationarity	
Gozgor	2013	Pesaran	x	hysteresis	1998-2012
		Maddala and Wu (bootstrapped c.values)	x	hysteresis	
Marjanovic and Mihajlovic	2014	univariate unit root tests		hysteresis	2000-2013
		Levin Lin Chu	x	stationarity	
		IPS	x	hysteresis	
		Fisher-ADF	x	hysteresis for all series rejected	
		Fisher-PP	x	hysteresis	
		Levin Lin Chu on series divided by breaks	x	hysteresis rejected for 3rd period	
		IPS on series divided by breaks	x	hysteresis rejected for 3rd period	
		Fisher-ADF on series divided by breaks	x	hysteresis rejected for 3rd period	
		Fisher-PP on series divided by breaks	x	hysteresis rejected for 3rd period	
Furuoka	2014a	univariate unit root tests		hysteresis	1998-2013
		SURADF		hysteresis	
		Fourier ADF		stationarity	
Bolat et al.	2014	Ucar and Omay 's KSS- ESTAR	x	hysteresis	2000-2013
		Sequential KSS	x	hysteresis	
		Sequential KSS with Fourier function	x	hysteresis	
Marjanovic, Maksimovic and Stanisic	2015	NAIRU - KPSS		hysteresis	2000-2012
Akdogan	2016	univariate unit root tests		hysteresis	1998-2014
		KSS-ESTAR		stationarity	
		AESTAR		hysteresis	
		Christopoulos and Leon Ledesma		stationarity	
		Lee and Strazicich		stationarity with one break	
Habrman and Rybák	2016	NAIRU -Kalman filter		hysteresis	2000-2014
Di Bella, Grigoli and Ramirez	2018	ADF		hysteresis	1998-2016
		Johansen VAR		hysteresis	
		Maddala and Wu	x	hysteresis	
		IPS	x	hysteresis	

Table 1. Hysteresis literature review with respect to Slovakia, own elaboration

2.2 Testing for the regional presence of hysteresis

Presence of hysteresis has already been tested at the regional level. Chang et al. (2007) study unemployment hysteresis in 21 Taiwanese regions (from June 1993-September 2001) using Levin, Lin and Chu, Taylor and Sarno and Im, Pesaran and Shin panel unit root tests. They rejected the hysteresis hypothesis.

García-Cintado, Romero-Ávila and Usabiaga (2015) tested for the presence of hysteresis in Spanish regions using data from 1976 to 2014. They used Narayan and Popp, Carrión-i-Silvestre, Lumsdaine and Papell, and Lee and Strazicich unit root tests. They find that hysteresis hypothesis explains the unemployment rate behavior in all Spanish regions.

Furuoka (2014b) studies 14 regions of the Czech republic using ADF, FADF and SURADF unit root tests. ADF test proved hysteresis hypothesis for all of the studied regions, SURADF test and non-linear FADF test proved hysteresis only for 9 of these regions, others being characterized by stationary processes in their unemployment rate. Furuoka sees as common attributes of regions where hysteresis was not found low unemployment rate, low female labor force participation rate, and low unemployment among highly skilled workers.

Šoltés (2014) studied regional unemployment hysteresis in his bachelor thesis using ADF, KPSS univariate unit root tests and Levin, Lin, Chu and Im, Pesaran, Shin panel unit root tests. He found only one region to be stationary, five he considered non-stationary, and the rest provided only weakly convincing or inconclusive results.

Bechný (2014) was also studying hysteresis in Czech regions in his bachelor thesis. He couldn't reject stationarity hypothesis in 7 regions using KPSS unit root test with a structural break.

Song and Wu (1997) study annual data of 48 states over 1962-1993 using univariate tests and Levin Lin Chu panel unit root test. Univariate unit root tests cannot reject the null of a unit root, whilst panel unit root tests reject the hysteresis hypothesis.

Leòn-Ledesma (2002) analyzed the data from 1985Q1 to 1999Q4 in 51 US states and 12 EU states using IPS panel unit root test. They rejected the null of non-stationarity for the US data (which showed persistence but not pure hysteresis), but could not reject the null for the EU countries (that showed therefore pure hysteresis).

Cheng et al. (2012) study hysteresis in the US on the state-level data. They use the PANIC method to identify the common and idiosyncratic components and then recursive mean adjustment (RMA) methods to test for unit roots. They found that some of the idiosyncratic components are stationary, whereas the common components evidence to be consistent rather with the hysteresis hypothesis.

Smyth (2003) uses quarterly data from 1982Q2 to 2002Q1 for the analysis of unemployment hysteresis in Australian states and territories. He uses ADF, Levin Lin (1992) test, and Im, Pesaran and Shin test. Smyth concludes that overall, results are consistent with hysteresis hypothesis.

Gomes and Da Silva (2009) studied hysteresis in six Brazilian metropolitan areas using Lee and Strazicich endogenous break unit root test. Except for Rio de Janeiro area, unit root null could not be rejected for analyzed metropolitan areas.

Bakas and Papapetrou (2012) use data (from 1998Q1 to 2011Q2) from 13 Greek regions to apply various panel unit root tests. They concluded that Greek regions probably suffer from hysteresis even taking account for structural breaks.

Hysteresis hypothesis was inspected using PANIC approach also by Gallegos et al. (2012) on unemployment rate data from Mexican states. The use monthly data from March 2005 to October 2011. They come to the conclusion that hysteresis hypothesis cannot be rejected in Mexican states, largely due to common factors and for some of the states also due to the idiosyncratic component.

Though not on intra-country regional data, PANIC approach was also used to study hysteresis in African states panel data by Do Ango and Amba Oyon (2016). They use PANIC (2010) test along with Pesaran and Chang tests. They conclude that hysteresis hypothesis is valid for the description of the unemployment rate in African states.

Lanzafame (2012) analyzed the presence of hysteresis in Italian regions using annual data from 1977 to 2003. Using panel unit root tests that allowed for the presence of structural breaks (Murray and Papell test and Breitung and Candelon test) he concluded that unemployment rate in Italian regions is following NAIRU and cannot be described by hysteresis hypothesis.

3. Data

I use monthly data taken from the Slovak Central Office of Labour, Social Affairs, and Family ("Employment office" or "COLSAF"). The unemployment rate used in this thesis is officially called "the rate of registered unemployment". This rate though does not count every officially registered unemployed person, only so-called disponible unemployed. Disponible unemployed are employment applicants registered at the Employment office who can assume position offered to them immediately after receiving employment offer.

Officially:

$$rate\ of\ registered\ unemployed = \frac{disponible\ applicants\ for\ employment}{economically\ active\ population} * 100 \qquad (4)$$

Until May 2013 group registered but non-disponible employment applicants consisted of people taking courses to increase their qualification, people taking care of family member, people temporally not able to work due to health reasons, and people engaged in program of work experience for fresh graduates. Since June 2013 group of non-disponible unemployed people was enlarged by people on "activation works", i.e. small jobs or volunteering in community services. As a result, since June 2013 the number of registered disponible unemployed decreased (Karšay 2013, Vanoch 2017). According to Karšay, the number of people whose status changed category from disponible to non-disponible in June 2013 was around 5500 people.[5] In comparison to ca 390 thousands of registered disponible unemployed in June 2013, it meant around 1,4 % of total disponible registered unemployed, constituting around 0.2 percentage point change of the registered unemployment rate. This difference is minimal, though creates slight doubts about whether the true effective rate of unemployment is equal to the officially proclaimed numbers. [6]

[5]According to the article by Vanoch in Hospodárske noviny of 24.3.2017 (Vanoch 2017), who cited Mr. Chovanculiak of Institute of Economic and Social Studies, the number of new non-disponible unemployed was around 10 000.

[6]For comparison: Eurostat EU Labour Force Survey (following guidelines of International Labour Organization): **Unemployed persons** are all persons 15 to 74 years of age (16 to 74 years in ES, IT and the UK) who were not employed during the reference week, had actively sought work during the past four weeks and were *ready to begin working immediately or within two weeks.* The unemployment rate is the number of unemployed persons expressed as a percentage of the total labour force.
(https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Labour_markets_at_regional_level#Unemployment)

The data from the Employment office is different than data from the Statistical Office of the Slovak Republic. The statistical Office acquires its data in the same way as Eurostat by executing labor survey in sample households. Some people considered non-disponible for immediate work and consequently not unemployed in the eyes of Employment office will be considered unemployed in the survey of the Statistical Office. The same is valid for the people who are erased from the Registry of the Employment Office because they failed to fulfill conditions of being registered as unemployed (they did not show up and proved they look for a job, they refused to take part in activation works[7] without serious reason etc.). On the other hand, some people who are employed illegally and are not registered in the Employment office registry may declare to be unemployed for the sake of the Statistical Office labor survey because of fear of being exposed. The unemployment rate measured by the Statistical Office is therefore higher than the unemployment rate of the Employment Office. The true value of unemployment is probably somewhere between. (Illés and Ódor 2005)

There are a few studies that allege that the seasonal adjustment procedure may lower the power of tests and therefore create bias in the unit root tests towards the hypothesis of unit root (Ghysels 1990, Ghysels and Perron 1993). Furthermore, unit root tests presented here test only for a unit root at zero frequency, not at seasonal frequencies, the existence of which could also induce a bias in the results of the conventional tests for unit roots (Balcombe 1999). Although there are also researchers trying to tackle this problem (Narayan Popp 2011, Balcombe 1999) many still use seasonally adjusted data for their evaluation of potential hysteresis in unemployment (García-Cintado, Romero-Ávila and Usabiaga 2015; León-Ledesma and McAdam 2003). I will not enter analysis of possible seasonal unit roots and their influence on the conventional unit root tests results in this thesis, and I will use data seasonally adjusted by the x13arima algorithm.

I used Excel, R and EViews software for the elaboration of my results in this thesis.

[7] Activation works are services defined in Law on Labour Services n.5/2004 Collection of Laws. These works are subsidized by the state in order to help maintain work habits for long-term unemployed people in material need. Activation works are works for the community or for the region that aim at improving the quality of life of its inhabitants. This is carried out either by helping in cultural, social or environmental services or similar.

4. Methodology and application

Simple unit root tests are testing for the presence of “pure hysteresis”. In the case of short time series or high persistence, but not pure hysteresis, they can have low power. In order to counter this problem, (when testing for linear model of hysteresis) researchers are applying either unit root tests with structural breaks, or panel unit root tests or their combination (Lanzafame 2012, p.417).

Among many possible approaches how to test for the unit root in unemployment series I chose Lee and Strazicich Minimum Lagrange Multiplier unit root test with two structural breaks (Lee and Strazicich 2003 – further only LM2 test). The LM2 test has been already applied on unemployment rates.[8] Then I will perform unit root tests on regional unemployment data. Due to the low power of the univariate unit root tests, I will continue with Pesaran (2007) and Bai and Ng (2004) panel unit root tests. The result of the panel unit root tests for Slovak regions can also serve as a control mechanism for the result of the LM2 univariate unit root test on the Slovak data.

4.1 State-level analysis

4.1.1 Unit-root testing of the macroeconomic time series

Economic time series can be characterized either as stationary, trend stationary, or difference stationary. Stationary series are mean reverting and show no sign of any continual change in mean (mean being either a constant or a trend with a constant). The behavior of trend stationary time series can be well described by a deterministic time trend. Swings away from the trend, caused by business cycles or some exogeneous shocks, are therefore only temporary and observations will come close to the trend in short time.

Nelson and Plosser (1982) tested several US macroeconomic time series for the presence of unit root using ADF test. They could not reject the unit root null for all tested series, except for the unemployment rate. Implication of a unit root process was that fluctuations, such as business cycles, were not transitory. Their study inspired other researchers to test for unit roots in various areas of the economy. The non-stationarity of the unemployment rate was studied in 1986 by the abovementioned Blanchard and

[8] For example: Meng et al. (2017), Khraief et al. (2015), García-Cintado et al. (2015)

Summers paper (Perron 1989 p. 1361-1362). In his 1989 paper Perron conducted a unit root test based on the Adjusted Dickey-Fuller strategy, taking account of two breaks in the formulae – points of structural changes in the economy. He tested the null hypothesis (H0) of a unit root test with drift against the alternative (H1) of a trend stationary process, where in both H1 and H0 he took account of the structural change. The structural change was represented either by a change in the level (Model A), change in the slope of the trend (Model B), or a change in both the level and the trend (Model C) (Zivot Andrews 1992). Perron selected two breakpoints: the year 1929 (Great Crash) and the year 1973 (oil price shock). He found out that most of the Nelson - Plosser series that were deemed unit root processes, were actually stationary processes with the change in intercept (1929) and change in the slope of the trend (a slowdown in growth after the oil shock 1973). Perron himself expected his method of exogenous determination of breakpoints will be labelled as "datamining" and pretesting. Being aware of this he claimed that a new test for structural changes in a trend function at unknown dates is needed (Perron 1989).

As a response, Zivot and Andrews (1992) introduced a unit root test (further ZA test) with endogenously determined structural break[9]. In contrast to Perron's exogeneous break test, Zivot and Andrews test the null of a unit root without any structural break against the alternative of a trend stationary process that allows for one time break in the trend function. The null is the same for all models.

H0: $$y_t = \mu + \beta y_{t-1} + e_t \qquad where\ \beta = 1 \qquad (5)$$

In order to find the break date, ZA test is looking for a break date, that gives the greatest weight to the alternative (least favorable result for the null hypothesis), i.e. λ^i is chosen to minimize the one-sided t-statistic for testing $\alpha^i = 1$. In other words, the test chooses such a break date that creates the lowest possible (infimum) value of the t-statistics. This lowest possible t-statistics is then compared to the critical values of the ADF distribution. We are choosing the break date from the trimmed time series in order to remove possible outliers to get the best estimation of the parameters.

[9] Zivot and Andrews were not the only ones who responded to Perron's challenge. Others were Banerjee Lumsdaine Stock (1992), Perron and Vogelsang (1998), Perron (1997) and Lumsdaine and Papell (1998) (Glynn, Perera and Verma 2007, p.6)

Formally:

$$t_{\widehat{\beta^i}}\left[\widehat{\lambda^i_{inf}}\right] = inf_{(\lambda \in \Lambda)}\, t_{\beta^i}(\lambda) \qquad (6)$$

where: i = *A, B, C (model selection);*

$\Lambda \in (0.1,0.9)$ *(trimming – number selected for LM2 test)*[10]

$T\lambda = T_b$ *(breakdate)*

Regression equations for ZA test for a unit root (naming according to Perron's terminology):

A – the Crash model (allowing for one time change in the level of the series):

$$y_t = \mu^A + \gamma^A t + \varphi^A DU_t(\lambda) + \beta^A y_{t-1} + \sum_{j=1}^{k} c_j^A \Delta y_{t-j} + e_t \qquad (7)$$

B – Changing growth model (allowing for change in magnitude of the slope of trend function):

$$y_t = \mu^B + \gamma^B t + \omega^B DT_t(\lambda) + \beta^B y_{t-1} + \sum_{j=1}^{k} c_j^B \Delta y_{t-j} + e_t \qquad (8)$$

C – Changing level and slope of trend:

$$y_t = \mu^C + \gamma^C t + \varphi^C DU_t(\lambda) + \omega^C DT_t(\lambda) + \beta^C y_{t-1} + \sum_{j=1}^{k} c_j^C \Delta y_{t-j} + e_t \qquad (9)$$

where

$$DU_t(\lambda) = 1 \quad if \;\; t > T\lambda$$
$$DU_t(\lambda) = 0 \quad otherwise$$
$$DT_t(\lambda) = t - T\lambda \quad if \;\; t > T\lambda$$
$$DT_t(\lambda) = 0 \quad otherwise$$

For each tentative choice of λ, ZA test determines a specific number of lags k. Test selects the right k from some maximum value $\bar{k}$ to value of k such that the t-statistic on $\hat{c}_k$ in absolute value is greater than 1.6 and t statistic on $\hat{c}_l$ was less than 1.6 for $l > k$ (Zivot and Andrews 1992, pp.251-255).

---

[10] Zivot and Andrews choose $\Lambda \in (0.001, 0.999)$, but state that the results are not sensitive to the choice of trimming values. (Zivot and Andrews 1992, p. 255)

Zivot and Andrews test prescribes to reject the null of a unit root if the minimum t-statistic is lower than left-tail critical value of the size (significance level) α ($\kappa^{i}_{inf,\alpha}$) from the asymptotic distribution of $inf_{(\lambda \in \Lambda)}\ t_{\beta^i}\ (\lambda)$ (Zivot and Andrews 1992, p. 255). Formally, we reject the unit root null if:

$$inf_{(\lambda \in \Lambda)}\ t_{\beta^i}\ (\lambda) < \kappa^{i}_{inf,\alpha} \qquad i = A, B, C \qquad (10)$$

Zivot and Andrews derived the asymptotic critical values by simulation methods and observed that densities of the minimum t-statistics are shifted to the left of Perron's densities, therefore also critical values are more negative than Perron's critical values. As a result, for ZA test it is more difficult to reject the unit root null than for Perron. Zivot and Andrews reversed some of the unit root conclusions in Nelson-Plosser series made by Perron, though at the same time carefully stated that inability to reject the unit root null should not be interpreted as an acceptance of the unit root hypothesis (Zivot and Andrews 1992, p.261). Perron reminds that failure to reject the null may also mean the low power of the test (Perron 2005, p.56).

Unit root tests with one endogenous break show a few advantages over those without a break. They decrease the bias toward non-rejection and can identify the date of the break. This can provide information for analyzing the policy change and the outcome associated with that date (Glynn, Perera and Verma 2007, p.7). On the other hand, as Lee and Strazicich (2001) suggest,[11] critical values of ZA or Perron (1997) increase if there is also a break under the null. Not taking account for structural breaks under the null can create another source of possible spurious rejections (Lee Strazicich 2001, p. 537-538). They also state that ZA test and Perron (1997) test *"tend to select the break point incorrectly where bias in estimating β (which tests the null of a unit root) and spurious rejections are the greatest in the presence of a structural break. In each case, the bias and spurious rejections increase with the magnitude of the break*" (Lee and Strazicich 2001, p.557).

Lumsdaine and Papell (1997) published a unit root test (LP test) allowing for the possibility of two endogenously determined breaks. They test the null of a unit root without breaks hypothesis against an alternative of trend stationarity with breaks. Using their newly developed test, they found more evidence against the unit root hypothesis

[11] Citing also Nunes, Newbold, and Kuan (1997)

than Zivot and Andrews, but less than Perron. However, as Hansen (2001) points out, *“the need for two structural breaks also reduces the distinction between the trend-break and random walk models”* (Hansen 2001, p. 125).

Lee and Strazicich claim that since LP and ZA tests do not allow for breaks under the null, the alternative hypothesis

“would be ‘structural breaks are present’, which includes the possibility of a unit root with breaks. Thus, rejection of the null does not necessarily imply rejection of a unit root per se, but would instead imply rejection of a unit root without breaks.” (Lee Strazicich 2003, p.1082)

Since LP test has also as a null the unit root process without breaks, Lee and Strazicich conclude it also suffers from the same source of bias of test statistics and spurious rejections of the null hypothesis as ZA. As stated above, these tests would reject the null of a unit root when the data-generating process is of a unit root, but with break(s). They are aware of the possibility that high rate of rejections of LP test may be due to the higher power of the test, but they claim that one would always have to examine the real *“source of rejection, since the alternative includes also unit root with breaks*.” (Lee and Strazicich 2003, p.1082). Besides, Lee and Strazicich (2003) state, that even if breaks under the null are included in the testing equation, LP test statistic diverges.

Lee and Strazicich (2001) propose that minimum LM test could overcome these difficulties inherently connected to the ADF-based unit root tests, due to their dependence on the break point nuisance parameters. Therefore, as a solution to the problem of divergence of test statistics inflicted by the size of breaks, bias and spurious rejections, they release the Lagrange Multiplier unit root test based on Schmidt and Phillips (1992) unit root test of.

4.1.2 Lee and Strazicich test

Lee and Strazicich (2003) released their LM2 test. LM2 test allows for two endogenously determined breaks both under the null hypothesis of a unit root as well as under the alternative of trend stationary process. Lee and Strazicich (2013) then complete their theory by designing minimum LM unit root test with one structural break.

Lagrange Multiplier test is based on estimating the parameter at some value and then checking the FOCs of the log-likelihood function (the score vector) whether they significantly vary from zero, or the variation is only due to sampling. Formally we define score vector as:

$$\nabla \ln L^*(\beta) = \frac{\partial \ln L^*(\beta|y)}{\partial \beta} = S\big(\widehat{\beta_{mle}}\big|y\big) = 0 \qquad (11)$$

Our tested hypotheses are:

If H0: $\beta = \beta_0$ is true, then $S(\beta_0|y) \approx 0$

If H0: $\beta = \beta_0$ is not true, then $S(\beta_0|y) \neq 0$

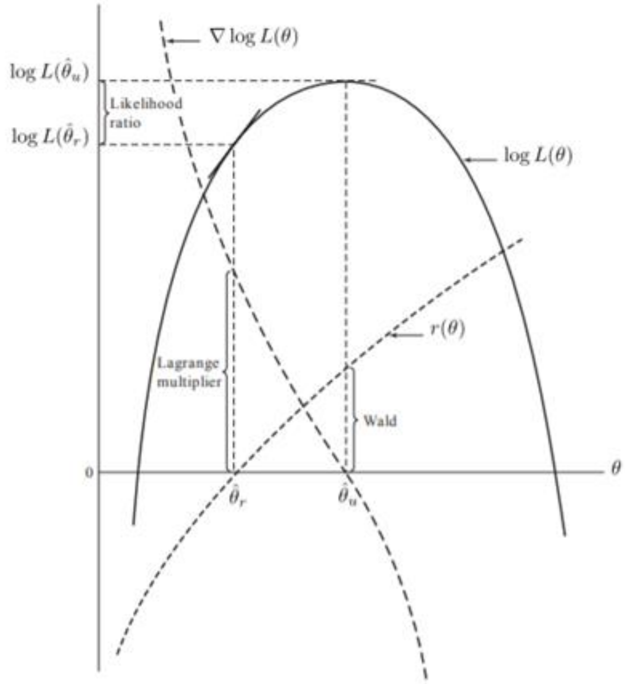

Figure 7. Graphical interpretation of log-likelihood based tests. LM test checks whether the slope of loglikelihood function at the restricted estimator $[\nabla \log L(\theta)]$ is near zero (taken from Songsiri, 2017, originally from Greene (2008))

Following derivations are mostly based on Schmidt and Phillips (1992) and Lee and Strazicich (2003) (further LS):

LS consider only model A (the Crash model – one-time change in level) and model C (the Break model – change in level and trend). They omit model B since most economic time series can be described adequately by model A or C (Lee and Strazicich 2003, p.1083).

LS consider data generating process to be of form (where y_t represents unemployment rate):

$$y_t = \delta Z_t + X_t \qquad X_t = \beta X_{t-1} + \varepsilon_t \tag{12}$$

Z_t is a vector exogeneous variables.

Model A (that allows for 2 changes in levels):

$$Z_t = [1, t, D_{1t}, D_{2t}]$$
$$where\ D_{jt} = 1\ \ for\ t \geq T_{Bj} + 1 \qquad j = 1{,}2,\ \ D_{jt} = 0\ \ otherwise$$

Model C (that allows for 2 changes in levels and trend):

$$Z_t = \left[1, t, D_{1t}, D_{2t,} DT_{1t}{}^{*}, DT_{2t}{}^{*}\right]$$
$$where\ DT_{jt}{}^{*} = t\ \ for\ t \geq T_{Bj} + 1 \quad j = 1{,}2,\ \ DT_{jt}{}^{*} = 0\ \ otherwise$$

Hypotheses for model A are therefore:

H0 corresponds to the unit root process:

$$H0{:} \quad y_t = \mu_0 + d_1 B_{1t} + d_2 B_{2t} + \beta y_{t-1} + v_{0t} \tag{13}$$
$$where\ \ B_{jt} = 1\ \ for\ t = T_{Bj}$$
$$and \quad \beta = 1$$

H1 corresponds to the trend stationary process:

$$H1{:} \quad y_t = \mu_1 + \gamma t + d_1^{*} D_{1t} + d_2^{*} D_{2t} + v_{1t} \tag{14}$$

Hypotheses for model C are construed in a similar manner by adding $D_{jt}\ \ to\ H0$ and $DT_{jt}{}^{*}\ to\ H1$.

Further I present only derivations for model A.

Model A:

$$y_1 = \delta Z_1 + X_1 \qquad X_1 = \beta X_0 + \varepsilon_t \tag{15}$$
$$y_t = \delta Z_t + X_t \qquad X_t = \beta X_{t-1} + \varepsilon_t \tag{16}$$

t = 1:

$$y_1 = \delta_0 + \delta_1 1 + \delta_2 D_{11} + \delta_3 D_{21} + \beta X_0 + \varepsilon_1 \tag{17}$$

Sum of squared errors at time 1 will be:

$$SSE_1 = (y_1 - \delta Z_1 - \beta X_0)^2 = (y_1 - \delta_0 - \delta_1 1 - \delta_2 D_{11} - \delta_3 D_{21} - \beta X_0)^2 \qquad (18)$$

t=2→T:

$$y_t = \delta_0 + \delta_1 t + \delta_2 D_{1t} + \delta_3 D_{2t} + \beta X_{t-1} + \varepsilon_t \qquad (19)$$

$$\textit{and because } X_{t-1} = y_{t-1} - \delta Z_{t-1} \qquad (20)$$

$$X_{t-1} = y_{t-1} - \delta_0 - \delta_1 (t-1) - \delta_2 D_{1(t-1)} - \delta_3 D_{2(t-1)} \qquad (21)$$

$$y_t = \delta_0 + \delta_1 t + \delta_2 D_{1t} + \delta_3 D_{2t} + \beta(y_{t-1} - \delta_0 - \delta_1 (t-1) - \delta_2 D_{1(t-1)} - \delta_3 D_{2(t-1)}) + \varepsilon_t \qquad (22)$$

Sum of squared errors at time 2 to infinity will be:

$$SSE_{2->T} = \sum_{t=2}^{T}[y_t - \delta_0 - \delta_1 t - \delta_2 D_{1t} - \delta_3 D_{2t} - \beta(y_{t-1} - \delta_0 - \delta_1 (t-1) - \delta_2 D_{1(t-1)} - \delta_3 D_{2(t-1)})]^2 \qquad (23)$$

Total sum of square errors is equation (18) + equation (23):

$$SSE = SSE_1 + SSE_{2->T} \qquad (24)$$

$$SSE = (y_1 - \delta_0 - \delta_1 1 - \delta_2 D_{11} - \delta_3 D_{21} - \beta X_0)^2 + \sum_{t=2}^{T}[y_t - \delta_0 - \delta_1 t - \delta_2 D_{1t} - \delta_3 D_{2t} - \beta(y_{t-1} - \delta_0 - \delta_1 (t-1) - \delta_2 D_{1(t-1)} - \delta_3 D_{2(t-1)})]^2$$

In order to get a score vector, we will need: *(25)*

$$\frac{\partial SSE}{\partial \beta} = -2X_0(y_1 - \delta_0 - \delta_1 - \delta_2 D_{11} - \delta_3 D_{21} - \beta X_0) - 2\sum_{t=2}^{T}[(y_t - \delta_0 - \delta_1 t - \delta_2 D_{1t} - \delta_3 D_{2t} - \beta(y_{t-1} - \delta_0 - \delta_1(t-1) - \delta_2 D_{1(t-1)} - \delta_3 D_{2(t-1)}))(y_{t-1} - \delta_0 - \delta_1 (t-1) - \delta_2 D_{1(t-1)} - \delta_3 D_{2(t-1)})]$$

$$= -2X_0(y_1 - \delta Z_t - \delta_1 - \delta_2 D_{11} - \delta_3 D_{21} - \beta X_0)$$

Since we are interested in finding an answer to the question what is the likelihood of the observed data if β = 1 (i.e. whether the (log)likelihood function is maximized at β = 1), we evaluate SSE for β =1:

$$SSE= (y_1 - \delta_0 - \delta_1 1 - \delta_2 D_{11} - \delta_3 D_{21} - X_0)^2 + \sum_{t=2}^{T}(y_t - y_{t-1} - \delta_1 t + \delta_1 (t-1) - \delta_2 D_{1t} + \delta_2 D_{1(t-1)} - \delta_3 D_{2t} + \delta_3 D_{2(t-1)})^2 \quad (26)$$

If we define: $\delta_0 + X_0 = \psi_x$ *(27)*

Then:

$$SSE=(y_1 - \psi_x - \delta_1 1 - \delta_2 D_{11} - \delta_3 D_{21})^2 + \sum_{t=2}^{T}(\Delta y_t - (\delta_1 t - \delta_1 (t-1) + \delta_2 D_{1t} - \delta_2 D_{1(t-1)} + \delta_3 D_{2t} - \delta_3 D_{2(t-1)})^2 \quad (28)$$

$$SSE=(y_1 - \psi_x - \delta_1 1 - \delta_2 D_{11} - \delta_3 D_{21})^2 + \sum_{t=2}^{T}(\Delta y_t - \delta \Delta Z_t)^2 \quad (29)$$

SSE is minimized by the restricted MLE's (based on contrasts): $\tilde{\delta}$ are coefficients in the regression of Δy_t on ΔZ_t

$$\tilde{\delta} = (\tilde{\delta}_1 \ldots coef.\ on\ \Delta t,$$
$$\tilde{\delta}_2 \ldots coef.\ on\ \Delta D_{1t},$$
$$\tilde{\delta}_3 \ldots coef.\ on\ \Delta D_{2t})$$

At restricted MLE (based on contrasts) $\delta_1, \delta_2, \delta_3$ equals $\tilde{\delta}_1, \tilde{\delta}_2, \tilde{\delta}_3$ respectively

At the restricted MLE: $\widetilde{\psi_x} = y_1 - \tilde{\delta} Z_1$ *(30)*

Therefore $\widetilde{\psi_x}$ represents the intercept parameter of the restricted model.

Then $\frac{\partial SSE}{\partial \beta}$ evaluated at the restricted MLE's becomes:

$$\frac{\partial SSE}{\partial \beta} = -2X_0(y_1 - \widetilde{\psi_x} - \tilde{\delta} Z_1) - 2\sum_{t=2}^{T}(\Delta y_t - \tilde{\delta}\Delta Z_t)(y_{t-1} - \widetilde{\psi_x} - \tilde{\delta} Z_{t-1}) \quad (31)$$

$$\frac{\partial SSE}{\partial \beta} = 0 - 2\sum_{t=2}^{T}(\Delta y_t - \tilde{\delta}\Delta Z_t)(y_{t-1} - \widetilde{\psi_x} - \tilde{\delta} Z_{t-1}) \quad (32)$$

If we define: $\widetilde{S_{t-1}} = (y_{t-1} - \widetilde{\psi_x} - \tilde{\delta} Z_{t-1})$ *(33)*

Then*:*

$$\frac{\partial SSE}{\partial \beta} = -2\sum_{t=2}^{T}(\Delta y_t - \tilde{\delta}\Delta Z_t)\,\widetilde{S_{t-1}} \qquad (34)$$

Maximum likelihood estimator is looking for a value of parameters that make the observed data most likely. To find that value we maximize the likelihood function (or the log-likelihood function for practical purposes) that is defined as the joint probability density function of observed data based on our parameters.

If we define vector of unknown parameters as $\theta = (\beta, \sigma^2)$ and our observed data as x then the likelihood function is defined as the joint density of independent observations x based on some (for us now unknown) parameters:

$$L(\theta|x_{1,}x_2, \dots, x_n) = f(x_{1,}x_2, \dots, x_n; \theta) = \prod_{i=1}^{n} f(x_i\ ; \theta) \qquad (35)$$

For the linear regression model of the form: $y_i = \beta x_i + \varepsilon_i \quad where\ \varepsilon_i|x_i \sim iid\ N(0, \sigma^2)$

is the probability distribution function of $y_i|\ x_i$ normal with mean βx_i and variance σ^2:

$$f(y_i|x_i;\theta) = (2\pi\sigma^2)^{-1/2}\exp\left(-\frac{1}{2\sigma^2}\ (y_i - x_i\beta)^2\right) \qquad (36)$$

The joint density of the sample is:

$$f(\boldsymbol{y}|\boldsymbol{X};\theta) = (2\pi\sigma^2)^{-n/2}\exp\left(-\frac{1}{2\sigma^2}\sum_i^n(y_i - x_i\beta)^2\right) \qquad (37)$$

$$L(\theta|\boldsymbol{y},\boldsymbol{X}) = f(\boldsymbol{y}|\boldsymbol{X};\theta) = (2\pi\sigma^2)^{-n/2}\ exp\left(-\frac{1}{2\sigma^2}(\boldsymbol{y} - \boldsymbol{X\beta})(\boldsymbol{y} - \boldsymbol{X\beta})\right) \qquad (38)$$

$$ln\, L(\theta|\boldsymbol{y},\boldsymbol{X}) = -\frac{n}{2}\ ln(2\pi) - \frac{n}{2}\ ln(\sigma^2) - \frac{1}{2\sigma^2}(\boldsymbol{y} - \boldsymbol{X\beta})(\boldsymbol{y} - \boldsymbol{X\beta}) \qquad (39)$$

And in our case:

$$ln\, L(\theta|\boldsymbol{y}) = -\frac{T}{2}\ ln(2\pi) - \frac{T}{2}\ ln(\sigma^2) - \frac{1}{2\sigma^2}SSE \qquad (40)$$

Since $\theta = (\beta, \sigma^2)$ we must concentrate out the nuisance parameter σ^2 from the log-likelihood function leaving a concentrated log likelihood function that is only a function of β (because we are interested only in estimation of β. Since we know variance at maximum equals:

$\sigma^2 = SSE/T$ (Schmidt and Phillips 1992, p.278) *(41)*

The concentrated log-likelihood will be:

$$\ln L^{*}(\beta|\boldsymbol{y}) = constant - \frac{T}{2}\ln\left(\frac{SSE}{T}\right) \qquad (42)$$

If the log-likelihood is concave, we can find the MLE by setting the Fisher score function to zero. The score function S is the vector of first partial derivatives of log-likelihood function with respect to its parameters. In our case it is the first partial derivative of the concentrated log-likelihood function with respect to β. We can find the maximum likelihood estimator by setting the score to zero.

$$S(\widehat{\beta_{mle}}|y) = \frac{\partial \ln L^{*}(\beta|\boldsymbol{y})}{\partial\beta} = -\frac{T}{2}\,\frac{1}{\frac{SSE}{T}}\,\frac{1}{T}\,\frac{\partial SSE}{\partial\beta} = -\frac{1}{2\sigma^2}\frac{\partial SSE}{\partial\beta} = 0 \qquad (43)$$

Therefore we find the value of our score function evaluated at β = 1 (to check how far is the score vector from zero for β = 1, if it equals zero at this point or is very close, then β = 1 would be maximum likelihood estimator of the β parameter based on the observed data). We insert equation (34) into the score vector:

$$S(\widehat{\beta_{mle}}|y) = -\frac{1}{2\sigma^2}\left(-2\sum_{t=2}^{T}(\Delta y_t - \tilde{\delta}\Delta Z_t)\,\widetilde{S_{t-1}}\right) \qquad (44)$$

$$S(\widehat{\beta_{mle}}|y) = \frac{\partial \ln L^{*}(\beta|\boldsymbol{y})}{\partial\beta} = \frac{1}{\sigma^2}\sum_{t=2}^{T}(\Delta y_t - \tilde{\delta}\Delta Z_t)\,\widetilde{S_{t-1}} \qquad (45)$$

According to Schmidt and Phillips 1992 (p.279) since sum of $(\Delta y_t - \tilde{\delta}\Delta Z_t)$ equals zero, we can write an equation:

$$S(\widehat{\beta_{mle}}|y) = \frac{\partial \ln L^{*}(\beta|\boldsymbol{y})}{\partial\beta} = \frac{1}{\sigma^2}\sum_{t=2}^{T}(\Delta y_t - \tilde{\delta}\Delta Z_t)\,\widetilde{S_{t-1}}$$

$$= \frac{1}{\sigma^2}\sum_{t=2}^{T}(\Delta y_t - \tilde{\delta}\Delta Z_t)\,(\widetilde{S_{t-1}} - \widetilde{S}) \qquad (46)$$

To construe LM test we need also the information matrix. The information matrix is defined as a minus expectation of Hessian, which is a matrix of second derivatives of log-likelihood (it indicates the extent to which log-likelihood is peaked rather than flat). Therefore:

$$I(\widehat{\beta_{mle}}|y) = -E\left[\frac{\partial^2 \ln L^{*}(\beta|\boldsymbol{y})}{\partial\beta\partial\beta'}\right] = -E\left[-\frac{1}{2\sigma^2}\frac{\partial SSE}{\partial\beta\partial\beta}\right] = \qquad (47)$$

$$= -E\left[-\frac{1}{2\sigma^2}\left(2{X_0}^2 + 2\sum_{t=2}^{T}(y_{t-1} - \delta_0 - \delta_1(t-1) - \delta_2\, D_{1(t-1)} - \delta_3\, D_{2(t-1)}\,)^2\right]$$

$$= \frac{1}{2\sigma^2}\left(2{X_0}^2 + 2\sum_{t=2}^{T}(y_{t-1} - \delta_0 - \delta_1(t-1) - \delta_2\, D_{1(t-1)} - \delta_3\, D_{2(t-1)}\,)^2\right)$$

Which evaluated at the restricted MLE's:

$$I(\widetilde{\beta_{mle}}|y) = \frac{1}{\sigma^2}({X_0}^2 + \sum_{t=2}^{T}(y_{t-1} - \widetilde{\Psi_x} - \tilde{\delta}Z_{t-1})^2) \qquad (48)$$

… and ignore X_0 as it will be negligible asymptotically.

$$I(\widetilde{\beta_{mle}}|y) = \frac{1}{\sigma^2}\sum_{t=2}^{T}(\widetilde{S_{t-1}})^2 \qquad (49)$$

After derivations of score function and information matrix evaluated at the restricted estimator, we can write the basic LM test statistic:

$$LM = \frac{s(\widetilde{\beta_{mle}}|y)^2}{I(\widetilde{\beta_{mle}}|y)} = \frac{\left(\frac{1}{\sigma^2}\sum_{t=2}^{T}(\Delta y_t - \tilde{\delta}\Delta Z_t)\,\widetilde{S_{t-1}}\right)^2}{\frac{1}{\sigma^2}\sum_{t=2}^{T}(\widetilde{S_{t-1}})^2} = \frac{\left(\sum_{t=2}^{T}(\Delta y_t - \tilde{\delta}\Delta Z_t)\,\widetilde{S_{t-1}}\right)^2}{\sigma^2\left(\sum_{t=2}^{T}(\widetilde{S_{t-1}})^2\right)} \qquad (50)$$

$$LM \xrightarrow{d} \chi^2(1)$$

Lagrange multiplier is sometimes presented at its square-rooted version, therefore in our case:

$$LM = \frac{\sum_{t=2}^{T}(\Delta y_t - \tilde{\delta}\Delta Z_t)\,\widetilde{S_{t-1}}}{\sigma\sqrt{\sum_{t=2}^{T}(\widetilde{S_{t-1}})^2}} \quad \sim \quad N(n-2) \qquad (51)$$

LM statistic is also a t statistic for the hypothesis **Φ=0** in

$$\Delta y_t = intercept + \boldsymbol{\Phi}\,\widetilde{S_{t-1}} + error \qquad (52)$$

We can see that $\sum_{t=2}^{T}(\Delta y_t - \tilde{\delta}\Delta Z_t)\,\widetilde{S_{t-1}}$ is the numerator in the estimator of **Φ** in a regression[12] :

$$\Delta y_t = intercept + \boldsymbol{\Phi}\,\widetilde{S_{t-1}} + error \qquad (53)$$

$$\widehat{\boldsymbol{\Phi}} = \frac{\boldsymbol{cov}(\Delta y_t, \widetilde{S_{t-1}})}{\boldsymbol{var}(\widetilde{S_{t-1}})} = \frac{\sum_{t=2}^{T}(\Delta y_t - \tilde{\delta}\Delta Z_t)\,\widetilde{S_{t-1}}}{\sum_{t=2}^{T}(\widetilde{S_{t-1}})^2} \qquad (54)$$

---

[12] For linear regression model $y_i = \beta_0 + \beta_1 x_i + \varepsilon_i$:

$$\hat{\beta} = \frac{cov\,(X,Y)}{var(X)} = \frac{\sum(x_i-\bar{x})(y_i-\bar{y})}{\sum(x_i-\bar{x})^2},\ se(\hat{b}) = \sqrt{\frac{\sigma^2}{\sum(x_i-\bar{x})^2}}\,, \sigma^2 \approx s^2(e) = \frac{1}{n-2}\sum e_i^2\,,$$

$$SE\ (\widehat{\Phi}) = \sqrt{\sigma^2\ \left(\sum_{t=2}^{T}(\widetilde{S_{t-1}})^2\ \right)^{-1}} \quad (55)$$

$$SE\ (\widehat{\Phi}) = \sqrt{\frac{\sum_{t=2}^{T}(\Delta y_t - \widehat{\Delta y_t})^2}{n-2}\ \left(\sum_{t=2}^{T}(\widetilde{S_{t-1}})^2\ \right)^{-1}} \quad (56)$$

$$\text{LM} = \tilde{\tau} = \frac{\tilde{\Phi}}{SE\ (\tilde{\Phi})} = \frac{\frac{\sum_{t=2}^{T}(\Delta y_t - \tilde{\delta}\Delta Z_t)\ \widetilde{S_{t-1}}}{\sum_{t=2}^{T}(\widetilde{S_{t-1}})^2}}{\sqrt{\frac{\sigma^2}{\sum_{t=2}^{T}(\widetilde{S_{t-1}})^2}}} = \frac{\sum_{t=2}^{T}(\Delta y_t - \tilde{\delta}\Delta Z_t)\ \widetilde{S_{t-1}}}{\sigma\sqrt{\sum_{t=2}^{T}(\widetilde{S_{t-1}})^2}} \quad (57)$$

Lee and Strazicich (2003a) use two types of test statistics: LM = $\frac{\tilde{\Phi}}{SE\ (\tilde{\Phi})}$= $\tilde{\tau}$ and $\tilde{\rho} = T\tilde{\Phi}$. I use only $\tilde{\tau}$. Location of the breaks is defined as $\lambda_j = \frac{T_{Bj}}{T}$. In order to account for autocorrelated errors, LS include augmented term $\widetilde{\Delta S_{t-j}}, j = 1, \ldots k$. In model A, null distribution and therefore critical values do not depend on location of the breaks, whereas in model C, the critical values have to be determined with respect to the breaks. The minimum LM test then searches for the location of the breaks such that $LM_{\tilde{\tau}} = Inf_{\lambda}\tilde{\tau}\ (\lambda)$. LS advise 10% trimming from both sides. Lag was selected according to the general-to specific-procedure. GTOS procedure is based on the idea that we choose the maximum number of lags and check if the last lag is significant on a certain significance level. Perron (1989 p.22) selects 8 as the maximum number of lag to begin the testing procedure with for yearly data and 12 for quarterly data. Perron states that with the higher number of lags the power of the test decreases. If too few lags are added, the size of the test decreases. I use 10% significance level for the significance of lags (Perron 1989, p.22) and 16 as a maximum number of lags since I use monthly data.

To execute the LM2 test I use the R code developed by Johannes Lips[13].

[13] https://github.com/hannes101/LeeStrazicichUnitRoot

Test	estimated τ	Lag Selected	Breakpoint λ1	Breakpoint λ2	Critic. Value (10%)	
Crash 1	-2.709571	14	43/265 ~ 0.2			-3.211
Crash 2	-2.876921	14	43/265 ~ 0.2	73/265 ~ 0.3		-3.504
Break 1	-2.627752	6	144/265 ~ 0.5			-4.17
Break 2	-4.283175	10	85/265 ~ 0.3	160/265 ~ 0.6	λ1=0.2, λ2=0.6	-5.32
					λ1=0.4, λ2=0.6	-5.31

** Critical values reported at 10% level of significance*

Table 2. Results of LM2 test, data from COLSAF, name of series: SR-ARIMA13, data from Slovakia covering the period from 01/1997 to 01/2019, own elaboration, based on Johannes Lips R code for LM2 test. Crash 1 test stands for Model A LM test with one structural break in intercept and Break 1 test stands for Model C that allows for 1 structural break in intercept and trend. Crash 2 and Break 2 allow for 2 breaks in respective models.

As we can see, the critical value was not exceeded in any of the cases. Even if we allowed for up to 2 structural breaks under the null and under the alternative, we cannot reject the null of a unit root and therefore a hysteresis hypothesis in Slovak unemployment rate. In another words, we allowed for up to two important changes to the Slovak labor market (possibly changing the inherent characteristics of the Slovak labor market) in the respective period. Breaks would divide the dataset into 2 (with one break allowed) or 3 (with two breaks allowed) time periods within which we would expect unemployment rate has different but equilibrium states. These break dates were chosen in such a way so that we would most probably (from all other possible break dates) reject the unit root null within the tested periods. But even taking account of the possible structural changes in the country during the tested period, we cannot reject the hypothesis that unemployment rate is path dependent and after a recession will not return to any equilibrium state without exogenous forces.

Perron mentions two unit root tests allowing for more than two breaks (Ohara 1999 and Kapetanios 2005). These tests though do not allow for the possibility of the break under the unit root alternative. There are also efforts to elaborate on stationarity KPSS test with two structural breaks as well as unit root tests using Bayesian framework (Perron 2005). The question is, if existence of too many breaks present in the time series data does not point on the unit root process. Hansen (2001) claims that

"the distinction between a random walk and a trend break largely concerns the frequency of permanent shocks to the trend. In a random walk process, such shocks

occur frequently, while in a trend break process, they occur infrequently (once or twice in a sample).” (Hansen 2001, p.125)

4.2 Unemployment hysteresis in regions

As is visible from tables and plots below, unemployment rate between regions varies substantially. Bratislava region has not only the lowest unemployment rate numbers, but also lowest variance. On the other hand, Banská Bystrica, Prešov, and Košice regions have the highest unemployment rates from the beginning of the sample to the end. Nitra region (in black on the plot below) has the highest variance. Nitra begins as a member of the “high-unemployment-group” at the end of the 1990s and since 2004 converges to the “low-unemployment-group”, which it meets around 2008 and remains part of it.

Descriptive statistics - regions

	Bratislava	Trnava	Nitra	Trenčín	B.Bystrica	Žilina	Prešov	Košice
Mean	4.53	8.85	13.11	8.55	17.54	10.70	17.49	17.81
Median	4.65	8.51	12.21	9.16	18.31	11.11	17.94	17.58
Std. Dev.	1.46	3.78	5.32	2.84	4.00	3.64	4.09	4.49
Sample Var.	2.12	14.27	28.28	8.09	16.02	13.26	16.74	20.14
Range	5.30	13.81	19.73	10.89	16.38	13.82	17.08	18.26
Minimum	1.83	2.30	3.12	2.88	7.04	3.97	8.56	8.23
Maximum	7.12	16.12	22.85	13.77	23.42	17.79	25.64	26.49

Table 3. Descriptive statistics-regions, datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019, own calculations

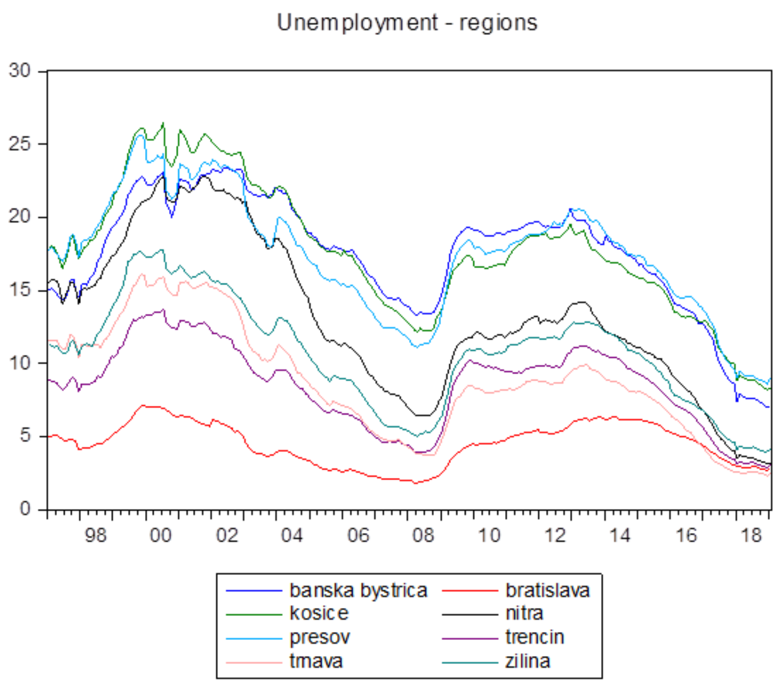

Figure 8. Unemployment rate - regions, datasrR_ARIMA13 regional data from COLSAF data, time period January 1997-January 2019, own elaboration in EViews.

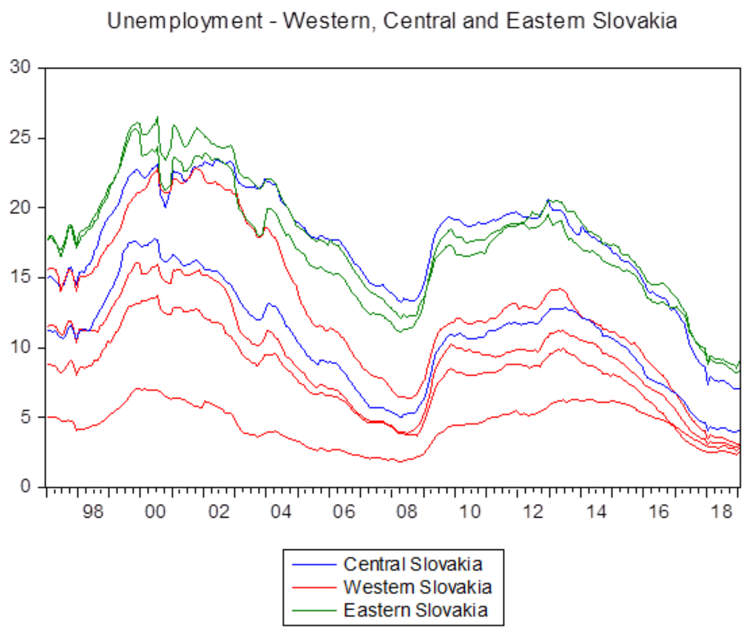

Figure 9. Unemployment rate in regions divided into East, West and Central Slovakia, datasrR_ARIMA13 regional data from COLSAF data, time period January 1997 – January 2019, own elaboration in EViews.

4.2.1 Univariate unit root tests

First, I will perform univariate tests for the presence of unit root on data from every Slovak region. Afterwards in order to increase power of the univariate unit root tests, I will perform panel unit root tests.

I chose to perform ADF unit root test and as a complement KPSS and Ng Perron unit root test. ADF is a standard unit root test based on OLS regression of differenced series, whose t-values are confronted with the Dickey-Fuller critical values. KPSS test is not a unit root test, but a stationarity test. For that reason, it can add up information about the (insufficiency of) information in the data in the case of certain results. That means that it tests the null of stationarity around a deterministic trend against the alternative of non-stationarity. It uses the LM statistic to evaluate the variance. The Ng Perron test is a modification of the Phillips-Perron test on the detrended data from ADF-GLS (Artlová and Fedorová 2016).

Globally, for long (T=100) or very long (T=500) time series (my series being somewhere in the middle with T=265) ADF and Ng Perron tests are among the recommended tests to use (Arltová and Fedorová 2016, p.62). I add also results of KPSS test for the sake of comparison.

Univariate tests - regions

	ADF		KPSS	
	c	c+t	c	c+t
Bratislava	-1.62	-1.658	0.252	0.237***
Trnava	-0.883	-1.61	1.256***	0.173**
Nitra	-0.155	-1.613	1.312***	0.141*
Trenčín	-1.48	-2.123	0.582**	0.152**
Banská Bystrica	-0.938	-1.629	0.848***	0.181**
Žilina	-0.844	-1.871	0.886***	0.15**
Prešov	-0.732	-1.7	0.864***	0.147**
Košice	-1.069	-2.73	1.232***	0.129*

** 10% level of significance*

*** 5% level of significance*

**** 1% level of significance*

Lags selected according to modified AIC.

Table 4. Univariate unit root tests – ADF and KPSS, data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019, own calculations.

As visible from Table 4, the results of all test statistics (except for the case of KPSS test with a constant for Bratislava region) are in favor of the unit root hypothesis. Either we cannot reject the unit root null (ADF case) or we must reject the stationarity null (KPSS test).

The individual results of Ng and Perron unit root tests are below in Table 5. As we can see, also Ng and Perron tests statistics cannot reject the unit root null at 5% significance level in any of the cases.

	Ng Perron unit root test - INTERCEPT				Ng Perron unit root test- INTERCEPT + TREND			
regions	MZa	MZt	MSB	MPT	MZa	MZt	MSB	MPT
Bratislava	-3.869	-1.245	0.322	6.459	-4.77	-1.504	0.315	18.865
Trnava	-0.084	-0.042	0.498	18.814	-4.801	-1.509	0.314	18.747
Nitra	0.4	0.207	0.523	21.863	-3.035	-1.141	0.376	27.814
Trenčín	-3.761	-1.111	0.295	6.672	-8.355	-1.959	0.234	11.194
B. Bystrica	-1.103	-0.475	0.431	13.208	-1.547	-0.626	0.405	36.969
Žilina	-2.328	-0.809	0.348	8.973	-4.612	-1.436	0.311	19.197
Prešov	-2.095	-0.714	0.341	9.271	-4.301	-1.341	0.312	20.08
Košice	-6.185*	-1.514	0.245*	4.742	-9.478	-2.086	0.22	10.009

** 10% level of significance*   *Spectral GLS-detrended AR based on SIC, maxlag=15 (Eviews).*

Table 5. Univariate unit root tests – Ng Perron unit root test. Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019, own calculations

Researchers have long been trying to exploit the information added by the cross-sectional dimension (Lee et al. 2009). However, the advantages of having more observations from the same time period are offset by considerable size distortions when cross-sectional dependence is present (Bai and Ng 2010). The common movement of regional unemployment rate series raise doubts about their independence from one another. Especially in the table representing the unemployment rate graphically divided into Western, Central, and Eastern Slovakia, the common (almost identical) movement of especially Eastern Slovakia regions unemployment rate is striking.

In order to test for unit roots in panels, one must assert whether there is cross-sectional correlation among the units in panel. If dependence is present, assumptions for executing first- generation panel unit root tests are violated, and only second-generation panel unit root tests will provide the correct results.[14]

In order to assess whether there is cross-sectional correlation among regions, I perform Breusch Pagan LM test on residuals from the ADF regressions on the regional unemployment rate. For the sake of future comparisons, I added 8 augmentations to filter out additional autocorrelation.

Regression formula: $$\Delta y_{it} = c + t + \beta y_{i(t-1)} + \sum_{j=1}^{p} \Delta y_{i(t-j)} + e_{it} \qquad (58)$$

Breusch-Pagan LM test: $$LM_{BP} = T \sum_{i}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij}^{\ 2} \ \sim \ \chi^2 \left(\frac{N(N-1)}{2}\right) \qquad (59)$$

LM_{BP} = 2849 is well over the critical value of χ^2 test with 28 degrees of freedom (41,34). The result of Breusch-Pagan LM test affirms there is cross-sectional correlation among regions.

In order to account for the cross-sectional correlation, I will perform Pesaran (2007) panel unit root test and Bai and Ng PANIC unit root test (2004).

Both these panel unit root tests were originally designed for the large panel data. Pesaran test should perform well even in the case of smaller panels when N=10 (Kappler 2006, pp.12,20 citing Pesaran 2007). Gengenbach et al. (2008) assert that when testing for unit root in idiosyncratic component, PANIC test performs reasonably well, despite some tendency to over-reject the null when the common factor is non-stationary (Gengenbach et al. 2008).[15] Both these panel unit root tests assume that the cross-sectional dependence arises from some unobserved common factor(s).

Pesaran assumes there is only one common factor and tries to approximate its influence by adding up means of differenced observed series to the regression. Then he tests for a unit root in the remaining de-factored series. Bai and Ng (2004) on the other hand approximate the factor analysis model expecting some latent common factor(s) that is

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[14] Some of the first-generation panel unit root tests are Im, Pesaran and Shin (1997), Levin, Lin, Chu (2002), Maddala and Wu (1999), Choi (2001), Hadri (2000). Except Pesaran (2007) and PANIC test (Bai and Ng 2004,2010). The second-generation panel unit root tests include: Phillips and Sul (2003aa), Moon and Perron (2004a), Choi (2002), Breitung and Das (2008), Chang (2002), Taylor and Sarno (1998).

[15] Also, Romero-Ávila (2007) uses PANIC test on a panel of 11 countries when testing for non-stationarity of short-term interest rates.

extracted by the method of principal component analysis. Bai and Ng (2004) also try to discover where the origin of the integrated series lies − either in the common factor(s) or some idiosyncratic component specific only to the certain unit or both. If the unit root process is generated in the series by means of the common factor, Bai and Ng test have decent properties compared to the Pesaran test, Moon and Perron test, Breitung and Das and Sul test (Gengenbach et al. 2008, pp. 3,8,15,23). On the negative side, Bai and Ng PANIC test was also designed to test the unit root in large panels. They state that with small number of variables, the estimation of common factors is inconsistent, since what is extracted is common only to small number of variables. (Bai and Ng 2004, p.1129).

4.2.2 Pesaran test (2007)

As written above, one of the assumptions of the Pesaran test is a single dynamic common factor among the units of the panel that accounts for the cross-sectional correlation. The most likely source of the co-movement among the units in the unemployment data panel is business cycle. According to 4 factor analysis methods (Eigenvalues, Parallel Analysis, Optimal Coordinates, and Acceleration factor) there is only one common factor in the regional data.

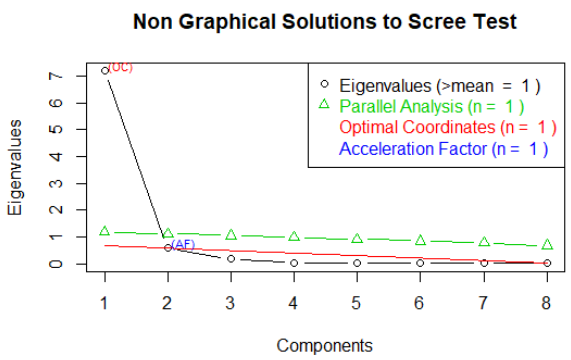

Figure 10. Defining the number of factors. Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019, own processing through R programme

Pesaran (2007) assumes that the data generating process is a simple dynamic heterogeneous panel data model. Heterogeneity in the panel data model means that units are characterized by different dynamics, and thus we must consider different models for testing unit roots on various units (Hurlin and Mignon 2007). Though I am working with a balanced panel, one of the advantages of the Pesaran test is also its applicability to unbalanced panels (Kappler 2006).

Pesaran tests the following adjusted model:

$$\Delta y_{it} = \alpha_i + \beta y_{i(t-1)} + u_{it} \tag{60}$$

Where α_i represents deterministic component – either a constant or a constant with trend. Error term u_{it} has a single factor structure:

$$u_{it} = \gamma_i f_t + \varepsilon_{it} \tag{61}$$

We may therefore write:

$$\Delta y_{it} = \alpha_i + \beta_i y_{i(t-1)} + \gamma_i f_t + \varepsilon_{it} \tag{62}$$

Pesaran tests whether it is possible to reject the null hypothesis of a unit root for all units (H0: $\beta_i = 0 \; for \; all \; i$), or if there is at least one unit for which we could reject the unit root null hypothesis (H1:$\beta_i < 0 \; at \; least \; for \; one \; i$).

Pesaran suggests that the common factor f_t can be proxied by the cross-sectional mean of y_{it} ($\overline{y_t} = N^{-1} \sum_{j=1}^{N} y_{jt}$). According to Pesaran adding up cross-sectional means to the ADF regression should be sufficient to proxy for cross-sectional correlation. Possible serial correlation is accounted for by augmentations to the DF model. Pesaran calls his model Cross-Sectionally Augmented Dickey-Fuller (CADF) and as a test of his null hypothesis he uses the t-ratio of OLS statistics in the coefficient of the lagged variable.

For data characterized by no serial correlation in u_{it} (a), and with serial correlation in u_{it} (b) he proposes the following model:

a.) $$\Delta y_{it} = a_i + b_i y_{i(t-1)} + c_i \bar{y}_{t-1} + d_i \Delta \bar{y}_t + \varepsilon_{it} \tag{63}$$

b.) $$\Delta y_{it} = a_i + b_i y_{i(t-1)} + c_i \bar{y}_{t-1} + \sum_{j=0}^{p} d_{ij} \Delta \bar{y}_{t-j} + \sum_{j=1}^{p} d'_{ij} \Delta y_{i(t-j)} + \varepsilon_{it} \tag{64}$$

Pooled test that has better power properties than individual CADF statistics (Gengenbach et al. 2008, p.25). CIPS is constructed as an average of the individual $CADF_i$ statistics. CIPS abbreviation stands for "cross-sectionally augmented IPS (Im

Pesaran and Shin) panel unit root test" (IPS test is being augmented by cross-sectional mean variables) (Hurlin 2010, p.1526).

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} CADF_i \qquad (65)$$

Pesaran test assumes the residuals have zero mean, constant variance, have finite fourth order moment, and are distributed independently across *i* and *t*. The common factor f_t is also assumed to be serially uncorrelated, with mean zero, constant variance and finite fourth-order moment.

Since the model is heterogenous, I use such number of lags for each $CADF_i$ regression that are capable of filtering out autocorrelation from the residuals (at least at 5% level of significance). Even though I use seasonally adjusted data, I cannot be completely certain that all seasonal effects were canceled out. For the purpose of capturing possible residual autocorrelation coming from the remnants of seasonal deviations, I checked against Breusch-Godfrey autocorrelation test with order of maximal autocorrelation 13. In this way, dependency on 12 months old observations is recovered. I also check for possible heteroskedasticity with Breusch-Pagan heteroskedasticity test. I report the results of Breusch-Godfrey autocorrelation test and Breusch Pagan heteroskedasticity test in Table 6 in Appendix 1. Since for some of the residuals of $CADF_i$ regressions, I have to reject the null of homoskedasticity at 5% level of significance, I use the robust estimation of standard errors (HC3 in R). Reported t-values are therefore the result of this robust estimator.

Strauss and Yigit (2003, p. 311) show that not only the magnitude of the cross-sectional correlation influences the extent of the size distortion of the test but also the magnitude of its heterogeneity. If there is a high variation in pairwise cross-sectional coefficients of the error components, using simple averages may not be enough to proxy for the common factor (Kappler 2006 p.12). As shown in Table 7 on the next page, cross-sectional correlations differ especially in the case of Bratislava. For that reason, in order to test the robustness of my statistics results, I present also the CIPS statistic that does not comprise Bratislava data.

Correlation table (based on residuals from ADF regressions of 8 lags)

	residfitBA	residfitTA	residfitNI	residfitTR	residfitBB	residfitZI	residfitPR	residfitKO
residfitBA	1							
residfitTA	0.555	1			Average pairwise correlation:			0.618
residfitNI	0.365	0.635	1					
residfitTR	0.449	0.666	0.725	1				
residfitBB	0.387	0.577	0.635	0.664	1			
residfitZI	0.377	0.652	0.72	0.697	0.676	1		
residfitPR	0.536	0.782	0.603	0.627	0.729	0.662	1	
residfitKO	0.379	0.628	0.641	0.624	0.816	0.704	0.796	1

Table 7. Correlation table ADF (8 lags, intercept and trend model). Data series: datasrR_ARIMA13 regional data from COLSAF, period from January 1997 to January 2019. Regional abbreviations: BA-Bratislava region, TA-Trnava region, NI- Nitra region, TR–Trenčín region, BB-Banská Bystrica region, PR-Prešov region, ZI-Žilina region, KO-Košice region. Own elaboration.

In Table 8 I report results of CADF and CIPS test statistics and in Table 9 in Appendix 1 I report critical values as derived by Pesaran (2007). I use the values belonging to the panel consisting of 10 units with 200 time periods that most closely resemble my data.

Pesaran Results

region	intercept $CADF_i$ t.val	intercept and trend $CADF_i$ t.val
BA	-1.095	-2.468
TA	-1.456	-0.911
NI	-1.799	-2.301
TR	-2.096	-1.809
BB	-0.636	-0.37
ZI	-1.786	-1.227
PR	-2.915*	-2.859
KO	-2.134	-1.656
	CIPS	CIPS
	-1.74	-1.7
	CIPS no BA	CIPS no BA
	-1.832	-1.59

** 10% level of significance ** 5%level of significance *** 1% level of significance*

Table 8. Pesaran test results. Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019. Regional abbreviations: BA-Bratislava region, TA-Trnava region, NI- Nitra region, TR–Trenčín region, BB-Banská Bystrica region, PR-Prešov region, ZI-Žilina region, KO-Košice region. Own elaboration.

Like univariate tests for unit roots, Pesaran test offers quite unambiguous answers. If we allow for the intercept, or intercept and trend (region specific and time specific effects) in intermediate regressions, we definitely cannot reject the null of a unit root for all regions considering 5% level of significance. This result means that according to the Pesaran test result the unemployment rate in all Slovak regions is defined by the hysteresis hypothesis. Thus, if there is a temporary shock that for example increases the unemployment rate in Slovak regions, even when the shock passes, the unemployment rate will not return to any equilibrium state by itself.

To check the assumption that error component is independent between units, I test again with the Breusch-Pagan LM cross-sectional dependence test on the residuals of intermediate $CADF_i$ regressions (Bratislava included).

Pesaran tests residual cross-sectional correlation

	intercept	intercept + trend
LM_BP	436	399

Table 10. Residual cross-sectional correlation from Pesaran tests.
Critical value (28) = 41,34. Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019, own elaboration

LM test statistics for cross-sectional dependence considerably decreased compared to the initial statistics from basic ADF regressions. LM test statistics show that most of the cross-sectional correlation was filtered out by adding average augmenting terms, but some dependence remained. Correlation Tables 11 and 12 in Appendix 1 show the correlation that remained after applying Pesaran models on the data. Due to these remains, we cannot reject the null of the cross-sectional dependence among units and therefore we must accept that assumption of independence of error term across units has not been not met. Consequently, the Pesaran test might suffer from the size distortion.

4.2.3 Bai and Ng Panel Analysis in Non-Stationarity in Idiosyncratic and Common Components (2004)

Bai and Ng model assumes data generating process is driven by one or more common factors and some idiosyncratic component.

The data generating process is of the following model:

$$Y_{it} = d_{it} + \lambda_i F_t + E_{it} \tag{66}$$

Y_{it} represents observed values of time series analyzed, d_{it} deterministic component (that can be either intercept or intercept and trend) λ_i factor loadings, F_t is a vector of common factors (factor scores, in my case as later explained F_t stands for only one common factor), E_{it} (largely) idiosyncratic component. $\lambda_i F_t$ together stands for the influence of common component. Series with a factor structure is non-stationary if either a common component, or an idiosyncratic component, or both are non-stationary (Chen 2013, p.59). Both common component and errors will be therefore tested for existence of a unit root process through ADF tests. Since the cross-sectional dependence should be well-represented by the common component, idiosyncratic component should be independent and can be subject to pooled tests (Gengenbach et al. 2008) that are more powerful with respect to individual unit root tests. Although Bai and Ng write they allow for weak cross-sectional correlation and weak serial correlation for idiosyncratic component (Bai and Ng 2004, p.1131)).

Principal component method

Factor analysis in PANIC model is done through the principal component method. Principal component method (PCA) that I use in R program is done through the singular value decomposition that produces matrix of eigenvectors belonging to all individual principal components. The main goal of PCA is to lower the dimension of the data by using components - certain linear combination of variables as ‘new variables’ - chosen in such a way that explain meaningful variation in the data. The point is therefore to have less components than original variables. Other than reduction of data, principal components (and factor analysis method) are trying to find *some "hidden (artificial, unquantifiable, latent) parameters, called principal components, or factors, that explain variability and dependence of the variables under consideration. These new… variables… are nothing more than linear combinations of original quantifiable … variable."* (Hebák 2015, p. 349).

As Hebák (2015, p. 349) writes, one of the advantages of PCA is that by creating artificial components out of quantifiable and observable characteristics, it can capture some unobservable characteristics, or characteristics that are hardly quantifiable by ordinary scientific measures. For this reason, principal component analysis is often used in social sciences. PCA enables researchers to transform information from observable variables into information about unobservable characteristic (for example value of self-esteem, tendency to depression, general variable "danger in quarter XY" based on information about number of rapes, and other types of crime and so on.)[16]

Principal components are designed in such a way that they are uncorrelated between each other (Pituch and Stevens 2016). This uncorrelatedness is interesting when studying the panel whose high cross-sectional correlation distorts unit-root testing. Since all variables in the panel are measured in the same units and have very similar scale, I use covariance matrix(S) as a base for conducting PCA.

Bai and Ng (2004) observe that when E_{it} is I(0), principal component estimates of factor and factor loadings is consistent, whether factor series is integrated or not. This does not hold though if E_{it} is I(1). In order to obtain consistent estimates of factor and factor loadings and preserve their order of integration, Bai and Ng suggest running principal component analysis on differenced series (if intercept is the only deterministic component) and on differenced and demeaned series (if both trend and intercept are deterministic components) (Bai and Ng 2004, pp.1131-1132).

[16] As an example can be used a study by Raskin and Terry (1988) who conducted a reasearch on narcissism on university students using questionnaire. By analyzing answers to many questions about how person reacts or feels in certain situations, researchers created 7 components amounting to „Authority, Self-Sufficiency, Superiority, Exhibitionism, Exploitativeness, Vanity, and Entitlement", which are all hardly measurable characteristics (Raskin and Terry 1988, p. 893-894).

Intercept only case:

$$y_{it} = \Delta Y_{it} \qquad (67)$$

Intercept and trend case:

$$y_{it} = \Delta Y_{it} - \overline{\Delta Y_i} \qquad (68)$$

Applying the principal component analysis to the differenced observed series, we can obtain estimated *factor score* $\hat{f}_t$, estimated *factor loadings* $\hat{\lambda}_i$, *correlation coefficient with PC1* $r(y_i, PC_1)$ and *communalities* c_i (among others Hebák 2015, pp.360-361).

$$\hat{f}_t = \sum_{i=1}^{N} \widehat{eigenvector}_{PC1,i} * y_{it} \qquad (69)$$

$$\hat{\lambda}_i = \widehat{eigenvector}_{PC1,i} * \sqrt{\widehat{eigenvalue}_{PC1}} \qquad (70)$$

$$r(y_i, PC_1) = \frac{\hat{\lambda}_i}{s(y_i)} \qquad (71)$$

$$c_i = \left(r(y_i, PC_1)\right)^2 \qquad (72)$$

Eigenvector is a direction of a variable in a new space created by principal components. Eigenvalue represents amount of variance that is accounted for by a given component[17]. Factor score is a representation of unobserved values of observed variable that are attributable to the working of the common factor. In our case it is most probably values of the unemployment rate that are due to the business cycle.

[17] SAS support document, Principal component analysis, p.22
https://support.sas.com/publishing/pubcat/chaps/55129.pdf

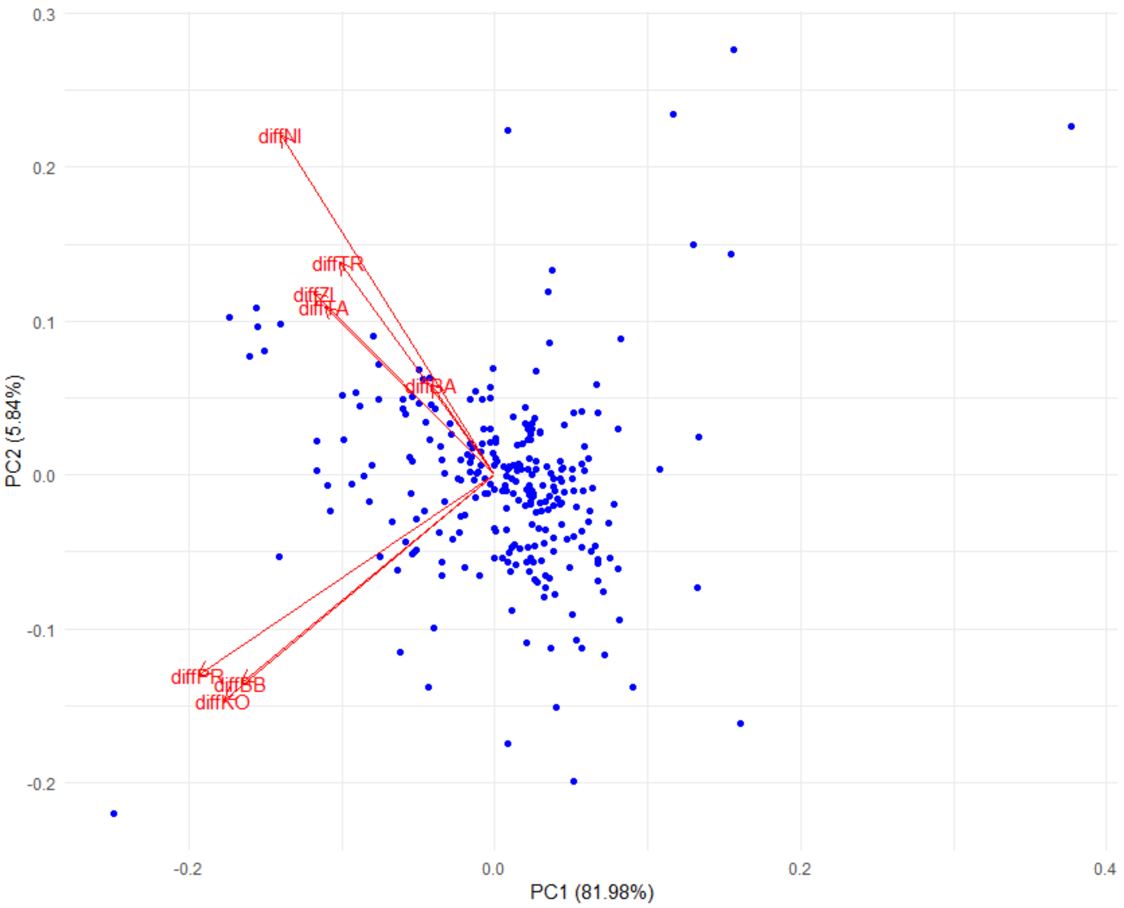

Figure 11. Biplot. Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019, own elaboration. **PCA – biplot description[18]:**The *dots in blue* represent *factor (component) scores* in every time period corresponding with component 1 (x-axis) and component 2 (y-axis). *Vectors in red* are the original variables from which the new PCs were computed. The *orientation of vectors* is an indicator how much the variable contributes to the PC space – the more parallel to a PC axis, the more it contributes only to that PC. *Length of the vectors* indicates how much variability of this variable is represented by the two displayed principal components. *Angles* between vectors show their correlation in the new PC space – small angle represents high positive correlation, right angle represents lack of correlation, opposite angle negative correlation (Rossiter 2014, p.107). Regional abbreviations: BA-Bratislava region, TA-Trnava region, NI- Nitra region, TR–Trenčín region, BB-Banská Bystrica region, PR-Prešov region, ZI-Žilina region, KO-Košice region

We can observe the same situation as in simple plots at the beginning of the regional analysis part of thesis. Regions with lower unemployment (Western Slovakia + Žilina)

[18] According to the Rossiter (2014) and Hartmann, Krois, Waske (2018)

have very high correlation among each other in the new PC space. The same is valid for regions with higher unemployment (Eastern Slovakia + Banská Bystrica region). The correlation between these two groups of regions is very small according to the biplot as visible from almost right angle between vectors of these two groups. Both groups contribute very similarly to the variance explained by the first component, maybe higher-unemployment group contributes slightly more to the variance of the first component than the second lower-unemployment group. Bratislava has the least variability explained by the two principal components. This is understandable since dynamics of unemployment in Bratislava differs the most from the rest of the regions.

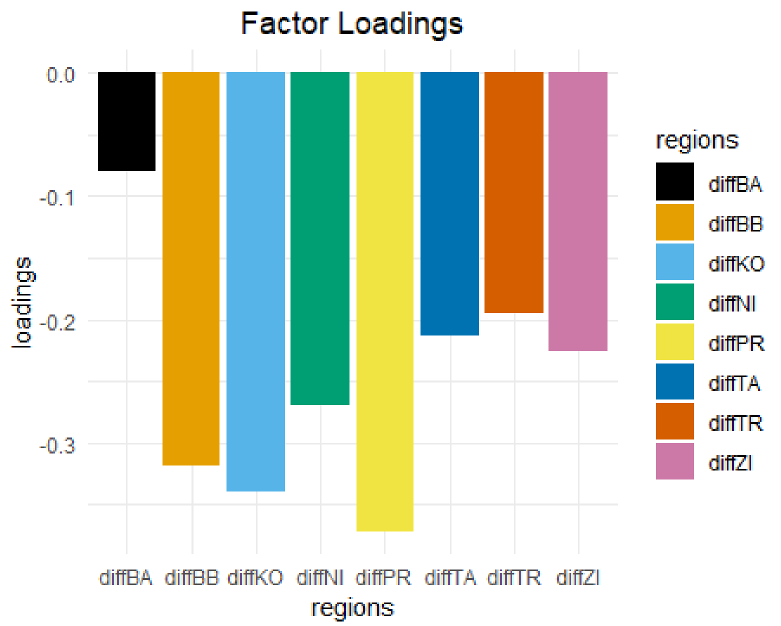

Figure 12. Factor loadings. Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019, own elaboration. Regional abbreviations: BA-Bratislava region, TA-Trnava region, NI- Nitra region, TR–Trenčín region, BB-Banská Bystrica region, PR-Prešov region, ZI-Žilina region, KO-Košice region

Having applied principal component analysis on differenced series, factor loading can be understood as a contribution of the factor to the value of observed variable (Hebák 2015, p.380). The observed variable is in our case differenced (and demeaned) unemployment rate. Estimated factor loadings define the elasticity at the origin of cross-sectional dependencies (Hurlin and Mignon 2007, p.8). The most responsive (the biggest contribution of the common factor) to the change of common factor is the change in unemployment rate in Prešov region, whereas change in unemployment rate in Bratislava region has very small response to the change in the common factor.

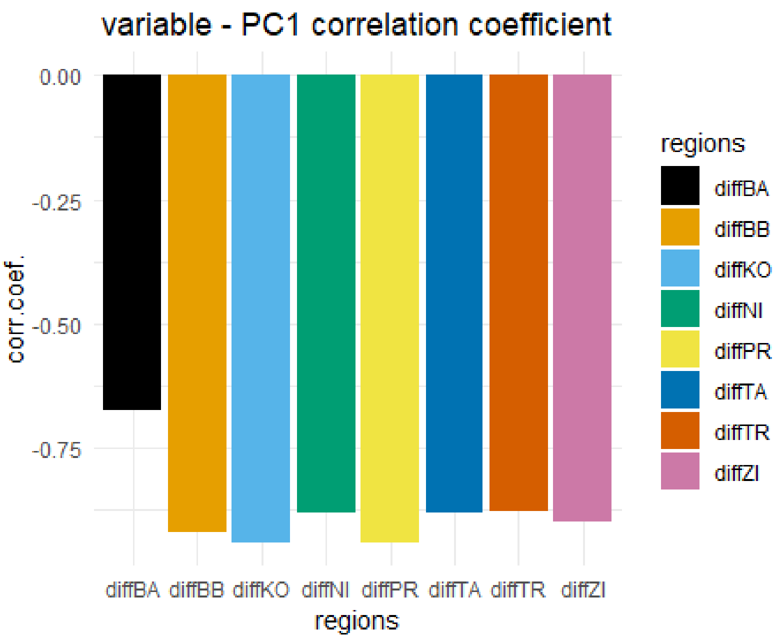

Figure 13. Correlation coefficient between original variable and first principal component. Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019, own elaboration. Regional abbreviations**:** BA-Bratislava region, TA-Trnava region, NI- Nitra region, TR–Trenčín region, BB-Banská Bystrica region, PR-Prešov region, ZI-Žilina region, KO-Košice region

As visible from Figure 13 according to the correlation coefficient between original variables and common factor, when common factor rises, all of the regions experience a decrease. If common factor was a business cycle, as is predicted, these results tell us that when economic situation improves, unemployment lowers, which is quite a logical and obvious conclusion.

Choosing the number of components

Various methods help the decision how many components to retain. Factor analysis Figure 10 above (based on various other factor extraction methods) suggested there is probably only one common factor.

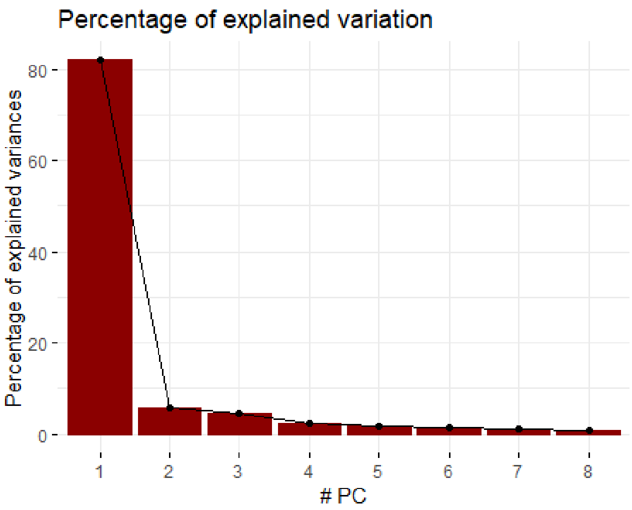

Figure 14. Percentage of explained variation. Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019, own elaboration.

From the Figure 14 we see that the first principal component explains far more variance than any other subsequent component. Retaining only one component can therefore be quite satisfactory.

As suggested above with the factor analysis, eigenvalue – one – criterion (or Kaiser criterion) instructs to choose only components whose eigenvalue is higher than one (interpretation of this rule is that a component with an eigenvalue lower than one explains less variance than a single variable). This is valid in the case of working with the correlation matrix as a base for PCA, where the sum of variable variances (trace of correlation matrix-sum of all ones on diagonal) equals number of parameters. With the covariance matrix, the sum of variable variances (tr(S)) equals the sum of eigenvalues[19]. This sum does not need to be equal to the sum of parameters. We can still use the screeplot method though. Screeplot is visible in Figure 15.

[19] Eigenvalues for each component can be computed by squaring the standard deviations obtained by principal component analysis.

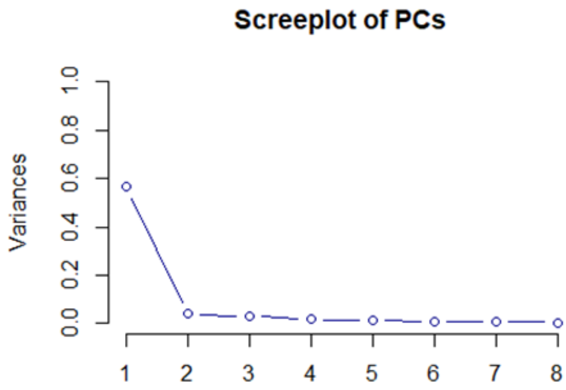

Figure 15. Screeplot of principle components. Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019, own elaboration.

The screeplot method was developed by Cattell (1966). Magnitude of eigenvalues is plotted on the vertical axis with ordinal numbers related to the components retained (eigenvalues) on the horizontal axis (Pituch and Stevens 2016, p.342). We should select the number of components before the last ‘elbow break’ of the screeplot. Since in my case there is only one obvious break, the screeplot method suggests choosing one component. This method works well on data sets with more than 250 observations and communalities of a mean higher than 0.6 (Pituch and Stevens 2016, p.342).

Communality of a variable is the proportion of variance of that variable accounted for by the number of retained components (Hebák 2015, p. 361). In my case communalities show how much variance of individual original variables is explained by the first principal component.

Communalities

	diffBA	**diffTA**	**diffNI**	**diffTR**	**diffBB**	**diffZI**	**diffPR**	**diffKO**	**MEAN**
variance explained by PC1	0.455	0.779	0.779	0.767	0.846	0.805	0.883	0.884	**0.775**

Table 13. Communalities. Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019. Regional abbreviations**:** BA-Bratislava region, TA-Trnava region, NI- Nitra region, TR–Trenčín region, BB-Banská Bystrica region, PR-Prešov region, ZI-Žilina region, KO-Košice region. Own elaboration.

Since I have 256 observations and mean of variable communalities for 1 PC retained is 0.775, I believe I can validly extract only 1 principal component.

Other methods how to choose the optimal number of components include interpretability criteria, proportion of variance accounted for and parallel analysis (SAS Support, Pituch and Stevens 2016, p.343). In the PANIC setting Bai and Ng (2004) also suggest criteria to select the optimal number of components. The criteria of Bai and Ng are elaborated for the purpose of application of factor analysis with principal component method on large panels, where the point is mainly to select the number of components that does not overfit the model, therefore they penalize for too many components according to the panel size. For very small N or T they consider their criteria inadequate (Bai and Ng 2002, pp. 203). Another approach to tackle the difficulty to accurately estimate the correct number of common factors in the case of small number of panel units is to simply impose a single factor, as does Romero-Ávila (2007).

For the above-mentioned reasons, I chose to retain only one component for the subsequent analysis.

4.2.3.1 Estimation of the common factor and idiosyncratic components and the unit root analysis

Applying the principal component analysis to the differenced (or differenced and detrended) series, the model becomes:

$$y_{it} = \hat{\lambda}_i \hat{f}_t + \hat{z}_{it} \qquad (73)$$

… where as was already stated:

a) $y_{it} = \Delta Y_{it}$ for the intercept only case

b) $y_{it} = \Delta Y_{it} - \overline{\Delta Y_i}$ for the intercept and trend case

Therefore:

$$\hat{z}_{it} = y_{it} - \hat{\lambda}_i \hat{f}_t \qquad (74)$$

Since the estimated common factor and idiosyncratic errors are derived using first-differenced or detrended data, in order to remove the effect of possible over-differencing (Gengenbach et al. 2008, p. 9), Bai and Ng (2004) suggest reintegrating data in the following way:

$$\hat{E}_{it} = \sum_{s=2}^{t} \hat{z}_{it} \qquad t = 2, \dots T \quad and \quad i = 1, \dots N \qquad (75)$$

$$\hat{F}_{t} = \sum_{s=2}^{t} \hat{f}_{t} \qquad t = 2, \dots T \quad and \quad i = 1, \dots N \qquad (76)$$

Then Bai and Ng suggest to test for the presence of the unit root by the ADF test on the idiosyncratic error and common factor:

Intercept only case:

$$ADF_{\hat{E}}^{c}: \quad \Delta\hat{E}_{it} = d_{i0}\hat{E}_{i(t-1)} + d_{i1}\Delta\hat{E}_{i(t-1)} + \cdots + d_{ip}\Delta\hat{E}_{i(t-p)} + error \qquad (77)$$

$$ADF_{\hat{F}}^{c}: \quad \Delta\hat{F}_{t} = c_0 + \delta_0\hat{F}_{t-1} + \delta_1\Delta\hat{F}_{(t-1)} + \cdots + \delta_p\Delta\hat{F}_{i(t-p)} + error \qquad (78)$$

Intercept and trend case:

$$ADF_{\hat{E}}^{\tau}: \quad \Delta\hat{E}_{it} = d_{i0}\hat{E}_{i(t-1)} + d_{i1}\Delta\hat{E}_{i(t-1)} + \cdots + d_{ip}\Delta\hat{E}_{i(t-p)} + error \qquad (79)$$

$$ADF_{\hat{F}}^{\tau}: \quad \Delta\hat{F}_{t} = c_0 + c_1 t + \delta_0\hat{F}_{t-1} + \delta_1\Delta\hat{F}_{(t-1)} + \cdots + \delta_p\Delta\hat{F}_{i(t-p)} + error \qquad (80)$$

Since $ADF_{\hat{E}}^{\tau}$ statistic does not follow usual Dickey – Fuller distribution, and critical values for its distribution are not tabulated yet (Gengenbach et al. 2008, p.10, Kappler 2006, p. 19), I will execute only $ADF_{\hat{E}}^{c}$ test. According to Bai and Ng 2004 (p.1135), the asymptotic distribution of $ADF_{\hat{E}}^{c}$ coincides with the DF test for the case of *no constant*. The one-common-factor test statistics $ADF_{\hat{F}}^{c}$ and $ADF_{\hat{F}}^{\tau}$ have the same limiting distribution as DF tests for the case of *constant only*, and *constant and trend respectively.*

As they are standard univariate unit root tests, we test the unit root null hypothesis:

$d_{i0} = 0$ for the unit root in the idiosyncratic error

$\delta_0 = 0$ for the unit root in the common factor

To increase power of the testing for the unit root, Bai and Ng (2004) suggest performing a pooled test.

$$Z_{\hat{E}}^{c} = Z_{\hat{E}}^{\tau} = \frac{-2\sum_{i=1}^{N} \ln \pi_i - 2N}{\sqrt{4N}} \tag{81}$$

$$where\ \pi_i\ is\ p-value\ for\ the\ corresponding\ intermediate\ ADF\ test$$

We test H0: $\rho_i = 1\ for\ all\ i$

against H1: $\rho_i < 1\ at\ least\ for\ some\ i$

Since critical values of $ADF_{\hat{E}}^{\tau}$ statistic are not yet tabulated, I will use only $P_{\hat{E}}^{c}$ test. Under the null the test statistic follows a normal distribution N (0, 1), whatever the panel size N (Hurlin and Mignon 2007, p.11).

The results of the PANIC unit root testing are shown below:

PANIC test results - intercept model

idiosyncratic component			
	lag (MAIC)	**tval**	**pval**
idiosyncratic BA	13	-1.39	0.153
idiosyncratic TA	2	0.238	0.755
idiosyncratic NI	13	-0.263	0.59
idiosyncratic TR	3	-1.89	0.056*
idiosyncratic BB	2	-0.48	0.507
idiosyncratic ZI	13	-1.399	0.15
idiosyncratic PR	12	-2.009	0.043**
idiosyncratic KO	7	-0.967	0.298
		value of stat.	**pval**
pooled test		1.592	0.055*

common component			
	lag (MAIC)	**tval**	**pval**
common component	6	-1.133	0.703

** 10% level of significance*

*** 5% level of significance*

**** 1% level of significance*

Table 14. PANIC test results for the intercept model.
Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019. Regional abbreviations**:** BA-Bratislava region, TA-Trnava region, NI- Nitra region, TR–Trenčín region, BB-Banská Bystrica region, PR-Prešov region, ZI-Žilina region, KO-Košice region. Own elaboration.

PANIC test results - intercept and trend model

	lag (MAIC)	tval	pval
common component	7	-1.449	0.137

** 10% level of significance*

*** 5% level of significance*

**** 1% level of significance*

Table 15. PANIC test (only common component) results for the intercept and trend model. Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019. Regional abbreviations**:** BA-Bratislava region, TA-Trnava region, NI- Nitra region, TR–Trenčín region, BB-Banská Bystrica region, PR-Prešov region, ZI-Žilina region, KO-Košice region. Own elaboration.

From the pooled test on intercept model it's visible that by rejecting the null of a unit root for all idiosyncratic factors we could commit a type I error with probability of 0.056. In other words, if we reject the null of a unit root for all regions, there is 5.6% probability that we made a mistake and unemployment rate in all regions is defined by a unit root process. It is therefore highly probable that the idiosyncratic component of the regional unemployment in at least one region is defined by the stationary process. On the other hand, according to the ADF statistics for both common factors (from the intercept model as well as from the intercept and trend model), we cannot reject the null of a unit root process behind their dynamics.

Running the PANIC (intercept) analysis again without the region of Prešov (Table 16), the pooled statistics shows we cannot reject the null of a unit root in all idiosyncratic components. This could prove Prešov is the region with stationary idiosyncratic component.

PANIC test results - intercept model - without Prešov

idiosyncratic component	lag (MAIC)	tval	pval
idiosyncratic BA	13	-1.361	0.161
idiosyncratic TA	12	0.294	0.770
idiosyncratic NI	7	-0.001	0.682
idiosyncratic TR	3	-2.034	0.0405**
idiosyncratic BB	3	-0.499	0.499
idiosyncratic ZI	13	-1.352	0.164
idiosyncratic KO	7	-0.984	0.291

	value of stat.	pval
pooled test	0.914	0.180

common component	lag (MAIC)	tval	pval
common component	6	-1.159	0.692

** 10% level of significance*

*** 5% level of significance*

**** 1% level of significance*

Table 16. PANIC test results for the intercept model without Prešov region.
Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019. Regional abbreviations**:** BA-Bratislava region, TA-Trnava region, NI- Nitra region, TR–Trenčín region, BB-Banská Bystrica region, ZI-Žilina region, KO-Košice region. Own elaboration.

To assess the relative importance of the common factor and the error component for each region (based on analysis including Prešov) I compare standard deviation of the common component ($\hat{\lambda}_i \hat{F}_t$) to the standard deviation of the idiosyncratic component ($\hat{E}_{it}$) (Romero-Ávila 2007 p.998, Kappler 2006 p.21).

Formally:

$$Imp = \frac{sd\ (\hat{\lambda}_i \hat{F}_t)}{sd(\hat{E}_{it})} \qquad (82)$$

Impact of common factor vs. idiosyncratic component		
	Intercept	Intercept + Trend
Bratislava	0.794	0.559
Trnava	1.296	1.479
Nitra	1.049	1.265
Trencin	1.821	1.263
B.Bystrica	2.294	1.684
Zilina	1.697	1.403
Presov	3.467	2.412
Kosice	3.006	3.053

Table 17. PANIC Impact of common factor vs. idiosyncratic component. Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019. Own elaboration.

Results show that the common component has larger influence in all regions except for Bratislava. Variation in the observed series is therefore driven by the common (republic wide) factor. The difference between the force of the common and region-specific component is substantial. In Prešov, Košice and Banská Bystrica region, common factor drives the unemployment rate twice-to-three times as much as the individual factors inherent only to that specific region for the intercept model. We may observe these regions are the regions with the highest unemployment.

Here I present four cases of the visual representations of the common and error components and real observed series for the case of intercept model – Bratislava, Nitra, Prešov and Banská Bystrica regions. Visual representations for the rest of the regions is in the Appendix 2.

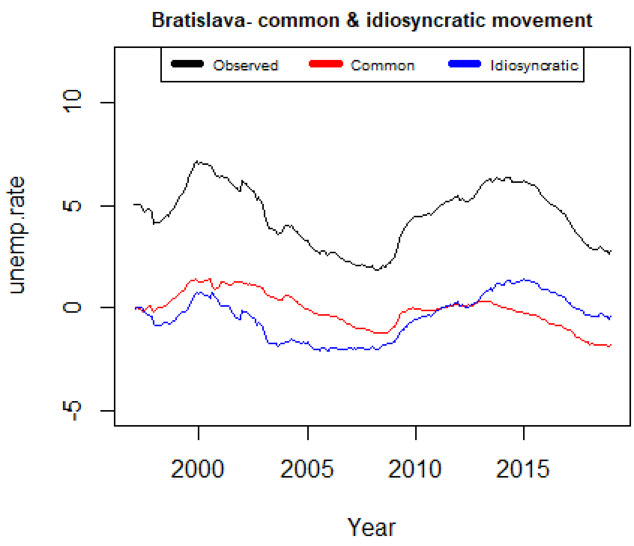

Figure 16. Bratislava region – dynamics of the common and idiosyncratic component. Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019. Own elaboration.

We may see the unemployment rate in Bratislava region mirrors movement of idiosyncratic component more than the common one.

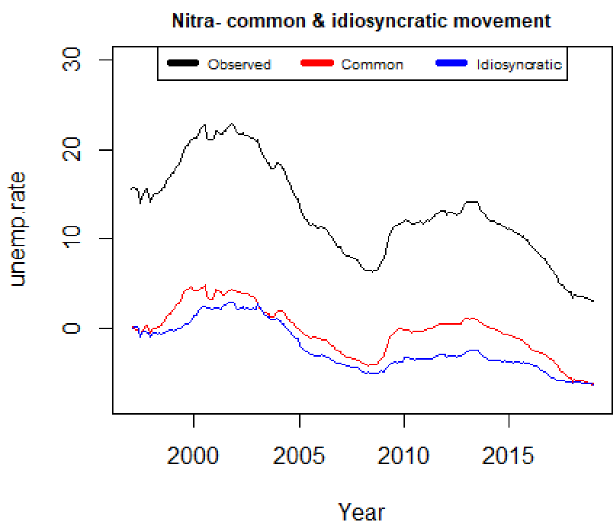

Figure 17. Nitra region – dynamics of the common and idiosyncratic component. Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019. Own elaboration.

Nitra region is influenced by the common factor as region-specific factors in the same way.

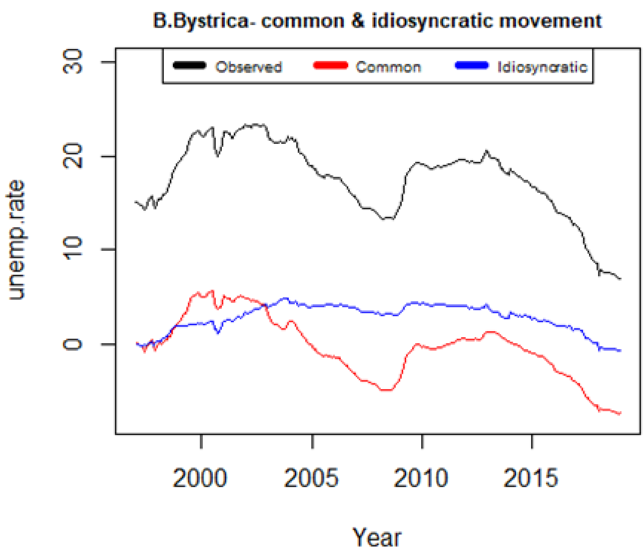

Figure 18. Banská Bystrica region – dynamics of the common and idiosyncratic component. Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019. Own elaboration.

Unemployment in Banská Bystrica region is clearly imitating movement of the common component. The unemployment rate in Banská Bystrica that would be due to the region-specific factors hardly even reacts to the economic crisis at the end of 2000s. This is valid also for the region-specific unemployment rate in Košice region as visible on Figure 21 in Appendix 2.

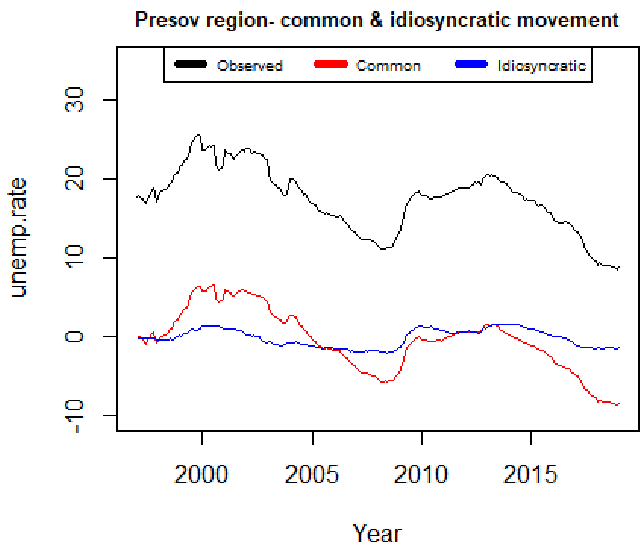

Figure 19. Prešov region – dynamics of the common and idiosyncratic component. Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019. Own elaboration.

Unemployment in Prešov region is also predominantly imitating movement of the common component.

From the above-mentioned results we may conclude that the unemployment rate in Slovakia is a unit root process. This unit root process has the origin in the dynamics of the common factor for all regions in Slovakia and for all regions, except for Prešov, also in the dynamics of the idiosyncratic component.

4.2.3.2 Business cycle as a common factor?

The advantages of application of the principle component analysis in panel unit root methodology lie especially in its ability to divide latent common and idiosyncratic factors and analyze them separately. The usage of principle component analysis has also some drawbacks. These are, for the most part, discussed in the conclusion of this thesis. One of the drawbacks of the factor analysis is especially its difficult interpretation. If we want to look at presumption that the common factor could possibly represent business cycle, we need to address this rather negative attribute of PCA here in more detail.

Interpretation of principal components is very subjective and depends on understanding of the researcher of the analyzed topic. Though many social scientists[20] use the method, some statisticians criticize it for *"not being exact enough, adequately convincing and especially for being too subjective."* (Hebák 2015, p. 350). Interpretation of common factors and idiosyncratic components may therefore be very problematic. Kappler when testing for unit roots in panels about hours worked states that *„rather abstract and intangible concepts like `common unobserved factors` and `persistent idiosyncratic components`... help to empirically model the data properties quite well, but give no further insights into economic relations"* (Kappler 2006, p.24).

In our analysis, we are working with the variables of the same subject type (unemployment rate), common factor therefore represents a latent force that is common driver of the unemployment rate dynamics in all regions. Our presumption that this common driver could be an economic cycle is feasible but not easy to prove beyond doubt. This thesis is particularly focused on hysteresis hypothesis therefore analysis of a common factor and its drivers could be another suggestion for its improvement in future. Here I present at least a graph of the common factor and output gap for visual comparison of their fluctuation in time. Output gap is taken in a frequency of quarterly

[20] Economists as well. PCA is used for example also in output gap measurement (Ódor and Jurašeková Kucserová 2014, p.8).

data from the National Bank of Slovakia, and the common factor data is monthly data transformed to quarterly data by taking end of period values beginning with March 1997.

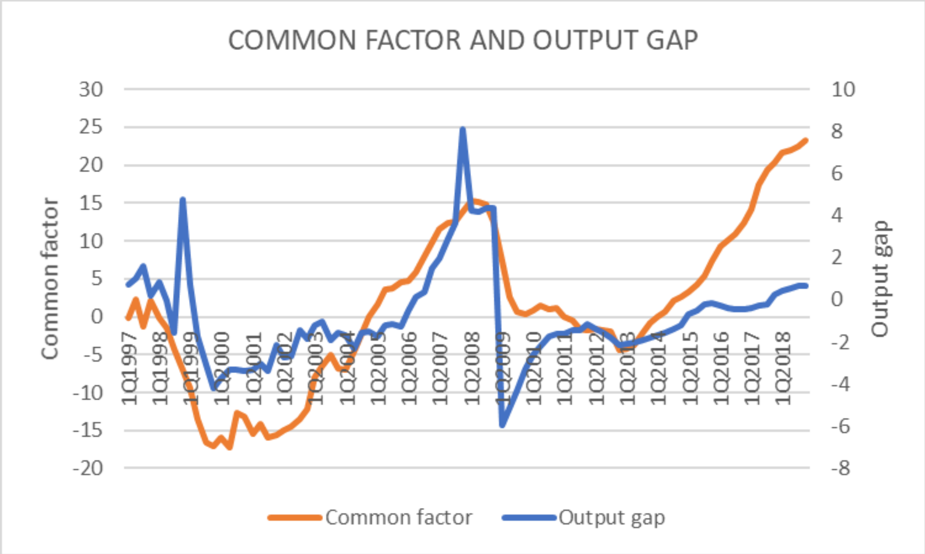

Figure 20. Common factor and output gap. Data series for the common factor: datasrR_ARIMA13 regional data from COLSAF, time period from March 1997 to December 2018. Source of data for output gap: database of the National Bank of Slovakia. Own elaboration.

The Pearson correlation coefficient between the common factor time series and output gap time series is 0.58 which means moderate correlation. We can therefore conclude that common factor definitely correlates with output gap, but output gap is definitely not the only correlating variable possibly defining the common factor of regional unemployment rates. The real causality of dynamics of common factor and economic cycle or other variables would have to be subject to further analysis.

4.2.4 Conclusion of regional analysis

It is difficult to draw some meaningful interpretation of a stationary idiosyncratic component in Prešov unemployment rate, especially due to its earlier debated abstract form. What makes Prešov stand out among other regions is especially its large emigration of personnel (Tiruneh Štefánik et al., p.136), but that is rather an effect of persistently high unemployment of the region. Prešov is also one of the main recipients of the EU funds in Slovakia, which could help getting faster out of the recession or not falling too deep during recession (Sivaev et al. 2019-World Bank report, p.38). On the other hand, it is also the region with the second highest Roma populations of all regions, and the most concentrated Roma population of all regions (Ibid., p.39-40). Considering the average education and skills level of the Roma population (on average), according to the theory this would produce higher fraction of low skilled workers and therefore higher chance of hysteresis effects. In reality, the unemployment rate of low-skilled people is the highest exactly in Prešov region (Ibid., p.36). Also, according to the World Bank report, it is believed to be mostly more educated people migrating out of the region (Ibid. p.33). This again would increase the portion of low-skilled personnel in the region and contribute to hysteresis. The share of population at the risk of poverty was in Prešov almost double than the average of other regions (without Bratislava) (Sivaev et al., p.32). People would be expected to be more prone to accept also non-ideal job position just to maintain their life quality over the poverty level which could again help to counter hysteresis. On the contrary, living in poverty or in the risk of poverty probably does not have on average positive effect considering any paid extra-work education that would improve skills and wages, therefore competitiveness and flexibility.

In Banská Bystrica, Prešov, and Košice region dynamics of the unemployment rate is largely determined by the common factor. These are regions with the highest unemployment rate, highest number of the long-term unemployed, regions with the lowest results in primary education testing (EC 2019, p.35), lowest regional GDP per capita, and highest percentage of population at the risk of poverty (Sivaev et al. 2019, p.24,30)

Conclusion

In this thesis I tested for the presence of hysteresis in multiple ways. I tested Slovak unemployment data for the presence of hysteresis in multiple equilibria model according to the structuralist approach, taking account of possible two endogenously determined breaks. Even with two breaks permitted, multiple equilibria model was not proved and Slovak unemployment data showed signs of hysteresis. In the regional data, signs of the presence of linear hysteresis are also quite convincing. Small doubts about the nature of Bratislava series due to the result of KPSS test and Prešov region due to the result of Pesaran test are by far exceeded by the results of other tests.

Due to the important practical implications of the presence of hysteresis to the monetary and fiscal policy that is largely accepted, I believe the analysis conducted in this thesis is of certain importance. Taking account of the cyclical nature of the state of the economy, analysis of its potential long-term effects on the labor market can hardly lose its interest.

The fact that unemployment rate in Slovakia and its regions is characterized by (pure) hysteresis means that any negative shock to the unemployment rate will last (permanently), unless some counter measures are adopted to mitigate the lasting effects of the negative shock. According to Smyth (p.189) *"The hysteresis hypothesis proffers that policies to decrease the actual rate, if successful, would also lead to a decline in the NAIRU. Thus, stabilization policies can have permanent effects on unemployment rates. This suggests that there is a role for greater government intervention to address unemployment issues, particularly policies which are designed to re-enfranchise the long-term unemployed."* Yellen (2016) is of the same opinion and states that when the hysteresis is present, policymakers should act *"quickly and aggressively to reduce the depth and persistence of the downturn, thereby limiting the supply-side damage".* Even when the recession slowly dissipates and damages are partially reversed, Yellen calls for the policy makers to "*aim at being more accommodative… than would be called for under the traditional view that supply is largely independent of demand."* Fatás and Summers (2016) also underline the necessity to take hysteresis into account when designing stabilization policies. They believe especially in the long-term importance of the benefits of expansionary policy and the subsequent fast recoveries.

Galí (2016, p.22) conducted an insider-outsider model of pure hysteresis. He suggests optimal monetary policy in the presence of hysteresis should concentrate on more aggressive stabilization of unemployment than the baseline simple rule, since the welfare gains of such an action would be considerable. Galí proposes the simple rule should be modified so that unemployment rate would act as an anchor and too much weight shouldn´t be put on inflation stabilization Very similar idea was suggested also Ball (2009) who states that any given inflation target is consistent with more than one level of unemployment even in the long-run, therefore any policy that focuses too heavily on targeting inflation could be dangerous. Ball advocates that central banks should respond fast to recessions, and shouldn't be too reluctant in easing their policies. He finds that hysteresis effects are larger when central banks respond less strongly to recessions.

Slovakia being part of the Eurozone is dependent on the European Central Bank's (ECB) monetary decisions. Although there is a number of studies confirming hysteresis hypothesis (or at least a high persistence) in European unemployment rates[21], it does not seem ECB is going to concentrate more aggressively on stabilization of unemployment (Cœuré 2017, 2018). According to Cœuré, ECB should, being aware of the possibility of the existence of hysteresis in its various forms, rather focus on its primary goal, which is price stability. Only in case of weak aggregate demand, when increasing unemployment rates would go hand-in-hand with decreasing inflation, should ECB consider action in order to help inflation increase back to its preferred levels (Cœuré 2017). For now, Cœuré considers current ECB's monetary policy stance with regard to potential hysteresis, appropriate (Cœuré 2018).

Along with more aggressive monetary policy, fiscal policy could be also a good assistant in counteracting aggregate demand shocks leading to recessionary unemployment. Jump and Stockhammer (2018) advise to use fiscal policy as an ordinary tool of demand stabilization since, as they calculated 80% of cyclical unemployment rate becomes permanent within a year's time. In order to maintain space for fiscal stabilizations even in times of recessions when output decreases, they propose to modify the Fiscal Compact.

[21] Jump and Stockhammer (2018), Romero-Ávila and Usabiaga (2009), Galí (2016)

The Fiscal Compact is Title III of the Treaty on Stability, Coordination and Governance in the Economic and Monetary Union (TSCG) that entered into force on 1 January 2013. Slovakia is legally bound by the Treaty. The Fiscal Compact states limits on its adherent countries' budget and debt management and strengthens the Excessive Deficit Procedure related to the breaches of the deficit limits (EC 2017, ECB 2012).

De Long and Summers (2012, p.3) add that discretionary fiscal policy *"maintained during a period when economic circumstances are such that multiplier and hysteresis effects are significant and then removed*" is useful and should take place in times of severe downturns. These temporary fiscal measures would not impose future fiscal burden (Ibid. p.37-39).

Provisions aimed at incentivizing employment, especially of low-skilled people should include measures at increasing the gap between minimum income support and potential income. This is very small and disincentivizing for certain number of unemployed to take a legally registered employment. Decreasing the tax wedge on the lowest incomes and potentially employer's social security contribution could also be the way. Social security contributions are very high with respect to most European countries and do not decrease with the lower income. Hiring low income workers is therefore relatively more costly. Due to the big regional differences in the labor market, it would be thoughtful to increase labor mobility by improving infrastructure and supporting house rent (Machlica Žúdel and Hidas 2014, p.27-34).

Active labor market policies (ALMP) represent another form of the supply side work incentives. Money spent on realization of these policies (calculated on one unemployed person) is among the lowest in the EU (Hidas Vaľková and Harvan 2016, pp. 14-15). Also the structure of ALMP expenses is different in Slovakia than in the rest of the EU countries, where more than 40% of ALMP expenses goes to educational and training programs which are deemed more efficient. In Slovakia in 2015 only 6% of all expenses on ALMP went to educational and training programs (Hidas Vaľková and Harvan 2016, p. 26).

Some of the policies show good results (subsidizing work placements for people under 29 years old, graduate praxis for people under 29 years old, voluntary services, subsidizing work placements for low-qualified individuals, individuals over 50 years old or long-term unemployed at public sector employees and others). On the other hand, participation in activation works[22] even decreases the probability of being employed (Hidas Vaľková and Harvan 2016, pp. 24,25; Harvan 2011, p.16).

Machlica et al. (2017, pp.33-34) advise to improve the attractiveness of teacher's profession, which is after the Czech Republic the lowest paid in Europe[23] (ibid., p.10). Machlica et al. (2017) also advise to support vocational training and more labor market oriented tertiary education. Measures oriented at Roma inclusion are a major topic that are and must be also largely discussed.

Due to the above mentioned, I believe that provisions useful from the long-term Slovak perspective would be the ones directed at the sources of unemployment persistence. Skills-increasing precautions would be helpful in fighting skills depreciation and lowering the ratio of long-term unemployed since they consist for the most part of low-skilled individuals. Also measures incentivizing employment, focused both on labor supply and labor demand would help tackle the downsides of hysteresis effects.

This analysis has also some drawbacks. The PANIC approach is preliminarily designed to be applied to large panel datasets. This is due to the fact that principle component analysis by itself was preliminary created to reduce the amount of data without losing too much information. Analyzing 8 (or 7) regions can definitely provide some insight into this problematics. To improve this analysis further I suggest using data for smaller regional districts. Another possible improvement of this analysis would be to include also non-linear models of hysteresis or fractional integration models to capture its presence in different structures. Especially interesting to me sounds the Markov switching model that grasps the presence of multiple-equilibria model with non-linearities.

[22] Contribution for activation activity in the form of minor communal services performed for a municipality or minor services for a self-governing region (Štefánik 2019, p.50)

[23] As ratio of average lower secondary teachers' salaries to the wages of workers aged 25-64 with tertiary education, 2014 (Machlica et al. 2017, p.10)

List of figures and tables

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Appendix 1: Pesaran (2007)

Pesaran test - Assumptions

region	intercept		intercept and trend	
	pval.BG.test	pval.BP.test	pval.BG.test	pval.BP.test
BA	0.086*	0.003***	0.064*	0.003***
TA	0.096*	0***	0.108	0***
NI	0.085*	0.18	0.054*	0.228
TR	0.082*	0.004***	0.051*	0.008***
BB	0.515	0.004***	0.717	0.01**
ZI	0.078*	0.056*	0.053*	0.035**
PR	0.092*	0.208	0.149	0.186
KO	0.09*	0.239	0.051*	0.045**

** 10% level of significance*

*** 5%level of significance*

**** 1% level of significance*

Table 6. Checking the fulfillment of Pesaran test assumptions, data series: datasrR_ARIMA13 regional data from COLSAF, period from January 1997 to January 2019. Regional abbreviations: BA-Bratislava region, TA-Trnava region, NI- Nitra region, TR–Trenčín region, BB-Banská Bystrica region, PR-Prešov region, ZI-Žilina region, KO-Košice region. Own elaboration.

Critical values CADF_i	intercept	intercept and trend
c.v. 10%	-2,91	-3,39
c.v. 5%	-3,22	-3,69
c.v. 1%	-3,81	-4,28
Critical values CIPS		
c.v. 10%	-2,21	-2,73
c.v. 5%	-2,32	-2,83
c.v. 1%	-2,53	-3,03

Table 9. Critical values of Pesaran test. Source Pesaran (2007).

Pesaran intercept: Cross-sectional correlation

	baresidC	taresidC	niresidC	trresidC	bbresidC	ziresidC	prresidC	koresidC
baresidC	1							
taresidC	0.240769	1						
niresidC	-0.17089	-0.09046	1					
trresidC	0.017426	0.042673	0.173183	1				
bbresidC	-0.2355	-0.54104	-0.18028	-0.16884	1			
ziresidC	-0.12465	-0.10027	0.120187	0.071897	-0.19553	1		
prresidC	0.117695	0.150899	-0.44454	-0.4099	-0.20929	-0.34024	1	
koresidC	-0.3305	-0.36687	-0.26917	-0.40605	0.189762	-0.13104	-0.01074	1

Table 11. Cross-sectional correlation of residuals from Pesaran intercept model equations. Data series: datasrR_ARIMA13 regional data from COLSAF, period from January 1997 to January 2019. Regional abbreviations: BA-Bratislava region, TA-Trnava region, NI- Nitra region, TR–Trenčín region, BB-Banská Bystrica region, PR-Prešov region, ZI-Žilina region, KO-Košice region. Own elaboration.

Pesaran intercept + trend: Cross-sectional correlation

	baresidCT	taresidCT	niresidCT	trresidCT	bbresidCT	ziresidCT	prresidCT	koresidCT
baresidCT	1							
taresidCT	0.211058	1						
niresidCT	-0.2062	-0.13187	1					
trresidCT	-0.02389	0.01384	0.159002	1				
bbresidCT	-0.19752	-0.53028	-0.17063	-0.14508	1			
ziresidCT	-0.10795	-0.10195	0.137612	0.08963	-0.21566	1		
prresidCT	0.155172	0.150776	-0.43816	-0.4108	-0.19185	-0.31367	1	
koresidCT	-0.29608	-0.30521	-0.24576	-0.39188	0.149914	-0.1633	-0.02411	1

Table 12. Cross-sectional correlation of residuals from Pesaran intercept plus trend model equations. Data series: datasrR_ARIMA13 regional data from COLSAF, period from January 1997 to January 2019. Regional abbreviations: BA-Bratislava region, TA-Trnava region, NI-Nitra region, TR–Trenčín region, BB-Banská Bystrica region, PR-Prešov region, ZI-Žilina region, KO-Košice region. Own elaboration.

Appendix 2: PANIC (2004)

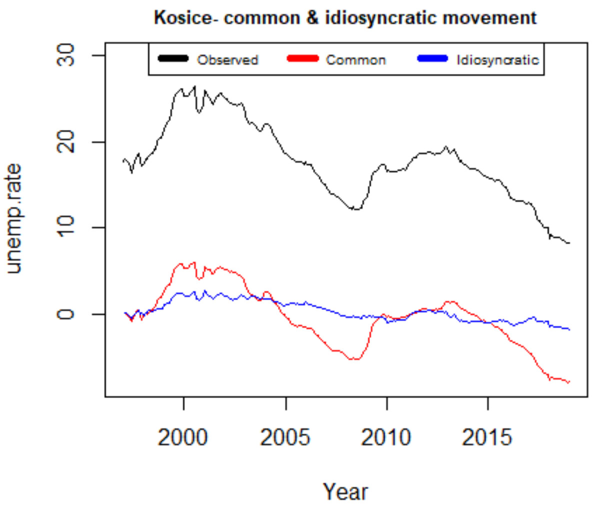

Figure 21. Košice region – dynamics of common and idiosyncratic component. Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019. Own elaboration.

Unemployment in Košice region is also imitating movement of common component. Unemployment rate in Košice that would be due to the region-specific factors almost does not react to the economic crisis at the end of 2000s.

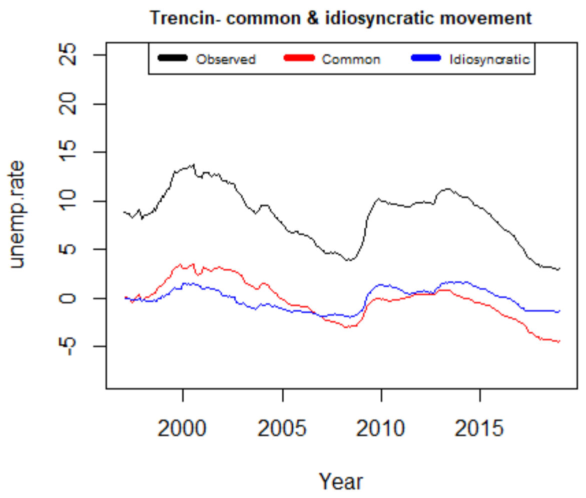

Figure 22. Trenčín region – dynamics of common and idiosyncratic component. Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019. Own elaboration.

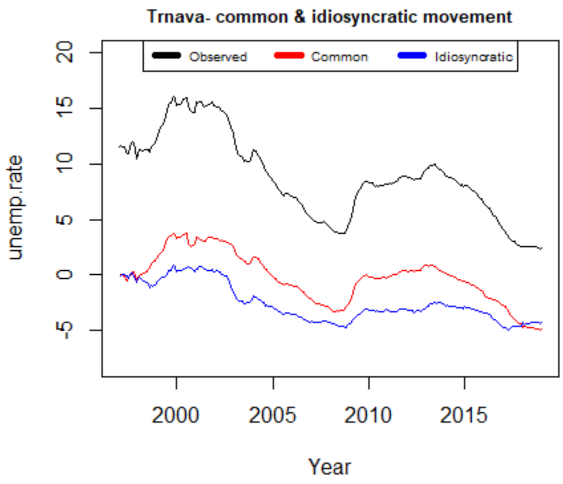

Figure 23. Trnava region – dynamics of common and idiosyncratic component. Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019. Own elaboration.

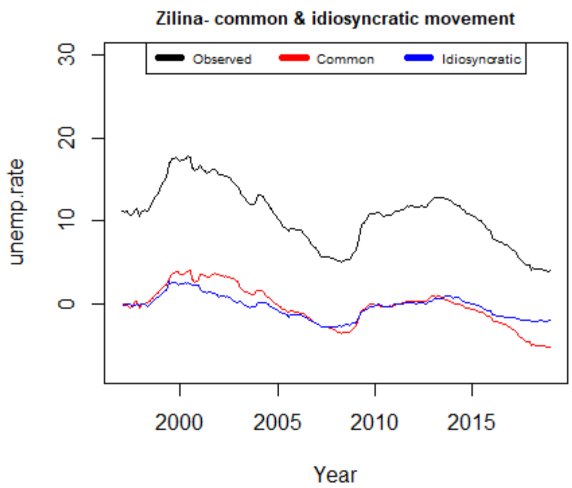

Figure 24. Žilina region – dynamics of common and idiosyncratic component. Data series: datasrR_ARIMA13 regional data from COLSAF, time period from January 1997 to January 2019. Own elaboration.

Appendix 3: CD

CD with following files:

Data series:

SR-ARIMA13 - seasonally adjusted data for Slovakia

datasrR_ARIMA13 - seasonally adjusted data for Slovak regions

cross correlation data - data for cross-correlation analysis

R codes:

LeeStrazicichApplicationFinal – Lee and Strazicich LM test application

LeeStrazicichUnitRootTest – Lee and Strazicich LM test code

Pesaran_regiony final2 – Pesaran (2007) test

PANIC final 2 – PANIC (2004) test

bez PR – PANIC (2004) test without Prešov