Charles University in Prague

Faculty of Social Sciences
Institute of Economic Studies

MASTER THESIS

The Relationship between Unemployment Components and Economic Growth: the Czech Republic Case

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Declaration of Authorship

The author hereby declares that he compiled this thesis independently, using only the listed resources and literature, and the thesis has not been used to obtain a different or the same degree.

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Prague, May 11, 2015

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Abstract

The choice of an appropriate government policy tool to promote the employment should be done with regard to the source of unemployment. This diploma thesis investigates structural and cyclical components of unemployment. The two components are induced by different causes. Search and matching frictions in the labor market are the source of the structural component. The cyclical component is induced by a low labor productivity which induces a negative gross marginal profit of firms. Consequently, they are obliged to cancel a portion of existing job-worker matches. The main finding is that during a period of economic slowdown the overall unemployment and its cyclical component rise while the structural component declines. The dynamics of the two components is reversed during a robust economic growth. The diploma thesis proceeds with investigating the public hiring, a policy potentially suitable to diminish the unemployment during an economic slowdown. The results show that the public hiring can be successfully applied despite the private employment crowding out. A New Keynesian DSGE model calibrated for the Czech Republic is used to model the labor market dynamics. The results are interpreted with regard to the historic development of the unemployment and the economic growth from 2000 to 2014.

JEL Classification	E24, J21, J38, J45, J63, J64
Keywords	unemployment, search and matching frictions, economic growth, DSGE

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Abstrakt

Výběr vládních nástrojů určených k podpoře zaměstnanosti by měl být podmíněn zacílením na zdroj zapříčiňující nezaměstnanost. Tato diplomová práce zkoumá strukturální a cyklickou složku nezaměstnanosti. Obě mají odlišné příčiny. Frikce na trhu práce jsou zdrojem strukturální složky. Cyklická složka je vyvolána nízkou produktivitou práce, která ústí v negativní hrubý mezní zisk firem. Firmy jsou tudíž nuceny přistupovat k rušení pracovních míst. Hlavním zjištěním je, že v období zpomalování růstu ekonomiky se celková nezaměstnanost a její cyklická složka zvyšují, zatímco strukturální složka klesá. V období robustního růstu se složky pohybují přesně naopak. Diplomová práce pokračuje zkoumáním zaměstnávání ve veřejném sektoru, politikou potenciálně vhodnou ve fázi zpomaleného ekonomického růstu. Výsledky ukazují, že tato politika může být úspěšná i navzdory vytěsňování zaměstnanosti v soukromém sektoru. Pro modelování procesů na trhu práce je využit nový keynesiánský DSGE model kalibrovaný pro Českou republiku. Výsledky jsou interpretovány v souvislosti s historickým vývojem hospodářského růstu a nezaměstnanosti od roku 2000 do 2014.

Klasifikace JEL	E24, J21, J38, J45, J63, J64
Klíčová slova	nezaměstnanost, frikce na trhu práce, ekonomický růst, DSGE

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Acronyms

CES Constant Elasticity of Substitution

DSGE Dynamic Stochastic General Equilibrium

FRED Federal Reserve Economic Data

Q Quarter

Master Thesis Proposal

Author	Bc. Vědunka Kopečná
Supervisor	PhDr. Jaromír Baxa, Ph.D.
Proposed topic	The Relationship between Unemployment Components and Economic Growth: the Czech Republic Case

Topic characteristics

A reasonably low unemployment is one of the priorities of all modern economies with the Czech Republic being no exception. However, it is a rather volatile variable and recent events such as the financial and economic crisis drove it higher across the European Union and also worldwide. The range of policy tools to choose from in order to diminish the number of jobless persons might be wide, but decision about the optimal choice entails the knowledge of labor market structure and sources of unemployment. Two of the possible sources are: lack of jobs and mismatch of jobs and workers. The influence on unemployment, each of these two factors have, varies in periods of robust growth and in economic slowdown. Therefore, the optimal government policy targeted towards improving the situation on the labor market should take the economic growth and an ongoing situation in the labor market into consideration.
The aim of this thesis is to examine the relationship of unemployment components behavior and the economic growth and investigate implications for unemployment policies.
In the first chapter, an overview of the literature on search and matching frictions in dynamic stochastic general equilibrium models and the development of Czech labor market modeling will be presented.
The second chapter will proceed with an estimation of matching function parameters with emphasis on matching efficiency. The mismatch between jobs and workers will be estimated using a rolling fixed effects model on panel data

for all 14 Czech regions during the last 15 years.
The third chapter will use a DSGE model with search and matching frictions in the labor market and to obtain impulse responses of labor market variables to a negative technology shock. Next, a non-linear rational expectations model will be adopted in order to decompose the unemployment rate into cyclical and structural components.
Finally, the last chapter will assess the effects of public employment, which can be used as an unemployment policy tool, on the unemployment during a period of economic slowdown.

Hypotheses

1. The importance of search and matching frictions differs with regard to changes in the economic growth.
2. The unemployment could be decomposed explicitly into cyclical and structural components.
3. The public hiring could be successfully used as an unemployment diminishing tool during an economic slowdown.

Methodology

In this thesis, two New Keynesian DSGE models will be used. Models will include a labor market block with search and matching frictions. Real wages will be taken as partially rigid. In this modeling framework, firms are the ones who determine the level of employment in the economy based on their gross marginal profit which is dependent on the labor productivity. The model will be calibrated for the Czech Republic and will yield a decomposed a time series of the unemployment rate over the past 15 years.
Second model will be an extension in the sense that a government block will be introduced in order to examine whether the public hiring is an effective tool to diminish unemployment during an economic slowdown and whether its positive effects neutralize the crowding out of private employment.

Outline

1. Introduction
2. Literature overview
3. Behavior of cyclical and structural unemployment with regard to the economic growth
4. Labor market model with search and matching frictions
5. Unemployment policy during an economic slowdown
6. Conclusion

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Author | Supervisor

Chapter 1

Introduction

The recent economic crisis drove the unemployment rate to unprecedentedly high levels in many countries and unemployment rates remain above the pre-crisis levels especially in those countries that pursued policies of fiscal consolidation. Even though in the Czech Republic, as one of the countries who follow the fiscal consolidation path, the unemployment rate had not been among the highest in the European Union, its return to a pre-crisis level has been relatively slow.

This thesis provides a complex view on the development of unemployment in the Czech Republic during the past 15 years through the lens of labor market dynamics models with incorporated search and matching frictions because they allow modeling of various sources of unemployment, especially a lack of jobs caused by fluctuations of the economic activity over the business cycle and structural causes driven by a level of mismatch between available jobs and workers.

In the first part of this thesis, an overview of the literature on labor market modeling with search and matching frictions and the unemployment in the Czech Republic is presented. One of the main topics the literature focuses on is the mismatch between jobs and workers. As has been found out, regional-, skill- and education-specific mismatch are typical in the domestic labor market. However, researches concentrating on the time-varying property of mismatch have been rather rare. An exception is the study by Galuščák & Münich (2005) who covered the development of matching efficiency between 1995 and 2004. A key concept for the estimation is the matching function which is closely related to its graphical counterpart - the Beveridge curve. Both these notions along with the accompanying theory are introduced here as well.

The second chapter proceeds with an estimation of matching function parameters and extends the knowledge of matching efficiency development provided by Galuščák & Münich (2005) to the period from 2000 up to the end of the year 2014. The mismatch development is estimated using a rolling fixed effects model on panel data. The data are collected for all 14 Czech regions and for the last 15 years. The results show that the mismatch in the labor market was not pronounced before the year 2004 when the Czech Republic was still in transformation process from central planning to a market economy. From 2005 onward, the matching efficiency became to be driven by economic frowth development. During a period of economic robust growth, defined as increasing output gap, the mismatch becomes more pronounced than during an economic slowdown period, defined as decreasing output gap.

In the third chapter, the labor market is examined as a complex structure and attention is paid to the behavior of related variables such as employment, output, unemployment, wages and labor market tightness. A dynamic stochastic general equilibrium model with search and matching frictions which follows Michaillat (2012) is used and parameters are calibrated for the Czech Republic. The originality of the model lies in the fact that the employment choice is left to firms because decision to open vacancies and hire workers is subject to the non-negativity of firms' gross marginal profit. Therefore, households do not solve the usual optimization problem.
Besides examining the labor market behavior, the model intends to determine effects of the two above introduced sources of unemployment. In order to do so, the model seeks to decompose the unemployment into its cyclical and structural components. Since this is a nonlinear problem, a nonlinear rational expectations model is employed.

The results of both impulse responses and unemployment decomposition problem are related to the results from the second chapter and show that during an economic slowdown the total unemployment and its cyclical component increase while structural component decreases. During a robust growth period, the result is exactly the opposite with increased cyclical and decreased structural component.

In the last part, I assess the effect of public employment, which is one of possible policy tools, on labor market variables during the economic slowdown. Thus, a DSGE model enriched by the government block is used. The fiscal consolidation policy carried out over the last decade by the Czech government comprises a target of reducing the number of public employees. This policy is pursued without regard to economic growth status. Therefore, I compare the effects of public firing versus potential effects of public hiring on labor market during the economic slowdown. The results show that even if the percentage of hired workers constituted only one fifth of the percentage of fired workers, the beneficial effect on overall unemployment would be clear despite the accompanying crowding out of the private employment.

Chapter 2

Literature overview

2.1 Search and matching frictions in DSGE modeling

Over the recent 20 years, the labor market dynamics has been modeled mainly using DSGE models. To grasp the labor market properties accurately the baseline DSGE model needed to be enriched in multiple ways. Namely, the enrichment lied in incorporating search and matching frictions, wage rigidities and staggered prices.

The search and matching frictions were first incorporated into a dynamic general equilibrium model by Merz (1995). The motivation was to better explain behavior of labor market variables, particularly the high volatility of unemployment and vacancies.

In the context of the New-Keynesian DSGE models with search and matching frictions, the nominal rigidites being price and wage stickiness are an important feature. The two most widely used pricing mechanisms are the Rotemberg and Calvo price-setting concepts where the latter was introduced by Chéron & Langot (2000), Walsh (2003) and Trigari (2006). The motivation for introducing real wage rigidities by Shimer (2005), Gertler & Trigari (2009) and Hall (2005) was to improve the impulse response of unemployment to a labor productivity shock. However, these first attempts were conducted separately. The joint incorporation of both nominal rigidities into one DSGE model was performed by the trio Gertler *et al.* (2008).

From that point onward the majority of working papers focused on DSGE model containing all three components, for instance Krause & Lubik (2007), Christoffel & Linzert (2005) or Faia (2008). Moreover, Krause & Lubik (2007) and later Kuo & Miyamoto (2014) took into account also an endogenous separation rate which is one of the parameters occurring in labor market frictions and stands for the proportion of the total number of terminations of employment to the total number of employees. The endogenous approach was first introduced by Trigari (2006).

Since the interest rates have recently reached the zero lower bound the importance of fiscal policy for stimulating the economy has risen. Therefore, a number of research papers have been focusing on fiscal policy effects particularly the effect on unemployment. Campolmi *et al.* (2011) examined various fiscal policies such as demand stimuli, cost of hiring subsidies or taxation policies. They found out that the most effective policy with regard to the unemployment mitigation are recruitment cost subsidies. The public employment and wages effects on the labor market were explored by Gomes (2010) with the result that high public wages induce an overall unemployment rise in the economy. Similar approach took Mayer *et al.* (2010) who used a New Keynesian DSGE model with the extension of distinguishing between rule-of-thumb and Ricardian type households. The authors found that a government expenditure shock decreased the unemployment of Ricardian households only.

The recent and most extended version of DSGE model for fiscal policy effects simulation includes two-country monetary union structure and takes into account also currency union as for example is the Euro area. Such a work was carried out by Stähler & Thomas (2011) who examined which type of fiscal consolidation policy is the least damaging for the economy with the result being public wages. On the other hand, diminishing public investment proved to deteriorate the economy the most.

2.2 Development of Czech labor market modeling

The labor market in the Czech Republic underwent a vast change when the economy transitioned from central planned to market. Jurajda (2003) summarized the three main aspects in which the labor market transformed. That being the reallocation of employees from state-owned organizations to private firms, the rise in number of university graduates and a stronger emphasis on gender equality. The transition was accompanied by a strong decrease of unemployment rate which fell to 2.8% between the years 1990 and 1994. Gitter & Scheuer (1998) described six factors causing this unemployment downturn including currency devaluation, less generous unemployment benefits or low minimum-wage rates.

An alternative explanation proposed by Treier (1999) was based on an assumption that the lower unemployment rate in the Czech Republic might had been the result of lower labor market participation and low productivity growth. The participation rate is not overly sensitive to wage changes as Bičáková *et al.* (2008) found out. On the other hand, a generous tax-benefit system the Czech Republic has, does have more pronounced effect. Galuščák & Kátay (2014) performed a comparison between the Czech and Hungarian relations of tax system and participation rate and their results supported this statement.

As the transformation into the market economy progressed and the previously favorable situation in the labor market deteriorated with the worst performance around the year 2003. Flek & Večerník (2005) attributed the accompanying high unemployment to long-term stagnation in total factor productivity, output growth dependency on real imports and low efficiency of investment in spite of a high investment rate. They also found out that the unemployed's reservation wage had been set above the subsistence minimum which causes that low-qualified jobs were taken by former Soviet union citizens. A high unemployment rate was not the sole labor market property which had worsened. Jánková (2006) and Flek (2004) detected an aggravated condition of NAIRU, lower labor mobility, skill mismatch, labor deprivation and wages rigidity as well. Němec & Vašíček (2008) and Pošta (2008) analyzed NAIRU in the period 1996-2007 and concluded that the Czech economy was close to its potential level.

The period after the year 2004 was marked by positive and accelerating output growth and overall improvement of the economy which spilled over to the labor market. The Czech unemployment rate dropped to its minimum of less than 5% and this favorable development continued up to the year 2008 when the global financial crisis took over and the unemployment rate increased considerably.Babecký *et al.* (2011) focused on identifying an explanation for that and they conclude that firms' labor demand was limited due to its increased elasticities with respect to wages and to sales. An alternative explanation was proposed by Tvrdoň & Verner (2013). They conclude that the Czech labor market was in a positive unemployment gap right before the crisis and that the subsequent rise in unemployment was only a return to long-term equilibrium.

The next strand of literature focuses on unemployment policies. Terrell & Šorm (1999) analyzed the impact of active labor market policies and the unemployment compensation system on unemployment duration during the transition period. It turned out that examined unemployment policies were particularly effective in case of socially disadvantaged people like handicapped or less educated. The social benefits are also the root of inactivity traps occurring mainly within the group of people on parental leave as found out by Galuščák & Pavel (2007). The latter author Pavel (2009) analyzed the impacts of the two tax-benefit reforms in 2007 and 2008 on the willingness to participate in the labor market with the result that labor supply did not become more flexible after implementing the reforms.

Besides the empirical approach, the structural models with labor market block started to appear in the literature in the late 2000's. Hloušek (2010) used a DSGE model of open economy with incorporated nominal rigidities - staggered wages and prices. The author concluded that nominal rigidities provided a significantly better fit of the model to the Czech data. Němec (2012) introduced search and matching frictions into a small open economy DSGE model. The attention was payed on wage bargaining, matching process, separation rate and wage rigidity and the author provided a Bayesian estimation of model parameters on 2000-2012 Czech data. The same author focused on structural characteristics of the Czech labor market and unions wage bargaining power. The model results stated that wages are determined primarily through unions' bargaining process and that the institutional changes on the labor market had only marginal impact on matching effectiveness. Another small open economy DSGE model called HUBERT was developed by Aliyev *et al.* (2014) from the Ministry of Finance. The baseline model in Štork *et al.* (2009) was enriched in 2014 by incorporating foreign trade, physical capital and capital services besides already existing fiscal block.

The last strand of literature to be review concerns matching process on the labor market. Burda & Profit (1996) found out that the unemployment rate differed significantly across Czech regions and argued that the cause was low labor mobility. Münich *et al.* (1999) compared the situation on the Czech and Slovak labor market using the matching function in the translog form rather than the usual Cobb-Douglas specification because the returns to scale were found to be strongly increasing in the Czech case during the 1992-1995 period. The authors explain the low unemployment rate by a steep rise in vacancies number, relatively low number of long-term unemployed and matching function's increasing returns to scale. The work by Münich & Švejnar (2009) presents an update to Münich *et al.* (1999) with similar findings but this time comparing the Czech Republic to other European countries besides Slovakia. The conclusion drawn from the analysis says that the Czech unemployment is driven by low labor demand and restructuring of labor market. Pedraza (2009) used the monthly data from 1992 to 2002 of all the 76 Czech districts and examined the matching properties of the market. The matching efficiency was higher for more educated workers and also for recently developed sectors with many new firms. The skill and regional mismatch in the Central Europe region was examined also by Kouba & Rozmahel (2013) who sought to quantify the amount of unemployment which could be avoided in case of perfect mobility of workers. They identified occupations which can benefit form workers' mobility the most. The potential of reduced unemployment was higher in occupations like bricklayers, social workers, drivers etc. Mysíková (2014) enriched the discussion on matching efficiency with an analysis on educational mismatch and its impacts on worker's wage level.

The level of mismatch regarding skills, education or region in the Czech Republic has been estimated numerous times, but Galuščák & Münich (2005) presented a very innovative usage of the matching function. The authors realized that the parameters can determine the condition of the labor market in the context of the business cycle and estimated their time-varying properties. They estimated the matching function using rolling regression to gain insight into the development of function parameters throughout the period 1995-2004. The matching efficiency is attributed to structural changes and unemployment and vacancies elasticities to cyclical changes in the labor market. Though this view is very informative and can provide us with indications on an appropriate unemployment policy to employ, to my knowledge this study has not been revised in order to include the development after 2005. Therefore, an attempt for updated evidence is presented in the chapter 3.

2.3 Some theory: Matching function, Beveridge curve and some useful labor market notions

This section introduces the matching function in detail and uses it to derive some labor market notions which will be used throughout the following chapters. Another purpose is to derive the expression for the Beveridge curve and show its graphical representation since the relation between unemployment and vacancies is essential for the understanding of labor market dynamics.

The concept of matching function introduced by Petrongolo & Pissarides (2011) can be considered as a key for the analysis of mismatch and thus structural changes on the labor market. The matching function relates the inflow to employment, also called new hires, H_t with the stocks of homogeneous vacancies V_{t-1} and pool unemployed persons U_{t-1} at the beginning of a time period t.

The inflow into employment H used in the matching function is measured by the number of previously unemployed and registered persons who found a job. However, they are only part of the employment inflow group. Other two subgroups are workers changing their job and persons previously not participating in the labor market (i.e. students, persons taking parental leave, handicapped) who got employed.

The matching function is often found in the Cobb-Douglas form which assumes constant returns to scale, is differentiable and increasing in both arguments.

$$H_t(U_{t-1}, V_{t-1}) = \omega U_{t-1}^{\eta_1} V_{t-1}^{\eta_2} \tag{2.1}$$

where ω denotes the efficiency of the matching process otherwise called also the level of mismatch on the labor market. The exponential coefficients η_1 and η_2 determine the sensitivity of new matches to the number of unemployed and the number of vacancies.

Multiple notions essential for the labor market modeling can be derived from the matching function. One of them is the probability of finding a job $f(\theta)$ which is related with the Cobb-Douglas matching function as

$$f(\theta_t) = \frac{1}{U_{t-1}} H_t \tag{2.2}$$

where θ_t is equal to $\dfrac{V_{t-1}}{U_{t-1}}$ and denotes the labor market tightness. A tight labor market means that it is difficult and costly for firms to fill a vacancy with a suitable worker. $f(\theta_t)$ also relates the labor market tightness θ_t and unemployment U_{t-1} as

$$f(\theta_t) = \frac{H_t}{U_{t-1}} = \omega \theta_t^{1-\eta} \tag{2.3}$$

where $H_t = \int_0^1 H_t(i)di$. One particular firm employs $N_t(i)$ employees where

$$N_t(i) = (1 - s)N_{t-1}(i) + H_t(i) \tag{2.4}$$

where s denotes the separation rate which is defined as the proportion of the total number of terminations of employment to the total number of workers employed. On the aggregate level the level of employment is $N_t = \int_0^1 N_t(i)di$.

Firms hire workers who produce labor product which is then sold to households. Each household member can be either employed or unemployed and looking for a job. The number of unemployed workers U_{t-1} searching for a job at time t is

$$U_{t-1} = 1 - (1-s)N_{t-1} \tag{2.5}$$

Next important concept is the probability of filling a vacancy

$$q(\theta_t) = \frac{1}{V_{t-1}} H_t = \omega \theta_t^{-\eta} \tag{2.6}$$

Based on Diamond (2013), job-finding probability, separation rate, employment and unemployment can be linked by the relation

$$f(\theta_t)U_{t-1} = sN_t \tag{2.7}$$

This relation indicates the assumption of equality between flows into and out of employment. From the equation 2.4 we express N_t as $N_t = (1-s)N_{t-1} + H_t$ and from the equation 2.3 H_t as $H_t = f(\theta_t)U_{t-1}$ and plug both these expressions into equation 2.7 to obtain

$$f(\theta_t)U_{t-1} = s[(1-s)N_{t-1} + f(\theta_t)U_{t-1}]$$

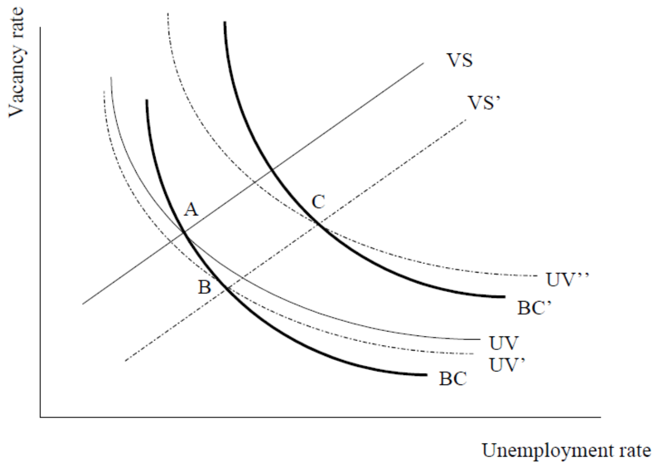
From the equation 2.5 we express $N_{t-1} = \dfrac{1-U_{t-1}}{1-s}$ and plug into previous equality to obtain

$$f(\theta_t)U_{t-1} = \frac{s(1-U_{t-1})}{1-s}$$

After rearranging, we get an expression relating unemployment with vacancies as

$$U_t = \frac{s}{s + (1-s)f(\theta_t)} \tag{2.8}$$

The equation 2.8 was first introduced by Dow & Dicks-Mireaux (1958) and was named the Beveridge curve after sir William Beveridge, British economist known for his works on unemployment. Its graphical representation contains three curves as is visible in the figure 2.1. The first one is supply of vacancies (VS) curve. The second one relates unemployment rate to vacancy rate (UV) in steady state. Each point of intersection of these two curves is a point through which the Beveridge curve passes. The VS curve reflects the willingness of firms to hire new employees and it depends on the firm's marginal profit and marginal cost of hiring. The main idea is that when there are more unemployed persons and the labor market is not overly tight, wages decreases and so decreases also the marginal hiring costs. This supports creation of new vacancies and leads to the fact that the VS curve has a positive slope.



Source: Galuščák & Münich (2005)

Figure 2.1: Beveridge curve

The equations 2.3, 2.5, 2.6 and 2.8 derived from the matching function are key for the labor market modeling and they are essential for building a DSGE model with search and matching frictions.

Chapter 3

Matching efficiency in the Czech labor market

3.1 Matching function estimation

In this chapter, I will estimate the matching function parameters. An assumption about their time-varying property allows me to examine the structural changes in the labor market over the past 15 years with regard to the economic growth development. The structural changes can be tracked down by looking at the behavior of the matching efficiency parameter ω which is computed using the parameters η_1, η_2 and κ.

First, I plot the figure 3.1 which shows the Beveridge curve in the Czech case. Compared to the theoretical curve shown in the figure 2.1 the differences are clear. The pattern is irregular and a combination of multiple curves appears. The Beveridge curve shifted several times over the examined period. As we can see, the curve lied on the bottom from 1997 to 2000, then shifted outward and lied on the top from 2004 to 2008. This shift indicates an increased mismatch between jobs and workers because both unemployment and vacancy rates increased. Then between 2008 and 2010, the curve shifted inward and therefore we can presume that the mismatch decreased. I will verify and extend these initial assumptions about the labor market behavior empirically through the matching function parameters estimation.

The matching function in the form presented in chapter 2 is now enriched by adding a flow variable S denoting the number of persons flowing into unemployment in a certain time period. The reason being that the assumed homogeneity of unemployed is not completely accurate because the newly unemployed people are more likely to be hired in a nearby future than the long term unemployed due to the fact that their working habits had not been damaged yet.

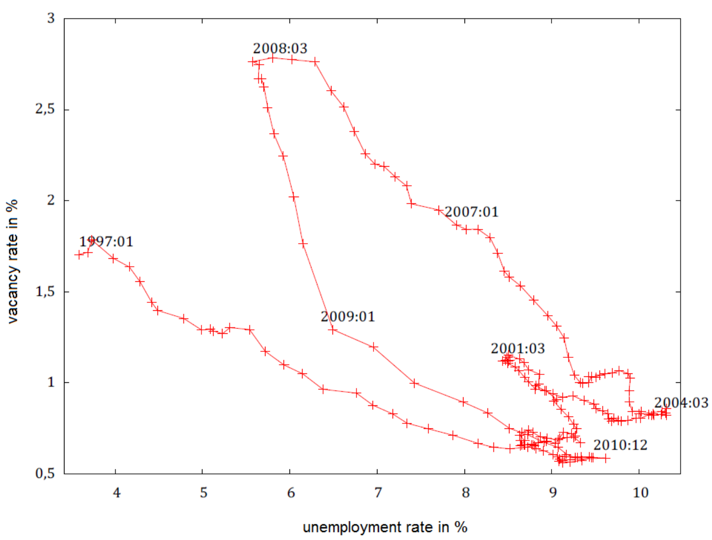
The estimable version of the matching function 2.1 for panel data with i units and t time periods after being transformed into a logarithmic form becomes

$$\log H_{i,t} = \eta_1 \log U_{i,t-1} + \eta_2 \log V_{i,t-1} + \kappa \log S_{i,t} + c_i + \epsilon_{i,t} \tag{3.1}$$

where the parameter c_i captures the heterogeneity across units. The unemployment and vacancy stocks are backward looking variables and their values at the end of period $t-1$ are taken. Since the heterogeneity term c_i captures unobserved effects, which are believed to be correlated with regressors, I will estimate the **fixed effects model**.

Instrumental variables are introduced into the model for two following reasons. First, it is supposed that unobserved variables determining the heterogeneity exist in the data and second, there is an endogenous relation among unemployment stock, unemployment inflow and outflow $U_{i,t-1} = U_{i,t-2} + S_{i,t-1} - H_{i,t-1}$. Lagged inflow into unemployment and also lags of other two regressors U and V are used as instruments as proposed by Woolridge (2001).

In order to track the time variation of the matching function parameters



Source: Hanzelková (2013)

Figure 3.1: Czech Beveridge curve during period 2000-2014

over the examined years 2000-2014 I estimate the fixed effects model using rolling window. The estimated parameters are saved in a vector every time the loop is repeated with a new time period window. This approach permits me to compute the matching parameter ω as

$$\overline{\alpha_i^j} = \overline{\log H_{i,t}^j} - \eta_1^j \overline{\log U_{i,t-1}^j} - \eta_2 \overline{\log V_{i,t-1}^j} - \kappa \overline{\log S_{i,t}^j} \tag{3.2}$$

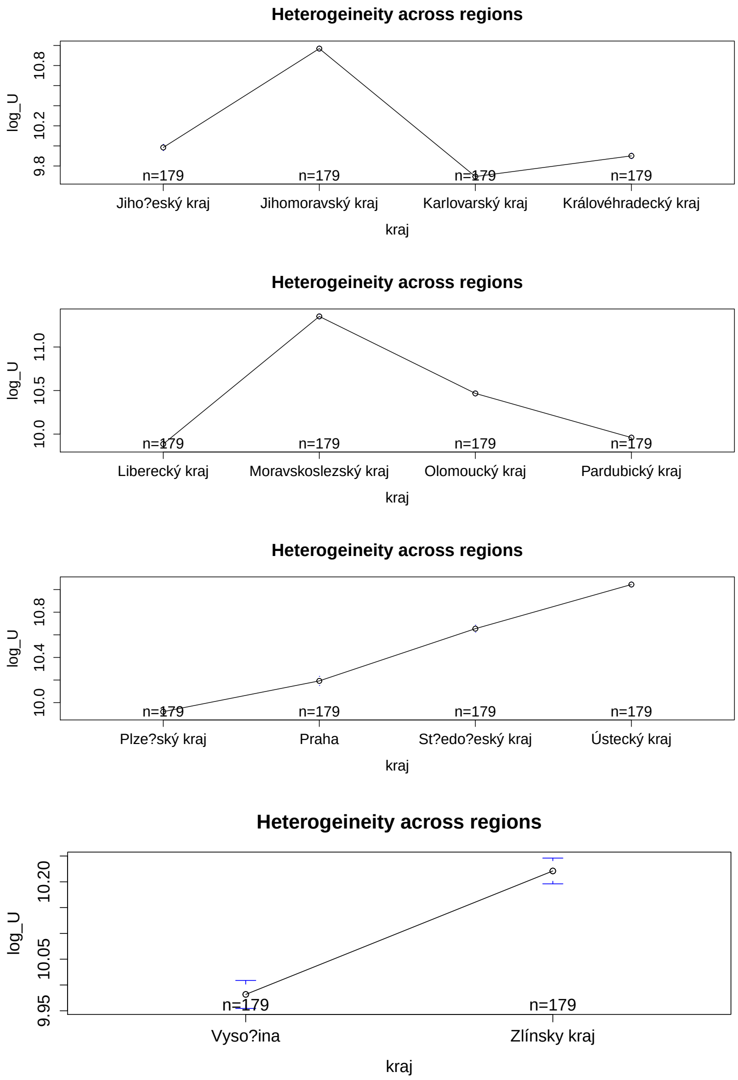
where $\overline{\alpha_i^j}$ is the mean of the calculated matching parameter over the rolling time period. Since the panel is composed of different units each having a different weight in the dataset I assign a weight parameter w_i to each of these units based on the unit's size, i.e. size of region's labor force, thus $\sum_i w_i = 1$.

$$\omega^j = \sum_i w_i \overline{\alpha_i^j} \tag{3.3}$$

3.2 Data

The dataset used for the estimation is of panel type and composed of stocks of unemployed persons U and vacancies V, inflow of unemployed persons S and outflow of persons to employment H. The data are monthly records from January 2000 to December 2014 for all the 14 regions of the Czech Republic (Prague, Central Bohemia, South Bohemia, Plzeň, Karlovy Vary, Ústí nad Labem, Liberec, Hradec Králové, Pardubice, Olomouc, South Moravia, Zlín, Vysočina and Moravian-Silesian region). The figure 3.2 shows the heterogeneity of mean unemployment across regions. Data was collected by the Ministry of Labor and Social Affairs. The rolling window for estimation loops stretches across 13 months. For example from January 2000 to January 2001 then from February 2000 to February 2001 and so on up to the period from December 2013 to December 2014.

First, the fixed effects model is estimated using lags 1-12 of the three regressors as instruments in order to inspect whether residual serial correlation is present and whether it is needed to drop at least first few lags. The standard approach how to measure the serial correlation in panel data is to use the Breusch-Godfrey test. I incorporate the test into the loop and save p-values into a vector. Orders 1 to 4 of serial correlation are tested separately. The null hypothesis states that the serial correlation of a certain order is not present. Below is reported the percentage of null hypothesis rejection on 1% confidence



Source: author's computations.

Figure 3.2: Heterogeneity of mean unemployment across regions

level for order 1 to 4 which in fact means how many times the serial correlation of residuals was statistically significant.

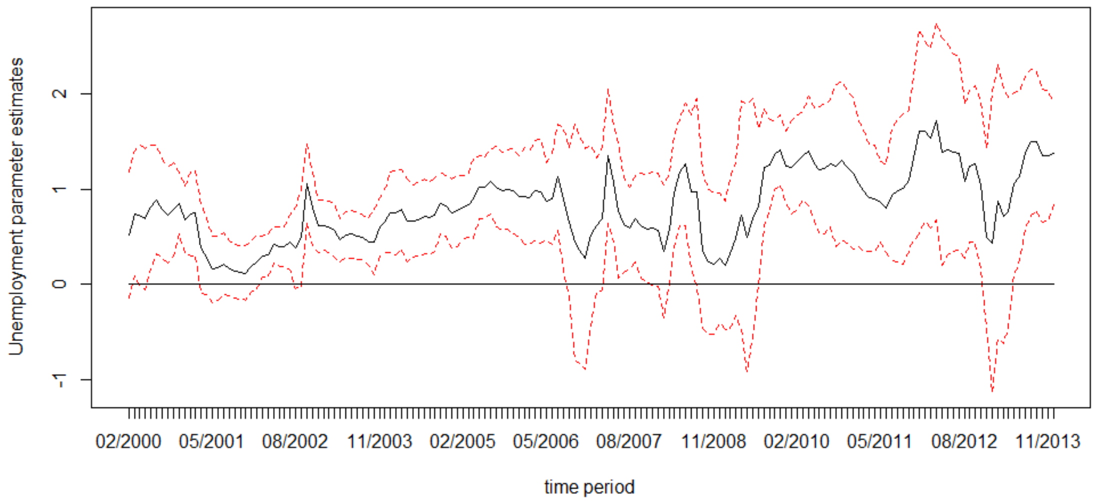
order	% of H0 rejected
1	73.05
2	59.88
3	34.73
4	16.77

Table 3.1: Order of residual serial correlation

In conclusion, it is convenient to drop at least first three lags of regressors. Therefore I will use lags 4 - 12 as instruments.

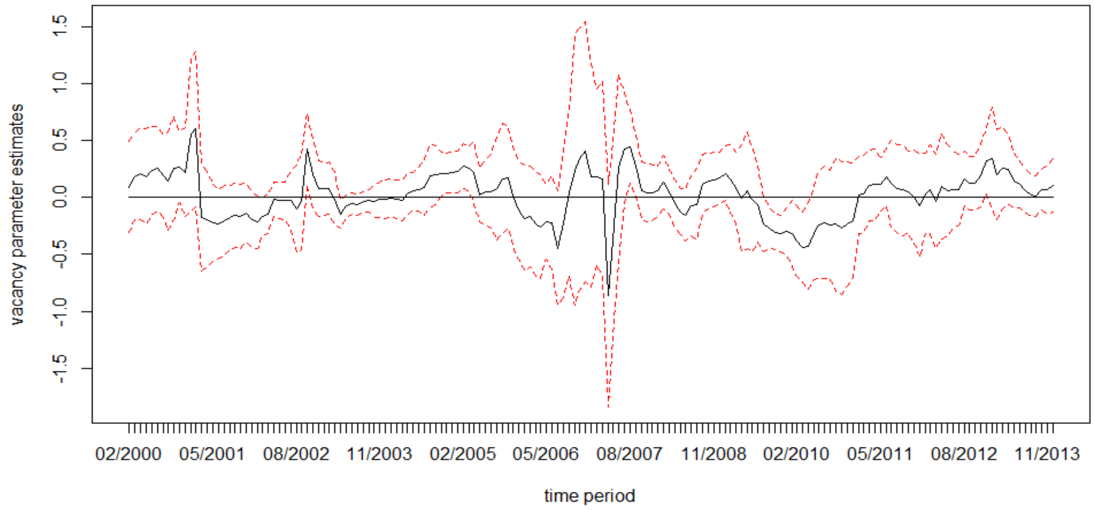
3.3 Results

The results of the rolling window fixed effects estimation are presented below. The figures 3.3 to 3.5 show the estimated parameters and also their 95% confidence intervals marked by the dashed lines. The figure 3.6 shows the computed matching efficiency with marked areas which correspond to the economic growth development over the past years.



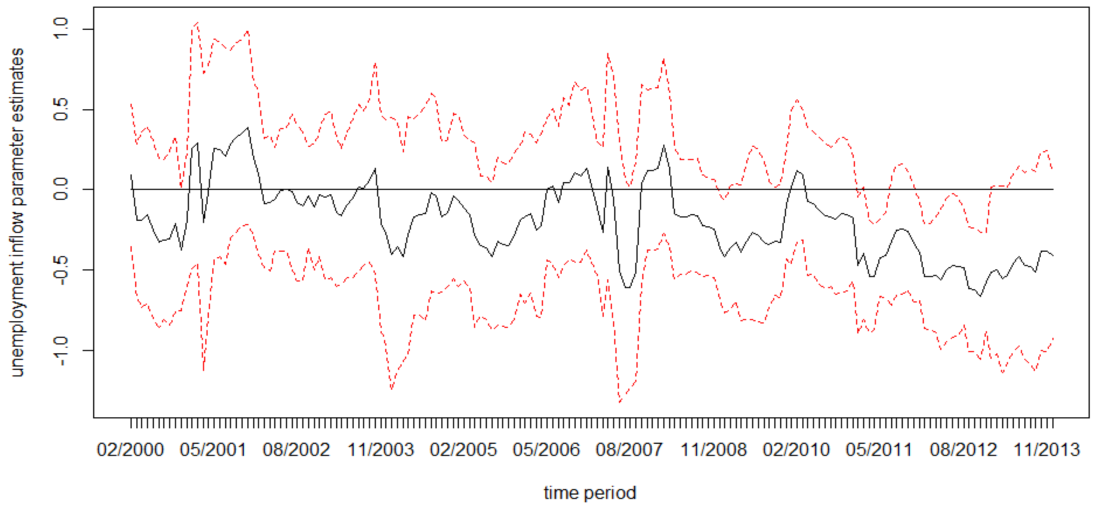
Source: author's computations.

Figure 3.3: Estimates of unemployment parameter



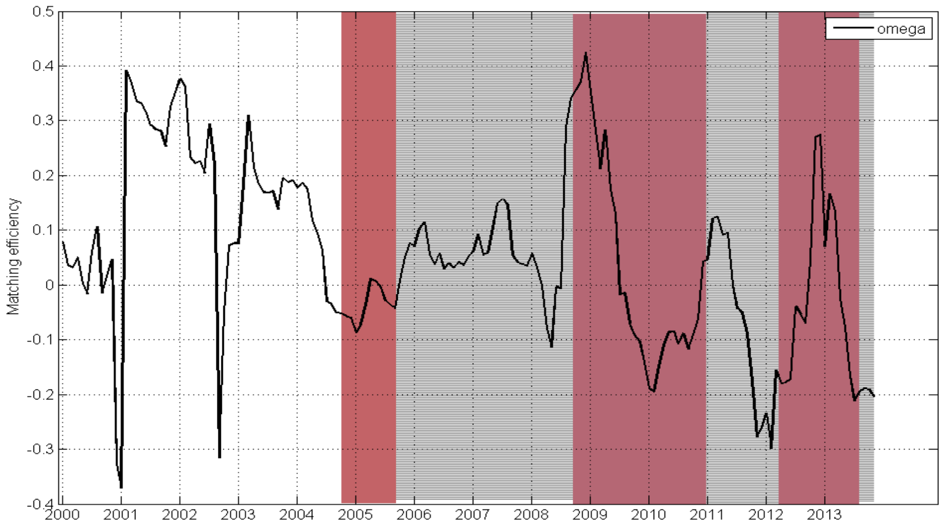
Source: author's computations.

Figure 3.4: Estimates of vacancy parameter



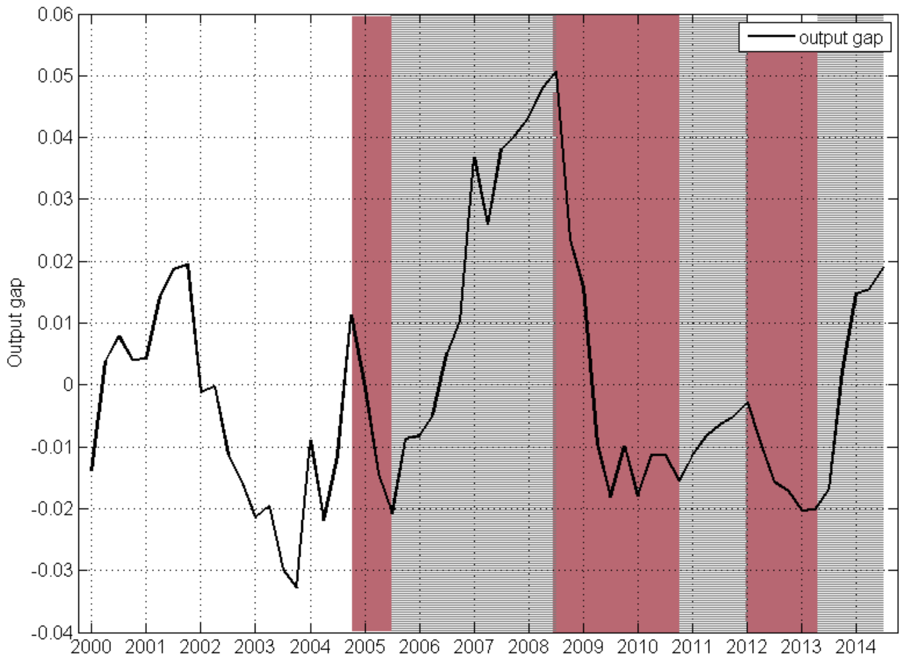
Source: author's computations.

Figure 3.5: Estimates of unemployment inflow parameter



Source: author's computations.

Figure 3.6: Computed matching efficiency parameter



Source: author's computations.

Figure 3.7: Economic growth development

Regarding the parameters' interpretation it is necessary to mention that before 2004 the structure of the labor market was different due to a still ongoing transformation process which started in 1990's, continued up to the year 2004 and consisted in restructuring previously state-owned firms into private businesses. Many state firms were privatized and sector of services, which basically did not existed before, was created. On the other hand, agricultural and industrial sector was considerably diminished. Münich & Švejnar (2006) in their work *"Unemployment and worker-firm matching in post-communist economies: Transition, policies or structural reforms?"* focused on estimating the reason why the unemployment in the beginning of the 21st century increased to more than 8%. They set and verify three hypotheses:

H1: The unemployment was the result of a still ongoing transformation process from a central planned to market economy where the inflow into unemployment was high due to destruction of job types connected with central planning.

H2: The level of labor demand was insufficient due to restrictive macroeconomic policies and the cause of high unemployment resided in low number of open vacancies.

H3: The mismatch on the labor market was high and might have been due to skill, education or regional mismatch. The matching process was inefficient. The manifestation was high number of unemployed and high number of open vacancies at the same time.

Authors came to a conclusion that the hypothesis H3 is rejected in favor of hypotheses H1 and H2. During the examined period the matching function's returns to scale in the Czech case were among the highest in the Central European region. This is in accordance with my results. The figure 3.6 shows the variations of the computed matching efficiency parameter $\hat{\omega}$ and the difference between the two periods 2000-2004 and 2005-2014 is clearly visible. During the first period its level is steadily high and equal to 0.1521 on average.

After 2004, the matching efficiency behavior underwent a significant change and it is worth examining the results with regard to the overall condition of the economy. Thus, the figure 3.7 shows the behavior of the output gap where the solid colored areas denote periods of economic slowdown and striped areas periods of robust growth. The output gap itself is computed from the Czech series of quarterly seasonally adjusted GDP in levels. The series is filtered with the Hodrick-Prescott filter with smoothing parameter $\lambda = 1600$ to obtain the cyclical component.

Between 2005 and 2008 $\hat{\omega}$ was relatively stable and rather low due to the growth of the Czech economy. Therefore, mismatch and thus also structural changes on the labor market became more pronounced.

Between 2008 and 2010 the previously low matching efficiency increased considerably and reached its global maximum 0.42 in the beginning of 2009. This period was marked by the slowdown of the Czech economy and even a recession connected to the global financial crisis. Therefore, unemployment due to structural changes was not important during this period.

In 2011, the Czech economy started to overcome negative impacts of the crisis and the output gap began to slightly increase and reached its local peak in the beginning of the year 2012. The matching efficiency reached similar values as in the pre-crisis period and continued to worsen and fell to its minimum of -0.3 as shown in the figure 3.6 which means that structural changes on the labor market became more pronounced and caused a higher number of unemployed.

However, the favorable development of the Czech economy did not last very long and from the second quarter of 2012 up to 2013 the efficiency of matching workers to jobs increased and reached another local maximum of nearly 0.3 at the beginning of 2013. Thus, cyclical unemployment increased while structural fell.

As far as other parameters are concerned, the unemployment parameter estimates fluctuate between 0.12 and 1.72 with a mean of 0.8215. $\hat{\eta_1}$ reaches its maximum at the beginning of the year 2012 when the Czech economy started to slow down. After 2008, which is considered to be the starting year of the global financial crisis, the unemployment parameter estimate rose to a higher level than it was before and the mean value increased from 0.66 (2000-2007) to 1.04 (2008-2014). Also, a cyclical pattern appears after 2008 which is in accordance with the economic growth interpretation.

The vacancy coefficient estimates $\hat{\eta_2}$ are rather stable over the examined years and also much lower than $\hat{\eta_1}$ oscillating around zero with a minimum of -0.86 and a maximum of 0.60. The mean value is 0.02. The minimum of -0.86 is correlated with the start of the global financial crisis. Vacancy rate is considered to be a procyclical variable and is expected to positively influence the employment inflow rate. However, since the estimates are in multiple cases below zero it is not the case.

The unemployment inflow coefficient estimates $\hat{\kappa}$ are almost always negative with a mean of -0.19 and a maximum of 0.39 and minimum of -0.66. Thus the effect of unemployment inflow is statistically insignificant.

Lastly, it is necessary to keep in mind that the data might be slightly biased due to a fact that probably not all the vacancies are registered at the Czech labor office and similarly not all the unemployed persons are registered. Also the model suppose that vacancies are taken only by previously unemployed persons and not be the ones that have been employed and searching for a new job at the same time.

3.4 Summary of results

This chapter aimed at examining the labor market condition, particularly the structural changes, over the past 15 years by estimating the matching function parameters. This study attempted to revise and update the estimation by Galuščák & Münich (2005). However, several alterations have been made. First, the work by the mentioned authors used a first difference pooled ordinary least squares model. However, after testing for fixed effects using the F-test, I found out that the fixed effects model should be preferred. Second, the authors use also monthly inflow of vacancies as a regressor and conclude that the coefficient is almost always insignificant. Due to unavailability of data in some years I decided to drop this variable from the estimation.

My results confirm that before 2004 the Czech economy was still in process of transitioning and mismatch between jobs and workers in the labor market was not significant. After 2004, the level of mismatch became to fluctuate accordingly to the economic growth condition. In periods of robust economic growth the matching efficiency was low and therefore structural changes on the labor market were prevalent. Analogously in periods of economic slowdown the mismatch between jobs and workers was not overly problematic.

The mean value of $\hat{\omega} = 0.05227$ will be used as a calibration for the parameter ω in the following chapters.

Chapter 4

Behavior of cyclical and structural unemployment components

In this chapter I will contribute to the knowledge about the relative share of structural and cyclical unemployment in the Czech labor market using both a DSGE model with search and matching frictions and a non-linear rational expectations model. To my current knowledge no studies focusing on the explicit decomposition of the Czech unemployment series have been carried out yet, although it is important to determine the composition of unemployment in order to draw appropriate conclusions about policy tools that shall be related to the state of the labor market. The results rely on a DSGE model with search and matching frictions and wage rigidity developed by Michaillat (2012), however, the main conclusion about the unemployment composition are drawn from the nonlinear rational expectation model.

The DSGE model consists of households, firms and a labor market block and incorporates wage rigidity and search and matching frictions introduced in section 2.3. The specialty of the model lies in the fact that households do not solve the usual optimization problem in which they choose their labor supply. Instead, the model attributes the decision whether household member will be hired and working or will be unemployed to firms. By this the model presents a more realistic assumption. The firms' hiring decisions are based on their gross marginal profit, which is the function of the overall employment in the economy and of the labor productivity. Firms seek to maintain at least zero gross marginal profit. Since this function is increasing in labor productivity and decreasing in employment, a decline in the labor productivity, large enough to cause the gross marginal profit to be negative, will inevitably induce a decline in employment in order to maintain the profit non-negative. The resulting unemployment is referred to as cyclical. In case the labor productivity is sufficient to not induce the decline in employment, all the unemployment in the labor market is due to search and matching frictions and referred to as structural. Obviously, the unemployment decomposition is a nonlinear problem, hence the choice of the nonlinear rational expectation model.

First, the chapter will introduce the DSGE model constituents and derive their optimal conditions. The concept of the gross marginal profit, labor productivity and employment will be presented in detail. The DSGE model will be log-linearized, calibrated for the Czech Republic and solved in order to obtain the impulse responses of variables to a negative technology shock representing an occurrence of the economic slowdown. The last part will consist in presenting and solving numerically the nonlinear rational expectations model with the aim of decomposing the Czech unemployment time series. Finally, the results will be interpreted with regard to the economic growth development in the Czech Republic over the past 15 years.

4.1 The DSGE model

4.1.1 The model specification

4.1.1.1 Households

The representative household is composed of a continuum of individuals of mass one. The household seeks to maximize its discounted sum of utilities from consuming

$$E_0 \left[\sum_{t=0}^{+\infty} \beta^t C_t \right] \tag{4.1}$$

where the parameter $\beta \in (0, 1)$ is a personal discount factor and E_t stands for the expectations operator conditional on time t information. C_t represents the utility of consumption and it is given by the CES function.

$$C_t = \left(\int_0^1 C_t(i)^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon-1}{\epsilon}}$$

where $\epsilon \in (1, +\infty)$ and $C_t(i)$ represents quantity of good $i \in [0, 1]$ consumed in time t. The usual notation of the utility function $U(C_t)$ is left behind in order to not reserve the term and be able to use it later for the unemployment. The aggregate price index is similarly to C_t given by the CES function

$$P_t = \left(\int_0^1 P_t(i)^{\epsilon-1} di\right)^{\frac{1}{\epsilon-1}}$$

where $P_t(i)$ represents the price of i-th good in the basket.

The household's budget constraint is given by

$$\int_0^1 P_t(i)C_t(i)di = P_t W_t N_t + P_t \pi_t \tag{4.2}$$

where W_t denotes the real wage, P_t the price level, N_t the employment level, π_t stands for real firms' profits and $P_t W_t N_t$ is the total wage income and $P_t \pi_t$ is the aggregate nominal profit. It is assumed that the saving decision is irrelevant and the household does not optimize intertemporally.

The household's intra-basket optimization problem is to optimize expenditures 4.2 subject to 4.1. The household chooses a stochastic process $\{C_t(i), C_t\}_{t=0}^{+\infty}$ and takes as given $\{P_t(i), P_t, W_t, \pi_t, N_t\}_{t=0}^{+\infty}$. The minimization problem yields a solution of the optimal demand function for the good i

$$C_t(i) = C_t \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} \tag{4.3}$$

4.1.1.2 Labor market

The search and matching frictions introduced in the section 2.3 are incorporated into the model. According to Borowczyk-Martins *et al.* (2011) constant returns to scale of the matching function can be assumed. Thus $\eta_2 + \eta_1 = 1$ and I set $\eta_1 = \eta$. The matching function then becomes $H_t = \omega U_{t-1}^{\eta} V_{t-1}^{1-\eta}$.

Other relations used in the model are:

- the relation between stocks of employed and unemployed: $U_{t-1} = 1 - (1-s)N_{t-1}$
- number of hired workers: $N_t(i) = (1-s)N_{t-1}(i) + H_t(i)$
- Cobb-Douglas matching function $H_t = \omega U_{t-1}^{\eta} V_{t-1}^{1-\eta}$
- the job-finding probability: $f(\theta_t) = \omega \theta_t^{1-\eta}$
- the probability of filling a vacancy: $q(\theta_t) = \omega \theta_t^{-\eta}$

where θ_t denotes the labor market tightness defined as the ratio of the number of unemployed to the number of vacancies.

The last term to be defined in this section is the recruitment cost. Since the process of hiring workers is costly for firms they open only limited number of vacancies during a time period t. The tighter the labor market becomes the higher the hiring cost for a firm is. The recruitment cost is thus defined as

$$R(\theta_t, c) = \frac{c}{q(\theta_t)} \tag{4.4}$$

where $c \in (0, +\infty)$ is a per-period vacancy cost which is a product of the steady state wage w_0 and the recruitment cost factor r where $c = rw_0$.

4.1.1.3 Wages

The individual wage is composed of three diverse parts

$$W_t(i) = E_t[W(N_t(i), \theta_t, \theta_{t+1}, a_t] \equiv S(N_t(i), a_t) + X(\theta_t, c) + E_t[Z(\theta_{t+1}, c)] \tag{4.5}$$

where $W_t(i)$ is an average wage paid by the firm i to its employees in the time period t.

The first part of the right-hand side of the equation $S(N_t(i), a_t)$ determines the influence of the labor productivity a_t and the employment $N_t(i)$ on the marginal firm productivity and thus also on wages paid to workers.

The second part $X(\theta_t, c)$ stands for the impact of current labor market conditions and the last one $E_t[Z(\theta_{t+1}, c)]$ for expected labor market conditions in the next time period.

The following two assumptions are needed in order to determine the wage schedule form:

Assumption 1: For all $\theta \in \mathbb{R}^+$, $X(\theta, 0) = 0$ and $Z(\theta, 0) = 0$. For all $c \in \mathbb{R}$,$X(0, c) = 0$ and $Z(0, c) = 0$

Assumption 2: For all $(\theta, c) \in \mathbb{R}^+ \times \mathbb{R}^+$, $\frac{\partial(X+Z)}{\partial\theta} \geq 0$

Assumption 1 states that in case of zero recruiting costs or zero labor market tightness, the labor market conditions do not have any impact on wages. Assumption 2 sets a relation between wages and labor market tightness when the former increases as increases the latter. The consequence of a tight labor market is a difficult hiring process for firms and easier job-finding process for unemployed which results in an increase in wages.

Wages are assumed to be partially rigid meaning that the labor productivity influences wages is in the following form

$$S(N_t(i), a_t) = w_0 a_t^{\gamma}$$

where w_0 is the steady state wage and γ denotes the elasticity of wages with respect to the labor productivity. Current and expected labor market conditions are assumed to have no impact on wages, thus

$$X(\theta_t, c) = 0$$

$$Z(\theta_{t+1}, c) = 0$$

Under these condition the aggregate wage is equal to

$$W_t = w_0 a_t^{\gamma} \tag{4.6}$$

4.1.1.4 Firms

The firms' problem is to maximize the discounted sum of expected profits

$$E_0 \left[\sum_{t=0}^{+\infty} \beta^t \pi_t(i) \right] \tag{4.7}$$

with

$$\pi_t(i) = Y_t(i) \frac{P_t(i)}{P_t} - W_t(i) N_t(i) - R(\theta_t, c) H_t(i)$$

where $\pi_t(i)$ denotes the real profit of firm i in period t. $Y_t(i)$ is the household's demand for goods sold by the firm i, $\frac{P_t(i)}{P_t}$ is the relative price set by the firm i and $W_t(i)$ is the real average wage paid to its employees. The equation 4.7 is maximized subject to the production constraint given by

$$Y_t(i) \leq F(N_t(i), a_t) \tag{4.8}$$

and constraint of number of employed workers in time t given by

$$N_t(i) \leq (1 - s) N_{t-1}(i) + H_t(i) \tag{4.9}$$

The production function has the following form

$$F(N_t, a_t) = a_t N_t^{\alpha} \tag{4.10}$$

We form the Lagrangian after plugging equations 4.5, 4.8 and 4.9 into 4.7 and taking as given the aggregate price index, labor market tightness, wage rule and labor productivity.

$$
\begin{aligned}
\mathcal{L} = E_0 \sum_{t=0}^{+\infty} \beta^t \Bigg\{ Y_t(i) \left(\frac{P_t(i)}{P_t}\right)^{1-\epsilon} & \\
& - [S(N_t(i), a_t) + X(\theta_t, c) + Z(\theta_{t+1}, c)] N_t(i) \\
& - R(\theta_t, c)[N_t(i) - (1-s) N_{t-1}(i)] \\
& + \nu_t \left[F(N_t(i), a_t) - Y_t \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} \right] \Bigg\}
\end{aligned}
\tag{4.11}
$$

where the Lagrange multiplier ν_t determines the marginal profit from producing one additional item.

First order conditions:

$$\frac{\partial \mathcal{L}}{\partial P_t(i)} = 0 \Rightarrow$$

$$(1-\epsilon) Y_t \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} + \nu_t \epsilon Y_t \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon-1} = 0$$

Using the equality $Y_t(i) = C_t(i)$ I plug 4.3 in the equation above, thus $Y_t(i) = Y_t \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon}$ and I get

$$(1-\epsilon) Y_t(i) = \epsilon \nu_t Y_t(i) \left(\frac{P_t}{P_t(i)}\right)$$

and finally

$$\frac{P_t(i)}{P_t} = \nu_t \frac{\epsilon}{\epsilon - 1} \tag{4.12}$$

$$\frac{\partial \mathcal{L}}{\partial N_t(i)} = 0 \Rightarrow$$

$$
\begin{aligned}
\nu_t \frac{\partial F(N_t(i), a_t)}{\partial N_t} =& W_t + R(\theta_t, c) + N_t(i) \frac{\partial S(N_t(i), a_t)}{\partial N_t} \\
& - \beta(1-s) E_t[R(\theta_{t+1}, c)]
\end{aligned}
\tag{4.13}
$$

The idea behind the equation 4.13 is that the hiring process by firm i continues until the marginal hiring cost and the marginal hiring profit are equal.

The left-hand side of the equation 4.13 is the product of marginal profit from producing one additional good and marginal labor product respectively. The right-hand side consists of the sum of wages, recruiting cost, wage bill change induced by marginal increase in employment minus the discounted recruitment cost.

Combining equation 4.12 and 4.13 yields the firm's optimal condition

$$\begin{aligned} \frac{\epsilon-1}{\epsilon}\frac{\partial F(N_t(i),a_t)}{\partial N_t} =& N_t\frac{\partial S(N_t(i),a_t)}{\partial N_t} + W_t + R(\theta_t,c) \\ & - (1-s)\beta E_t[R(\theta_{t+1},c)] \end{aligned} \tag{4.14}$$

Since the production function has the form of the equation 4.10 and the recruitment cost of 4.4, the final form of the firm's optimal condition is

$$\frac{\epsilon-1}{\epsilon}\alpha a_t N_t^{\alpha-1} - W_t - \frac{c}{q(\theta_t)} + (1-s)\beta E_t\left[\frac{c}{q(\theta_{t+1})}\right] = 0 \tag{4.15}$$

4.1.2 Equilibrium

The model is closed by the resource constraint

$$Y_t = \int_0^1 C_t(i)di + R(\theta_t,c)H_t \tag{4.16}$$

where the total output Y_t in time t is

$$Y_t = \int_0^1 Y_t(i)di \tag{4.17}$$

When this resource constraint is considered, the symmetric equilibrium of the model is a set of stochastic processes

$$\{C_t, N_t, Y_t, H_t, \theta_t, U_t, W_t\}_{t=0}^{+\infty}$$

which satisfy the following set of equations:

- Law of motion for employment

$$N_t = (1-s)N_{t-1} + H_t \tag{4.18}$$

- Law of motion for unemployment

$$U_{t-1} = 1-(1-s)N_{t-1} \tag{4.19}$$

- Law of motion for labor market tightness

$$f(\theta_t) = \frac{H_t}{U_{t-1}} = \omega\theta_t^{1-\eta} \tag{4.20}$$

- Resource constraint

$$Y_t = C_t + R(\theta_t, c)H_t \tag{4.21}$$

- Production constraint

$$Y_t = F(N_t, a_t) = a_t N_t^{\alpha} \tag{4.22}$$

- Wage rule

$$W_t = w_0 a_t^{\gamma} \tag{4.23}$$

- Firm's Euler equation

$$\frac{\epsilon - 1}{\epsilon}\alpha a_t N_t^{\alpha-1} - W_t - \frac{c}{q(\theta_t)} + (1-s)\beta E_t\left[\frac{c}{q(\theta_{t+1})}\right] = 0 \tag{4.24}$$

- Labor productivity process

$$a_t = \rho a_{t-1} + z_t \tag{4.25}$$

4.1.3 Steady state

Combining equations 4.18, 4.19 and 4.20 in steady state yields the stationary number of unemployed workers

$$\bar{u} = \frac{s}{s + (1-s)f(\bar{\theta})}$$

Using previous stationary state $\bar{u}$ and equation 4.19 yields the steady state of job-worker matches

$$\bar{n} = \frac{1-\bar{u}}{1-s}$$

From equation 4.18 we get the stationary number of recruits

$$\bar{h} = s\bar{n}$$

The previous result together with equation 4.21 in steady state determine the steady state consumption

$$\bar{c} = \bar{n}^{\alpha} - \frac{cs}{q(\bar{\theta})}\bar{n}$$

Steady state product from equation 4.22

$$\bar{y} = \bar{a}\bar{n}^{\alpha}$$

From wage rule 4.23 we get steady state wage as

$$\bar{w} = w_0 \bar{a}^{\gamma}$$

The firm optimal condition in steady state is

$$0 = \frac{\epsilon - 1}{\epsilon}\alpha\bar{n}^{\alpha-1} - \bar{w} - [1 - \beta(1-s)]\frac{c}{q(\bar{\theta})}$$

Labor market productivity in stationary state is equal t

$$\bar{a} = 1$$

4.1.4 Log-linearized model

- Law of motion for employment4.18

$$\hat{n}_t = (1-s)\hat{n}_{t-1} + s\hat{h}_t \tag{4.26}$$

- Law of motion for unemployment 4.19

$$\hat{u}_{t-1} + \frac{1-\bar{u}}{\bar{u}}\hat{n}_{t-1} = 0 \tag{4.27}$$

- Law of motion for labor market tightness 4.20

$$1 - \eta\hat{\theta}_t = \hat{h}_t - \hat{u}_{t-1} \tag{4.28}$$

- Resource constraint 4.21

$$\hat{y}_t = (1-s_1)\hat{c}_t + s_1(\hat{h}_t + \eta\hat{\theta}_t) \tag{4.29}$$

  where $s_1 = \dfrac{cs}{q(\bar{\theta})}\bar{n}^{1-\alpha}$

- Production constraint 4.22

$$\hat{y}_t = \hat{a}_t + \alpha\hat{n}_t \tag{4.30}$$

- Wage rule 4.23

$$\hat{w}_t = \gamma \hat{a}_t \tag{4.31}$$

- Firm's Euler equation 4.24

$$\hat{a}_t + (1-\alpha)\hat{n}_t + s_2 \eta \hat{\theta}_t + (1 - s_2 - s_3) E_t[\eta \hat{\theta}_{t+1}] = 0 \tag{4.32}$$

where $s_2 = \bar{w} \dfrac{\epsilon}{\alpha(\epsilon - 1)} \bar{n}^{1-\alpha}$ and $s_3 = \dfrac{c}{q(\bar{\theta})} \dfrac{\epsilon}{\alpha(\epsilon-1)} \bar{n}^{1-\alpha}$

- Productivity shock

$$\hat{a}_t = \rho \hat{a}_{t-1} + z_t \tag{4.33}$$

4.1.5 Cyclical and structural unemployment

This section will define the cyclical and structural components of unemployment. A key notion to be introduced is the **the gross marginal profit** of firm which has the following form

$$J(N_t, a_t) = \frac{\epsilon - 1}{\epsilon} \frac{\partial F(N_t(i), a_t)}{\partial N_t} - S(N_t, a_t) - N_t \frac{\partial S(N_t(i), a_t)}{\partial N_t} \tag{4.34}$$

4.34 is an important factor in determining firm's hiring decisions. Since in the environment with partially rigid wages with $S(N_t(i), a_t) = w_0 a_t^\gamma$ and $F(N_t, a_t) = a_t N_t^\alpha$, 4.34 the gross marginal profit takes the following form

$$J(N_t, a_t) = \frac{\epsilon - 1}{\epsilon} a_t \alpha N_t^{\alpha - 1} - w_0 a_t^\gamma \tag{4.35}$$

where $\frac{\partial F(N_t(i), a_t)}{\partial N_t} = a_t \alpha N_t^{\alpha-1}$ is the marginal productivity of labor. Combining equation 4.35 with 4.15 yields

$$J(N_t, a_t) = \frac{c}{q(\theta_t)} - (1-s)\beta E_t \left[\frac{c}{q(\theta_{t+1})} \right] \tag{4.36}$$

which means that in equilibrium the gross marginal profit is equal to marginal cost induced by matching frictions.

The gross marginal profit is a function decreasing in employment because in case the employment rises and consequently the marginal productivity of labor diminishes, also the gross marginal profit will diminish due to the fact that wages are partially rigid and cannot be adjusted adequately in order to maintain the gross marginal profit stable. Conversely, the gross marginal profit is increasing in the labor productivity.

$$\frac{\partial J(N_t, a_t)}{\partial a_t} > 0 \tag{4.37}$$

$$\frac{\partial J(N_t, a_t)}{\partial N_t} < 0 \tag{4.38}$$

To each level of labor productivity there is a corresponding level of employment. Under the assumptions 4.37 and 4.38, I can deduce the existence of a unique solution denoted $N^\star \in (0,1)$ to the equation $J(N_t, a_t) = 0$. There exist such a pair of $(N_t, a_t) \in (0,1]$ that the gross marginal profit $J(N_t, a_t) < 0$.

Since the relation 4.38 holds, an employment level higher than $N^\star$ would induce a negative gross marginal profit. To compute the least possible labor productivity, which ensures that the gross marginal profit is still non-negative, I set $N^\star = 1$.

Plugging $N^\star = 1$ into equation 4.35 and expressing corresponding level of the labor productivity denoted as $a\star$ yields

$$a^\star = \left(\frac{\alpha(\epsilon - 1)}{\epsilon w_0}\right)^{1-\gamma} \tag{4.39}$$

Therefore, if the labor productivity a_t falls below $a^\star$ then it lies in the interval of additional employment reduction $\mathcal{A} = (0, a^\star)$ and the marginal product of labor is too low to cover marginal costs. Hence, the corresponding level of employment $N^\star$ falls in order to maintain the gross marginal profit non-negative. The unemployment induced from the employment reduction is referred to as cyclical and is denoted U_t^C and is equal to

$$U_t^C = 1 - N^\star \tag{4.40}$$

To find out the exact expression for the cyclical unemployment, I set the equation 4.35 equal to 0 and solve for N_t. This employment level is then plugged into 4.40 in order to obtain

$$U_t^C = 1 - \left(\frac{\alpha(\epsilon - 1)}{\epsilon w_0}\right)^{\frac{1}{1-\alpha}} a_t^{\frac{1-\gamma}{1-\alpha}} \tag{4.41}$$

Consequently, U_t^C increases during economic slowdown periods which is connected with a lower labor productivity.

In the model, the remaining part of unemployment is the structural component, which is assumed to by determined by search and matching frictions and is denoted as U_t^F. Therefore

$$U_t^F = U_t - U_t^C \tag{4.42}$$

The structural unemployment U_t^F is partly given by the exogenous separation rate s causing a destruction of sN_t existing job-worker matches and partly by the difference of the labor productivity corresponding $N^\star$ and the actual employment in the market N_t. $N^\star$ is the employment which would dominate if the labor market frictions were zero. Since N_t takes them into consideration, $N^c(a_t) > N_t$. Therefore

$$U_t^F = sN_t + [N^c(a_t) - N_t] \tag{4.43}$$

If $a_t \notin \mathcal{A}$ all the unemployment is caused only by labor market frictions and additional employment reduction does not occur. Therefore $U_t^C = 0$ and $U_t = U_t^F$.

The behavior of unemployment and its components could be, based on the argumentation above, summarized as follows:

If the overall labor productivity decreases, likewise the level of employment N_t has to decrease in order to ensure at least zero gross marginal profit. Therefore, the total and cyclical unemployment increase and based on the specification of the structural component given by 4.42, the structural unemployment decreases. Formally written

(i) $\dfrac{\partial U}{\partial a} < 0$

(i) $\dfrac{\partial U^C}{\partial a} < 0$

(i) $\dfrac{\partial U^F}{\partial a} > 0$

In a period of economic slowdown, when the labor productivity is lower than in normal times, the employment reduction is even more pronounced.

4.2 Nonlinear rational expectations model of unemployment

This section seeks to determine the share of cyclical and structural unemployment on the total unemployment in each time period over the past 15 years from 2000 to 2014 in the Czech Republic.

In order to do so I cannot use the log-linearized DSGE model presented in the previous section because the unemployment is a non-linear variable in the sense that it has its cyclical and structural component and their share is conditional on the labor productivity and whether it lies inside the interval of additional employment reduction $\mathcal{A}$. Thus, certain modification of the model have to be made in order to be able to solve it numerically.

First, the productivity series a_t is approximated by a discrete Markov chain state space representation. The outcome of this procedure is the productivity series realized in multiple states. The labor productivity therefore follows a first-order Markov process which is characterized by the fact that the next realization a_t depends solely on the previous step a_{t-1} and not on past states of the process as it was the case for the AR(1) process. The algorithm was proposed by Tauchen (1986) and it is a very standard method used in the literature.

Next, I rewrite θ_t, U_t and N_t as functions of labor productivity and thus these variables become dependent on labor productivity following above mentioned Markov process. The rewriting is possible thanks to the relation 2.7 between employment outflow and inflow.

The last step is to use the Fair & Taylor (1980) algorithm for solving the non-linear rational expectations model.

4.2.1 Markov chain approximation of labor productivity

The construction of the Markov chain begins with computing the labor productivity series a_t as a ratio of output and employment real Czech time series. Next, the new time series is detrended using the Hodrick-Prescott filter with the smoothing parameter $\lambda = 10^5$. The labor productivity follows a stochastic process in the form

$$a_t = \rho a_{t-1} + z_t$$

The white noise z_t is assumed to be normally distributed with zero mean and variance σ_z. In order to estimate autoregressive coefficient ρ and variance

σ_z I fit an AR(1) model to the labor productivity series. I interpolate output, employment and labor productivity series to obtain weekly series. For the finite-state Markov chain to be a good approximation to the AR(1) process I set a relatively large dimension of state space. I choose 200 as the number of states. I follow the Tauchen (1986) algorithm for constructing the Markov chain as formulated by Adda & Cooper (2003).

The AR(1) process a_t is discretized into 200 intervals and in each interval i where $i = 1, ..., N$ its conditional mean x^i is computed. Next, a matrix of probabilities of transitions between states $\pi_{i,j}$ is computed as well. The probability of a_t falling into each state is the same and equal to 1/200=0.5%. The bounds of intervals are given by

$$F\left(\frac{a^{i+1}}{\sigma_a}\right) - F\left(\frac{a^i}{\sigma_a}\right) = \frac{1}{200} \text{ for } i = 1, ..., 200,$$

where F is a cumulative distribution function of the normal density. The standard deviation of a_t, σ_a, is computed as $\sigma_a = \sqrt{\frac{\sigma_\epsilon^2}{1-\rho^2}}$. Inverting F permits to express a^i as

$$a^i = \sigma_a F^{-1}\left(\frac{i-1}{200}\right)$$

The conditional mean m^i computed as

$$m_i = \sigma_a \frac{f\left(\frac{a^i}{\sigma_a}\right) - f\left(\frac{a^i}{\sigma_a}\right)}{F\left(\frac{a^{i+1}}{\sigma_a}\right) - F\left(\frac{a^i}{\sigma_a}\right)}$$

which can be simplified to

$$m_i = 200\sigma_a \left(f\left(\frac{a^i}{\sigma_a}\right) - f\left(\frac{a^{i+1}}{\sigma_a}\right)\right)$$

The last step consists in defining the conditional probability of transition $\pi_{i,j}$ from interval i to interval j.

$$\pi_{i,j} = \frac{200}{\sqrt{2\pi\sigma_a}} \int_{a^i}^{a^{i+1}} e^{-z^2/2\sigma_a^2} \left[F\left(\frac{a^{j+1} - \rho z}{\sigma}\right) - F\left(\frac{a^j - \rho z}{\sigma}\right)\right] dz$$

The approximation to AR(1) process is the Markov process m_i of order one and values this process are given by $\{m_i\}_{i=1}^{200}$ which transitions between two states with a probability given by

$$P(m_t = m_j | m_{t-1} = m_i) = \pi_{i,j}$$

Since the number of states is 200 in this case, the dimension of the transition matrix π is 200x200 and the dimension of the matrix X defining state means is 1x200.

4.2.2 Method for solving the nonlinear model

A dynamic nonlinear rational expectation model as presented by Fair & Taylor (1980) is characterized by the following general representation

$$f_i(y_t, y_{t-1}, ..., y_{t-p}, E_{t-1}[y_t], E_{t-1}[y_{t+1}], ..., E_{t-1}[y_{t+h}], x_t, \alpha_i) = u_{i,t}$$

where y_t is a vector of endogenous variables, x_t is a vector of exogenous variables, E_{t-1} is a conditional expectations of endogenous variables at time $t+h$ based on the available information at time t, α_i being the parameter vector and finally $u_{i,t}$ which is a potentially cross-correlated and autocorrelated random variable scalar with zero mean.

The model is composed of relations specified in section 4.1.1.2 and of the definition of the Beveridge curve 2.8, wage schedule 4.5 and 4.6, firm's Euler equation 4.14, job limiting conditions 4.34 and 4.36 and the definitions of cyclical 4.41 and strucutral 4.42 unemployment.

The section 4.1.1.4 defined the interval of additional employment reduction $\mathcal{A} = (0, a^c)$. As was explained previously, when the labor productivity a_t falls in $\mathcal{A}$ employment is diminished in order to keep the gross marginal profit of firms non-negative. After rearranging the firm optimal condition 4.14 I can express the wage schedule as

$$W_t = R(\theta_t, c) - N_t \frac{\partial S(N_t(i), a_t)}{\partial N_t} + \frac{\partial F(N_t(i), a_t)}{\partial N_t} + (1-s)\beta E_t[R(\theta_{t+1}, c)] \quad (4.44)$$

where $N_t = (1-s)N_{t-1}$. Using above stated assumptions leads to express the previous equation as

$$\alpha a_t[(1-s)N_{t-1}]^{\alpha-1} + \beta(1-s)\mathbb{E}_t\left[\frac{ca_{t+1}}{q(\theta_{t+1})}\right] - w_0 a_t^{\gamma} = 0 \quad (4.45)$$

This equation is used to determine labor market tightness as a solution to the dynamic system where the labor productivity is approximated by the Markov chain computed in the previous section. In order to be able to solve the nonlinear equation for θ it is necessary to set the initial guess. Thus, shifting 4.45 one period back yields

$$\alpha a_{t-1} \cdot N_{t-1}^{\alpha-1} = w a_{t-1}^{\gamma} + \frac{ca_{t-1}}{q(\theta_{t-1})} - \beta(1-s)\mathbb{E}_{t-1}\left[\frac{ca_t}{q(\theta_t)}\right] \quad (4.46)$$

For other variables in the system I use steady state values as the **initial guess**:

- **labor productivity** initial guess is obtained using computed means m^i in each state
- **labor market tightness** initial guess is obtained using $\bar{\theta}$ computed by solving 4.46 for θ
- **employment** initial guess is computed in a same way as in section 4.1.3, i.e. ratio $\bar{n} = \dfrac{1-\bar{u}}{1-s}$
- **unemployment** initial guess is obtained from the Beveridge curve equation as $\bar{u} = \dfrac{s}{s+(1-s)f(\bar{\theta})}$
- **marginal productivity of labor** initial guess is the derivation of production constraint with regard to employment $\bar{mpl} = m_i \bar{n}^{\alpha-1}$
- **wage** initial guess is computed using the wage rule $\bar{w} = w_0(m_i)^{\gamma}$
- **hiring cost** initial guess: $\dfrac{cm_i}{q(\bar{\theta})}$
- **number of recruits** initial guess: $\bar{h} = s\bar{n}$
- **job-finding probability** initial guess: $f(\bar{\theta}) = \omega\bar{\theta}^{1-\eta}$
- **probability of filling a vacancy** initial guess: $q(\bar{\theta}) = \omega\bar{\theta}^{-\eta}$

In order to solve the model numerically I will use the method as presented by Fair & Taylor (1983) which is composed of three types of iteration.

One condition is to know the expected values of all the variables used for the simulation. For the Markov process of labor productivity the expected value is determined by the product of the current value and the transition probability. The horizon used for constructing expectations is 400 time periods which should be enough for the iteration to run successfully. The same case applies for labor market tightness whose expected value is derived from the Markov process of labor productivity. Since other variables are expressed as functions of labor productivity or labor market tightness I can obtain their expected values simply by plugging already computed expected values of θ and A in their formulas. Computing the expected values is an iteration by itself because once an expected value is determined from the initial guess, it itself is used as an initial guess in order to compute next expected value. I denote WY_t the matrix of simulated variables stored in rows (each row for one variable).

The solution method lies in three types of iteration. For a more precise results the quarterly series are interpolated to a weekly frequency. After determining initial guesses I choose $k_0 = 25$ as the number of expectations to be computed. The total number of computed expectations is $k_1 = k_0 + 2h + 1$ where h=1 is the expectations' horizon. The third type of iteration consists of $k_3 = k_1 + 1$ rounds. Iterations are pursued until convergences given by tolerance limit are achieved. For type II iteration the convergence limit is set to 0.00005 and for type III iteration it is 0.001.

Iterative solution

The solution of the whole model including all the three types of iteration is repeated n times where n is the number of weeks, in my case 697. Therefore solving the model becomes a computationally intensive task.

The model is each of n times solved numerically for all the variables. Now I proceed with the description of the solution process repeated n times.

First, the initial values are used as current values and expectations k_2 periods ahead are computed. The mechanisms lies simply in the process where first initial value as described above is used to compute expected value one period ahead. The model used for computing expected values has the following form

- labor productivity a_t using the Markov process next expected value
- employment $n_{t-1} = \dfrac{1 - u_0}{1 - s}$
- unemployment $u_{t-1} = 1 - (1 - s)n_{t-1}$
- wage $w_t = wm_i^\gamma$
- expectation of recruitment cost $\mathbb{E}[R(\theta_t, c)] = \dfrac{h_t m_i c}{q\left(f^{-1}\left(\dfrac{h_t}{u_{t-1}}\right)\right)}$
- number of hires is obtained by solving the firm Euler equation 4.14 for h_t using the previous expression for recruitment costs
- labor market tightness as $\theta_t = \left(\dfrac{\frac{h_t}{u_{t-1}}}{\omega}\right)^{\frac{1}{1-\eta}}$, this equation resulted from combining $f(\theta_t) = h(1, \theta) = \omega\theta^{1-\eta}$ with $f(\theta_t) = \dfrac{h_t}{u_{t-1}}$

- marginal product of labor $mpl_t = m_i \alpha n_t^{\alpha-1}$

These obtained solutions are stored, used as initial guesses for the subsequent period and also used for computing the expectations for the next period. This iteration process which is called type I and is repeated up to the last included period i.e. kIII times. Each of kIII times the absolute value of the difference between current expectations and current solution of the model is computed and stored. The maximum out of kIII absolute values of these differences is compared to the type II convergence limit. The iteration of type III compares the estimates of θ to the artificially set value of θ which is chosen big enough to force one iteration.

While these two criteria for iteration of type II and III are still not lower than the tolerance limits and thus the convergence is not achieved, the model solution is repeated. After convergence has been achieved, the model moves one week further.

The cyclical component of unemployment is computed based on the equation 4.41 using the approximated labor productivity m_i as

$$u_{t-1}^C = max\left(1 - \left(\frac{\alpha}{w_t}^{\frac{1}{1-\alpha}} m_i^{\frac{1-\gamma}{1-\alpha}}\right), 0\right)$$

The structural component is computed as a difference between the overall unemployment u_{t-1} and the cyclical component u_t^C

$$u_{t-1}^F = u_{t-1} - u_{t-1}^C$$

4.3 Data and calibration

The data used for estimating both the log-linearized DSGE and the nonlinear rational expectations model are naturally specific Czech time series for employment, unemployment, vacancies, labor force, output, consumer price index and wages. All the time series are seasonally adjusted with the X-13ARIMA-SEATS software package.

The data on the current price gross domestic product, consumer price index for all items, stock of unemployed aged 15-64, stock of employed aged 15-64, number of active population aged 15-64 and hourly earnings are downloaded from the Federal reserve bank of St. Louis and was collected by the Organization for Economic Cooperation and Development.

The time series of current price gross domestic product, stock of unemployed, stock of employed and the manufacturing sector hourly earnings which are takes as a wages representative have quarterly frequency. The examined period stretches from Q1 2000 to Q3 2014, which is 59 quarters.

The inflation measured by the consumer price index for all items is 177 months long, from January 2000 to September 2014. Therefore, the time series is aggregated into quarterly.

The data on monthly stock of vacancies is collected by the Czech Labor Office for the Czech Republic as a whole. The series stretches from January 2000 to September 2014 as well, therefore is transformed into quarterly and also seasonally adjusted.

Due to the fact that the Czech Labor Office changed its methodology of computing the unemployment rate three times in the last 15 years, the unemployment rate is incomparable and thus I had to compute it with one methodology only for the whole examined period. The unemployment rate was computed as a ratio of the number of unemployed aged 15-64 to the number of active population aged 15-64.

The nonlinear model developed in the section 4.2 primarily aims at determining the behavior of unemployment and its structural and cyclical components using labor market tightness and labor productivity in terms of which wages, employment, number of hires, marginal productivity of labor, hiring cost, probabilities of finding a job and filing a vacancy are expressed.
The log-linearized DSGE model delivers the responses of labor market variables to a productivity shock.

The labor productivity series is created as a ratio of employment and output. The equation $a_t = \rho a_{t-1} + z_t$ comprises two parameters to calibrate - productivity persistence factor ρ and standard deviation of the error component σ_z. z_t is independent identically distributed with zero mean and variance σ_z^2. ρ is estimated with the AR (1) model. Before estimation the productivity series is detrended using Hodrick-Prescott filter with the smoothing parameter $\lambda = 10^5$. The estimated autocorrelation parameter is 0.9620 which at weekly frequency is 0.9968. σ_z is estimated as 0.0034.

Parameters to calibrate related to the labor market are per-period vacancy cost c, separation rate s, matching coefficient ω and job-filling elasticity η.

The separation rate s is calibrated according to Hobijna & Şahin (2009). The sample period taken into account was 1997-2004 and the estimation of s for the Czech Republic is $s = 0.0024$.

The per-period vacancy cost c estimation varies with different sources. Pissarides (2009) estimated it as 0.357 of worker's wage. Shimer (2005) as 0.213 and Hall & Milgrom (2008) as 0.433. Therefore I use a geometric mean of these values and calibrate c as $c = 0.3205w_0$.

In order to obtain the labor market tightness in steady state $\bar{\theta}$ I use monthly seasonally adjusted series for unemployed level and vacancies. I calculate a ratio of number of vacancies to unemployment. Then I obtain $\bar{\theta}$ as the mean of this ratio $\bar{\theta} = 0.1343$.

The production function parameter α is calibrated to 0.53 according to Aliyev *et al.* (2014).

The steady state wage w_0 can be found using the relation of wage share w_s which is a ratio between compensation of employees and output.

$$\bar{w_s} = \frac{w_0 \bar{n}}{\bar{y}}$$

substituting $\bar{y}$ by $\bar{n}^{\alpha}$ from the production function in steady state and rearranging the expression yields

$$w_0 = \bar{w_s} \bar{n}^{\alpha - 1}$$

The wage share w_s is calibrated to value 0.5425 which is the mean of Czech wage shares reported by the OECD for the years 1995 to 2010. Thus steady state wage w_0 is equal to 0.5425. This allows to compute the per-period vacancy cost as $c = 0.3205 \cdot 0.5425 = 0.1739$.

The elasticity of wages with respect to labor productivity γ is set to value 0.7 as estimated by Haefke *et al.* (2008).

The rest of the parameters are calibrated based on the matching function estimation obtained in the section 3.3.

I calibrate the matching efficiency coefficient ω based as a mean of the computed estimates $\hat{\omega}$ which leaves me with $\omega = 0.0523$.

To calibrate the job-filling elasticity parameter η I take the matching function in logarithmic form and estimate it by fixed effects similarly as in section 3.

$$\log H_{i,t} = \eta \log U_{i,t-1} + (1 - \eta) \log V_{i,t-1} + c_i + \epsilon_{i,t} \tag{4.47}$$

which can be rewritten as

$$\log H_{i,t} = \beta_1 \log U_{i,t-1} + \beta_2 \log V_{i,t-1} + c_i + \epsilon_{i,t} \tag{4.48}$$

where $\beta_2 = 1 - \beta_1$. Incorporating the parameter restriction into 4.48 yields

$$\log H_{i,t} - \log V_{i,t-1} = \beta_1(\log U_{i,t-1} - \log V_{i,t-1}) + c_i + \epsilon_{i,t} \tag{4.49}$$

After setting $G = (\log H_{i,t} - \log V_{i,t-1})$ and $Z = (\log U_{i,t-1} - \log V_{i,t-1})$ I get an estimable form of the model 4.49

$$G = \beta_1 Z + c_i + \epsilon *_{i,t} \tag{4.50}$$

I use lag 4 to 12 of Z as instruments to prevent endogeneity. The model 4.50 is estimated on the same panel data as in section 3. I obtain estimation of job-filling elasticity parameter $\beta_1 = \eta$ as 0.78254.

The steady state unemployment rate $\bar{u} = 0.07143$ is the mean unemployment rate obtained from the same dataset this time for the Czech Republic as a whole.

The steady state employment rate $\bar{n}$ is computed based on the equation 2.5 as

$$\bar{n} = \frac{1 - \bar{u}}{1 - s} = \frac{1 - 0.07143}{1 - 0.0024} = 0.9308$$

The table 4.1 summarizes calibrated parameters.

symbol	interpretation	value	source
ρ	productivity autocorrelation	0.9968	own calculation
σ_z	standard deviation of productivity	0.0034	own calculation
s	separation rate	0.0024	Hobijna & Şahin (2009)
c	per-period vacancy cost	0.1739	$0.3205w_0$
ω	matching efficiency coefficient	0.0523	own calculation
η	job-filling elasticity	0.7825	own calculation
$\bar{u}$	steady state unemployment rate	0.07143	own calculation
$\bar{n}$	steady state employment rate	0.9308	own calculation
α	production function parameter	0.53	Aliyev *et al.* (2014)
w_0	steady state wage	0.5425	own calculation
$\bar{\theta}$	steady state labor market tightness	0.1343	own calculation
$\bar{a}$	steady state labor productivity	1	normalization
γ	elasticity of wages	0.7	Haefke *et al.* (2008)

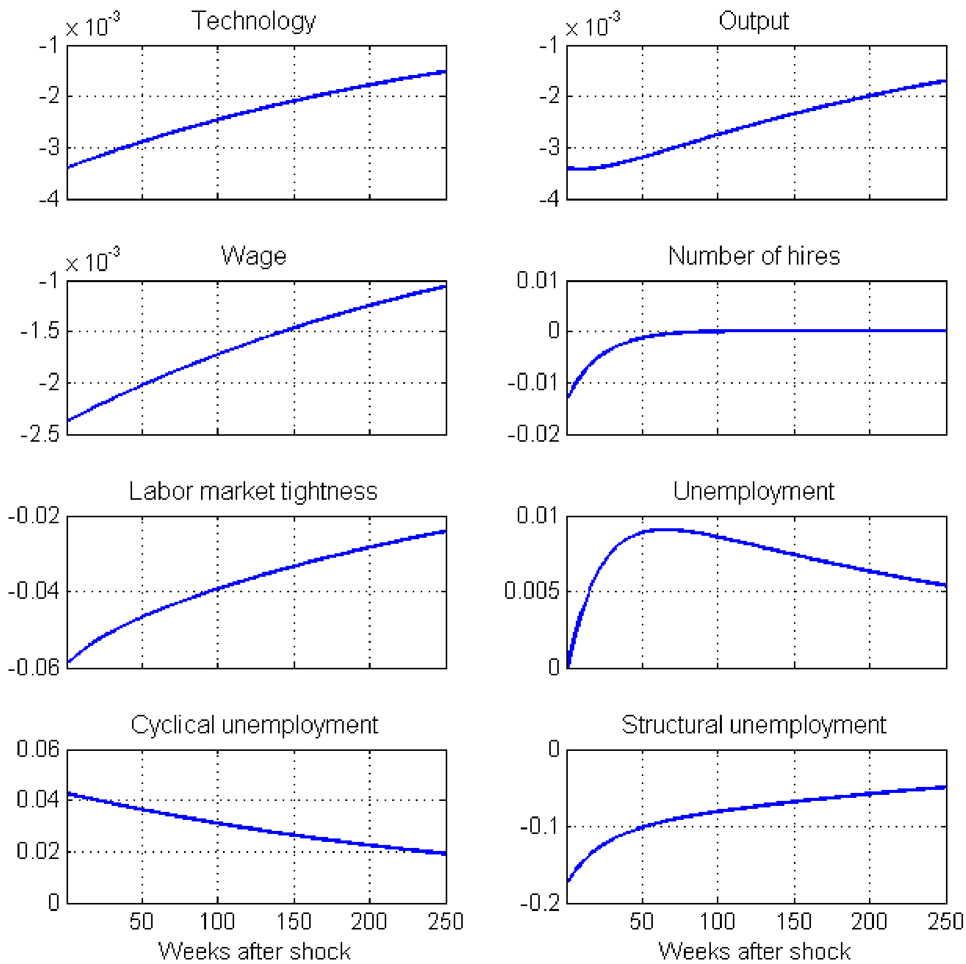
Table 4.1: DSGE model parameters calibration

4.4 Results

4.4.1 Impulse response functions in log-linear model

The non-linear rational expectations model is focused on the situation in which the low labor productivity occurring during economic slowdown induces a shortage of jobs. Therefore I am interested in examining the behavior of model variables after a negative productivity shock. For this purpose I plot the impulse response functions of the log-linearized model. The magnitude of the negative shock equals to one standard deviation of the productivity and was calibrated in section 4.3 as -0.0034. The impulse responses are shown in the the figure 4.1.

Since wages are partially rigid, after a negative labor productivity shock they cannot fully adjust, recruitment cost of firms increases and induce lower number of hires and lower number of vacancies. Due to the fact that separation rate is exogenous and does not depend on labor productivity, the reaction of unemployment is not immediate but rather gradual and reaches its peak after approximately 50 weeks after the shock. The cyclical and structural components of unemployment computed using the relations 4.42 and 4.41 are shown in the last two subplots. Since the economy slows down, the cyclical unemployment increases alongside with the technology shock. The structural unemployment reacts in opposite direction and decreases. Therefore, the impulse responses coincide with the theory in the section 4.1.5 where it was derived that the overall and cyclical unemployment is a function decreasing in labor productivity and structural is increasing in labor productivity.



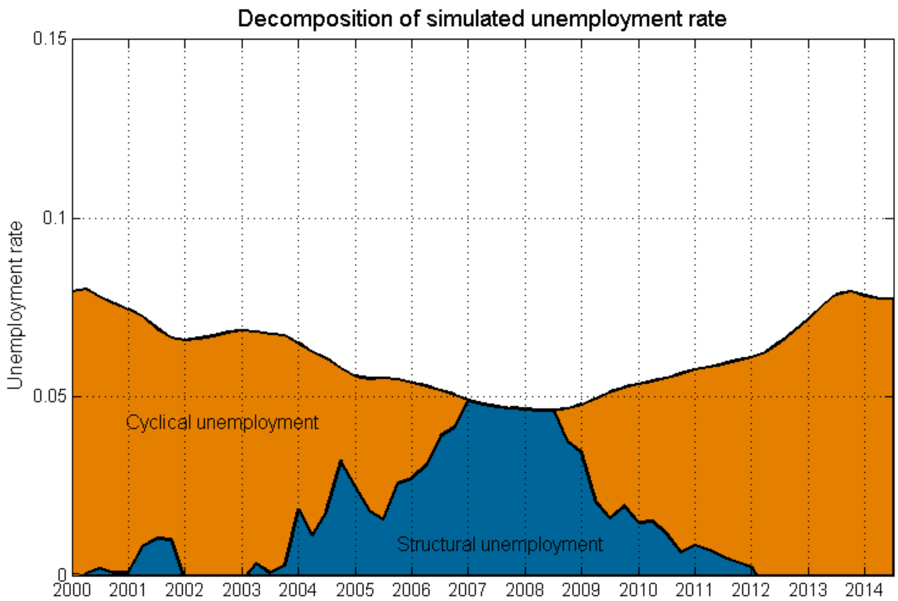
Source: author's computations.

Figure 4.1: Impulse responses to the negative technology shock

4.4.2 Unemployment decomposition

In this section I present the results of the non-linear rational expectations model in the form of decomposed simulated unemployment.

The decomposition of simulated unemployment is shown in the figure 4.2. The overall mean of the structural unemployment is 1.33%. It becomes pronounced between the years 2006 and 2008 when the mean rose to 4.22%. During the period Q1 2007 - Q2 2008 including, all the unemployment was due only to labor market frictions. Therefore, we can see that if the unemployment rate falls under 5% it is exclusively structural. The opposite movement of the two unemployment components is evident and overall increase in unemployment rate is always associated with the rise of cyclical and fall of structural component exactly as shown by the impulse responses previously.



Source: author's computations.

Figure 4.2: Decomposed unemployment rate

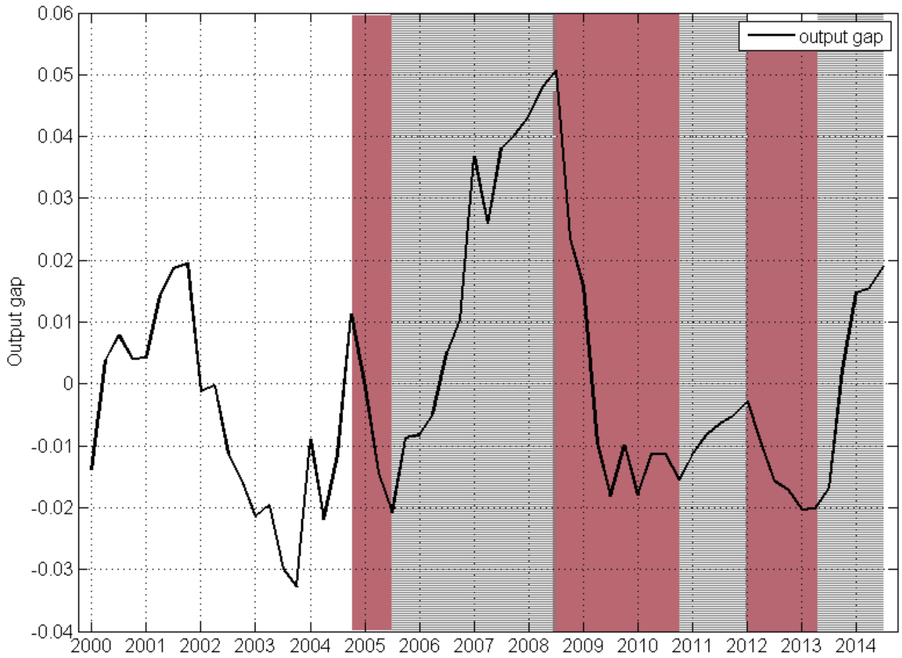
4.4.3 Interaction of unemployment components and the economic growth

The last part of this chapter aims at uniting the results from chapters 3 and 4 through the lens of the business cycle stages.

The examined years 2000 - 2014 are divided similarly to the chapter 3 into two periods. First period stretches from 2000 to 2004 and the second one from 2005 to 2014 which is interpreted with regard to the economic growth development.

The robust growth is defined here again as an increasing output gap and the economic slowdown as a diminishing output gap. According to the figure 4.3, three economic growth, marked by solid-colored areas, and three slowdown periods, marked by striped areas, occurred after 2004.

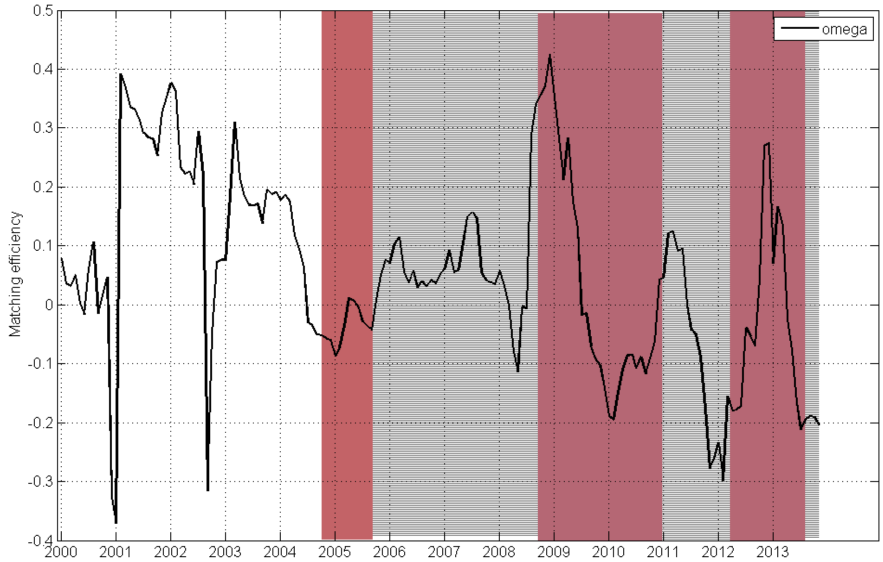
The figure 4.5 shows the actual and simulated unemployment for the Czech Republic. The figures 3.6 and 4.2 are plotted again and all the three figures include the marked robust growth and slowdown periods.



Source: author's computations.

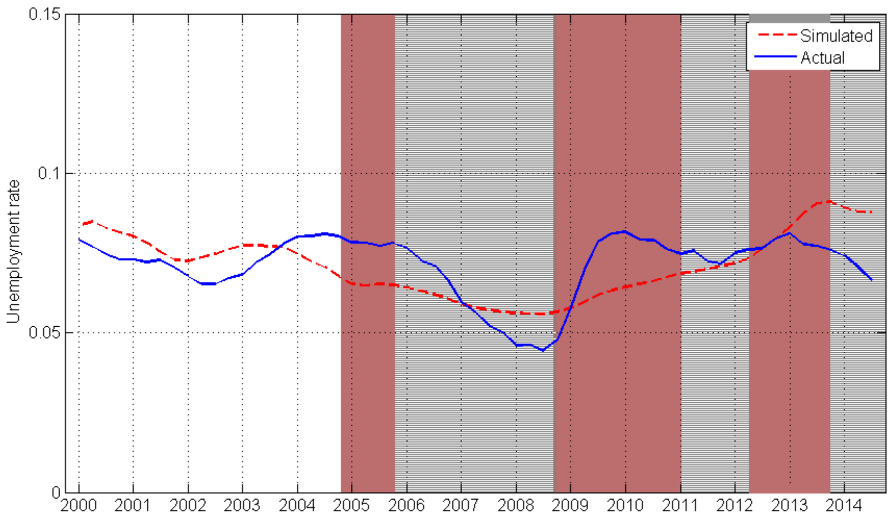
Figure 4.3: Economic growth development

The first slowdown started in Q4 2004 right after the Czech Republic entered into the European Union and lasted up to Q3 2005 including. The labor market was still not fully adjusted to the economic transformation and the unemployment stayed on approximately the same level during this whole period and began to decrease only in the following growth period. Still, in accordance with theory, the structural component diminished and can be seen



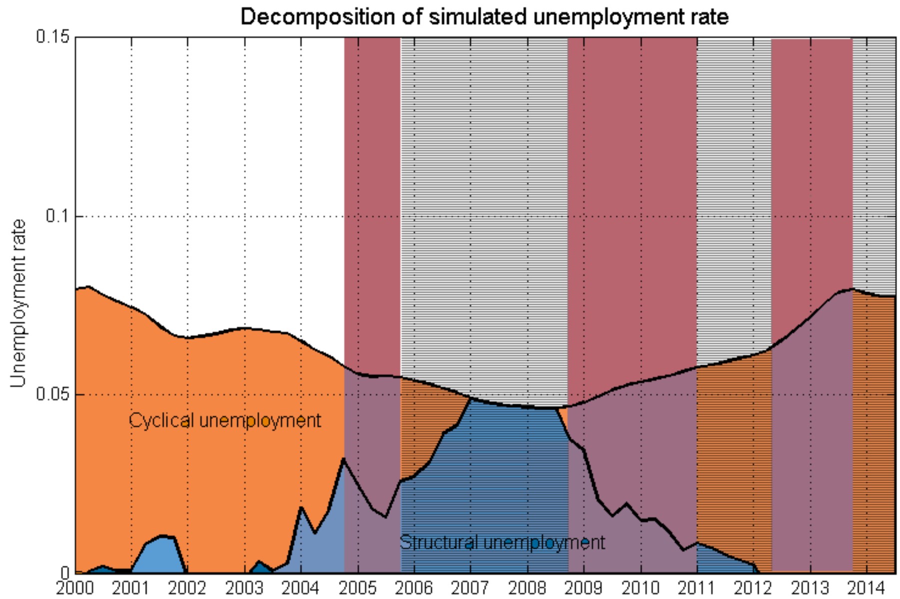
Source: author's computations.

Figure 4.4: Matching efficiency



Source: author's computations.

Figure 4.5: Comparison of actual and simulated unemployment rates



Source: author's computations.

Figure 4.6: Decomposed unemployment rate

as a V-shape in the figure 4.6. The matching efficiency slightly increased over this period.

The first and longest robust growth of the economy stretched from Q4 2005 up to Q3 2008 including. At first, the simulated unemployment lies below the actual series, but as the robust growth progressed and the output gap reached its global maximum in Q3 2008, the actual unemployment series dropped to its minimum. The simulated unemployment decreased as well thus grasping the real dynamics of the labor market, but overestimated the lowest unemployment by 1.1%. Consistently with the theory, the cyclical component decreased significantly and even became zero, as the figure 4.6 shows. Analogously, the structural unemployment increased distinctly, constituting up to 100 % of the simulated rate of unemployment. The matching efficiency fluctuated around zero and dropped even further as the period progressed as is visible in the figure 4.4. Therefore, the mismatch as a type of labor market friction become far more pronounced due to the long duration of the robust growth and the high positive output gap because the cyclical component had time to properly adjust to the cycle.

The second and longest economic slowdown took place between Q4 2008 and Q4 2010 including, thus lasting more than two years. The model underestimated the actual unemployment rate particularly in 2009 suggesting that other factors not included in the model drove the unemployment higher. As we can see in figure 4.3 in 2010 the output gap remained at approximately the same local minimum level during 2009 and 2010. The low output was caused mainly by a low external demand. In accordance with the theory, the cyclical unemployment increased while the structural had been steadily decreasing over this period. The previously low matching efficiency, which dominated over the labor market in the antecedent period, rose in this period and reached its global maximum 0.42 in the beginning of 2009.

The second growth period started in Q1 2011 and ended in Q1 2012. The simulated unemployment was nearly equal to the actual one. Although this period was rather short, structural component growth was restored for a brief period and appeared as an inverted V-shape. The mismatch between jobs and workers returned to its pre-crisis level at first but as the economic growth was progressing the mismatch worsened and fell to its minimum -0.3 as shown in the figure 4.4. The fact that structural component became very low is connected to the steady increase of the unemployment rate since 2009. The structural component was consequently steadily diminishing.

The unemployment rate increase intensified since 2012 when the last slowdown occurred between Q2 2012 and Q2 2013 including. The structural unemployment reached zero and remained null during the whole period. The efficiency of matching workers to vacancies increased and reached another local maximum of nearly 0.3 at the end of 2013.

During the last robust growth period, the matching efficiency could not have been estimated due to rolling window method when matching function elasticity parameter are estimated on 13 months of data and the dataset span ended in Q3 2014. However the actual unemployment became to decrease and according to latest news, the labor market might be in slightly better condition.

4.5 Summary of results

The chapter 4 aimed at examining the labor market condition over the past 15 years by using the DSGE model with the labor market block and incorporating search and matching frictions.

Although the Czech Republic is a small open economy and the model assumes a closed economy, it can be supposed that the qualitative results would not differ under an open economy specification, besides being slightly more pronounced. This assumption is based on the labor productivity specification.

The labor productivity is computed as a ratio of the output to the employment where the output is determined to a large extent by the level of demand and in the Czech case, mainly the level of external demand. Therefore, the labor productivity shock comprises external demand shocks as well. Hence the effects of foreign variables are captured also by this shock.

The impulse responses show reactions of output, wages, number of hires, labor market tightness and unemployment with its cyclical and structural components to a negative labor productivity shock which symbolizes the act of the economic slowdown. The induced downfall of market tightness resulted in lower number of vacancies and hires. The overall and cyclical unemployment increased gradually after the shock, while structural component decreased.

The second part of this chapter consisted of the numerical simulation based on the nonlinear rational expectations model with the aim of decomposing the unemployment into its cyclical and structural components. During a period of robust growth, defined here as increasing output gap, the model succeeded in generating a rise in structural unemployment whose existence was acknowledged by the significant mismatch between jobs and workers in the labor market. The second observation, which can be drawn, is that in good times, the model grasped the behavior of the unemployment rather accurately with the exception of the last robust growth period when the simulated unemployment overestimated the reality.

In reality, robust growth periods are not always based only on a positive technology shock and other beneficent aspects such as simply a pure good mood of investors based on psychological factors do play a role in determining the unemployment rate. The results from the two models suggest that the optimal unemployment policy in good times should be targeted on improving labor market mismatch by using policies such as for example placement services.

During an economic slowdown, the situation was exactly the opposite as far as structural component is concerned - it decreased and most profoundly during the last slowdown when it reached the zero level. Thus, the matching efficiency improved during each economic slowdown period and confirmed the theory which stated that labor market frictions loose their importance in bad times. Suggested outcome is that when the economic growth slows down, unemployment policies should not focus on diminishing mismatch, but rather target the cyclical component of the unemployment using policies such as wage subsidies or a direct employment. Particularly around the year 2009, the model did not grasp the amplitude of unemployment behavior as accurately. This was due to the fact, that the slowdown in that period was caused by a fall of external demand to a large extent and the technology shock captured only part of this strong fall.

In the next and at the same time last chapter, I will extend the New Keynesian DSGE model by incorporating final and intermediate goods firms, interest rate rule and government block with intention of examining the effects of public employment on the labor market, as one of the possibly suitable policies during an economic slowdown period.

Chapter 5

Unemployment policy during the economic slowdown

As we have seen in the previous chapter, unemployment policies should vary with regard to the economic growth condition due to the fact that the size of cyclical and structural components of unemployment are different in growth and in slowdown periods. When the economy slows down, the unemployment has the tendency to increase and the need to diminish it is more pronounced. Since the labor market frictions are of low importance in bad times, policies intended to diminish the effect of frictions such as job placements are ineffective and other options, such as for instance direct employment, could be preferred.

Therefore, I will focus on the public hiring, as one of the potentially suitable unemployment policies during an economic slowdown. However, one of the main trends in the Czech Republic has been cutting government expenses, which has led to reductions of the public sector size and reductions of the number of public jobs. During an economic slowdown, the government is more likely to fire a part of its employees than it is likely to hire new ones. Thus, the goal of this chapter is to quantify the effects of public firing during a slowdown period on overall unemployment and verify the hypothesis that public hiring could be an appropriate tool to mitigate unemployment effectively, meaning that the decrease of overall unemployment would outweigh the negative effect of the private employment crowding out.

The labor market model introduced in the section 4.1.1.2 will be incorporated into a New-Keynesian DSGE model consisting of households, final and intermediate good firms, a monetary policy and a fiscal block. Since I am interested in assessing the effects of public hiring, the private employment is distinguished from the public employment. Similarly as before, households cannot choose their level of employment.

The driving force of fluctuations of the economy in this model is the labor productivity shock ϵ_t again, which follows random walk and is *i.i.d.* This shock enters into the technology AR(1) process defined as

$$a_t = \rho a_{t-1} + \epsilon_t \tag{5.1}$$

5.1 The model

5.1.1 Labor market

The overall employment is a combination of public g_t and private l_t employment. Thus the aggregate employment is a sum of shares of workers working in the public and private sector. The share of public employment is determined by the parameter ζ.

$$n_t = (1-\zeta)l_t + \zeta g_t \tag{5.2}$$

There is a continuum of intermediate goods firms indexed by $k \in [0,1]$ and each firm employs $l_t(k)$ workers during time period t. Thus the aggregate number of employed workers in a particular time period t is $l_t = \int_0^1 l_t(k)dk$.

Analogously to labor market model developed in section 4 workers can be either employed or unemployed and searching for a job. Each period, a fraction s of existing worker-job matches is destroyed and these newly unemployed start looking for a job immediately. The number of unemployed workers searching for a job at the beginning of period t is equal to

$$u_{t-1} = 1 - (1-s)n_{t-1} \tag{5.3}$$

The job-finding probability $f(\theta_t)$ is given by the ratio of newly hired h_t workers in period t to the number of unemployed u_{t-1} at the beginning of period t . The number of newly hired is again given by the Cobb-Douglas matching function $h_t = \omega u_{t-1}^{\eta} v_{t-1}^{1-\eta}$. The labor market tightness is $\theta_t = \dfrac{v_{t-1}}{u_{t-1}}$. Thus $f(\theta_t) = \dfrac{h_t}{u_{t-1}} = \omega\theta_t^{1-\eta}$. The vacancy-filling probability is given by $q(\theta_t) = \dfrac{h_t}{v_{t-1}} = \omega\theta_t^{-\eta}$.

5.1.2 Households

The household problem consists of maximizing the expected utility in the form proposed by Blanchard & Galí (2008)

$$E_0\left[\sum_{t=0}^{+\infty}\beta^t[ln(c_t)+\chi\frac{n_t^{1+\Phi}}{1+\Phi}\right] \tag{5.4}$$

where c_t denotes the aggregate consumption and n_t the fraction of employed household members. Household maximizes 5.4 subject to the budget constraint

$$p_tc_t+b_t=(1-\tau_t)w_tn_tp_t+b_{t-1}r_{t-1}+T_tp_t \tag{5.5}$$

where p_t denotes the price level, c_t consumption, n_t employment, b_{t-1} bonds purchased in previous time period $t-1$, w_t wage, b_t bonds purchased in current time period t, r_{t-1} the gross interest rate, τ_t the income tax and T_t transfers to households. The usual no-Ponzi game constraint applies to the optimization problem

$$E_0\left[\lim_{t=+\infty}\frac{b_t}{\prod_{i=0}^{t}r_{t-1}}\right]\geq 0 \tag{5.6}$$

We denote $\pi_t=\left(\frac{p_t}{p_{t-1}}-1\right)$ as the inflation rate in time period t.
The Lagrangian is formed as

$$\mathcal{L}=E_t\sum_{t=0}^{+\infty}\beta^t\left\{\left[ln(c_t)+\chi\frac{n_t^{1+\Phi}}{1+\Phi}\right]+\lambda_t\left(p_tc_t+b_t-(1-\tau_t)w_tn_tp_t-b_{t-1}r_{t-1}-T_tp_t\right)\right\} \tag{5.7}$$

Households choose the set of stochastic processes $\{c_t,b_t\}_0^{+\infty}$ in order to solve the maximization problem. As was already explained in the introduction to chapter 4, the usual feature of the New Keynesian model that the household chooses $\{n_t\}_0^{+\infty}$ as well does not apply in this particular case. In the conventional labor supply case the workers decide about the aspect of their job, i.e. amount of hours worked. however, in this case they cannot choose directly how much they will work due to search and matching frictions existence. Thus, the only decision left for household is to choose how intensively it will search for a job if being unemployed. As was already stated in section 2.3 by equation 2.7, the inflow rate into employment is equal to the outflow rate from unemployment. Plugging the relation for unemployment and employment 2.5 into 2.7

yields the household employment law of motion

$$n_t = (1-s)n_{t-1} + [1-(1-s)n_{t-1}]f(\theta_t) \tag{5.8}$$

In a steady state $n_t = n_{t-1}$ and this relation becomes the quasi-labor supply which replaces the conventional labor supply and determines the stationary employment.

$$n^s(\theta) = \frac{f(\theta)}{s+(1-s)f(\theta)} \tag{5.9}$$

The first order conditions are formed as follows

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial c_t} &= 0 \Rightarrow \frac{1}{c_t} + \lambda_t p_t = 0 \\ \lambda_t &= -\frac{1}{p_t c_t} \end{aligned} \tag{5.10}$$

$$\frac{\partial \mathcal{L}}{\partial b_t} = 0 \Rightarrow \lambda_t = \beta \lambda_{t+1} r_t \tag{5.11}$$

The Euler equation is obtained after combining the first order condition 5.10 with 5.11

$$\frac{1}{\beta} = E_t \left[\frac{r_t}{1+\pi_{t+1}} \frac{c_t}{c_{t+1}} \right] \tag{5.12}$$

5.1.3 Final good firms

The total final goods Y_t are given by the CES aggregator of the different quantities of intermediate goods produced:

$$Y_t = \left(\int_0^1 Y_t(k)^{\frac{\psi-1}{\psi}} dk \right)^{\frac{\psi}{\psi-1}} \tag{5.13}$$

where $\psi > 1$ stands for the final goods substitution elasticity. Final goods firms operate on a perfectly competitive market, buy intermediate goods $Y_t(k)$ and produce the final good Y_t in order to maximize profits. In other words, firms try to minimize expenditure given the production constraint. The Lagrangian can be written using the modified version of the equation 5.13 as:

$$\mathcal{L} = \int_0^1 P_t(k) Y_t(k) dk + \lambda_t \left(Y_t^{\frac{\psi-1}{\psi}} - \int_0^1 Y_t(k)^{\frac{\psi-1}{\psi}} dk \right) \tag{5.14}$$

Optimal choice of $Y_t(k)$ solves $\dfrac{\partial \mathcal{L}}{\partial Y_t(k)} = 0$, that is

$$P_t(k) = \lambda_t \frac{\psi - 1}{\psi} Y_t(k)^{\frac{-1}{\psi}} \tag{5.15}$$

$$Y_t(k) = P_t(k)^{-\psi} \left(\lambda_t \frac{\psi - 1}{\psi} \right)^{\psi} \tag{5.16}$$

Afterwards, this can be plugged into (5.13):

$$Y_t = \left(\int_0^1 \left[P_t(k)^{-\psi} \left(\lambda_t \frac{\psi - 1}{\psi} \right)^{\psi} \right]^{\frac{\psi-1}{\psi}} dk \right)^{\frac{\psi}{\psi-1}} \tag{5.17}$$

$$Y_t^{\frac{\psi-1}{\psi}} = \int_0^1 P_t(k)^{1-\psi} \left(\lambda_t \frac{\psi - 1}{\psi} \right)^{\psi-1} dk \tag{5.18}$$

$$Y_t^{\frac{\psi-1}{\psi}} = \left(\lambda_t \frac{\psi - 1}{\psi} \right)^{\psi-1} \int_0^1 P_t(k)^{1-\psi} dk \tag{5.19}$$

$$Y_t^{\frac{\psi-1}{\psi}} = \left(\lambda_t \frac{\psi - 1}{\psi} \right)^{\psi-1} P_t^{1-\psi} \tag{5.20}$$

utilizing assumption, that $P_t = \left[\int_0^1 P_t(k)^{1-\psi} dk \right]^{\frac{1}{1-\psi}}$.

Consequently,

$$\left(\lambda_t \frac{\psi - 1}{\psi} \right) = P_t Y_t^{\frac{1}{\psi}} \tag{5.21}$$

And after plugging 5.21 into (5.16), the individual demand becomes:

$$Y_t(k) = P_t(k)^{-\psi} \left(P_t Y_t^{\frac{1}{\psi}} \right)^{\psi} = \left(\frac{P_t(k)}{P_t} \right)^{-\psi} \cdot Y_t \tag{5.22}$$

Such result is conditioned on the price assumption, that

$$P_t = \left(\int_0^1 P_t(k)^{1-\psi} dk \right)^{\frac{1}{1-\psi}} \tag{5.23}$$

5.1.4 Intermediate goods firms

There is a continuum $k \in [0, 1]$ of monopolist firms, each employing $l_t(k)$ workers to produce output $y_t(k)$. Each firm has the same production function of the form:

$$y_t(k) = a_t l_t^{\alpha}(k) \tag{5.24}$$

where a_t is the technology process same for all firms and $\alpha \in (0,1)$ denotes diminishing marginal returns to labor. The aggregate number of recruited employees each period is

$$l_t = (1-s)l_{t-1} \tag{5.25}$$

and firms pay them wage w_t. The price setting mechanism is subject to the adjustment costs given by Rotemberg (1982) as

$$\frac{\phi}{2}\left(\frac{p_t(k)}{p_{t-1}(k)} - 1\right)^2 c_t \tag{5.26}$$

where $\phi > 0$ denotes adjustment costs coefficient.

The intermediate good firm faces also ra_t, a cost for holding a vacancy open in time period t. Thus we can express hiring costs as

$$[l_t(k) - (1-s)l_{t-1}(k)]\frac{ra_t}{q(\theta_t)} \tag{5.27}$$

Firm's profit in period t is equal to

$$\begin{aligned}\pi_t =& y_t(k)\left(\frac{p_t(k)}{p_{t-1}(k)}\right) - w_t l_t(k) - \frac{\phi}{2}\left(\frac{p_t(k)}{p_{t-1}(k)} - 1\right)^2 c_t \\ &- [l_t(k) - (1-s)l_{t-1}(k)]\frac{ra_t}{q(\theta_t)}\end{aligned} \tag{5.28}$$

Firm solves the optimization problem where it seeks to maximize the discounted sum of expected profits

$$\begin{aligned}E_0 \sum_{t=0}^{+\infty} \frac{\beta^t}{c_t} \Bigg\{ & \frac{p_t(k)}{p_{t-1}(k)} y_t(k) - w_t l_t(k) - \frac{\phi}{2}\left(\frac{p_t(k)}{p_{t-1}(k)} - 1\right)^2 c_t \\ & - \frac{r \cdot a_t}{q(\theta_t)}[l_t(k) - (1-s)l_{t-1}(k)] \Bigg\}\end{aligned} \tag{5.29}$$

subject to 5.22 and 5.24.

We construct the Lagrangian as

$$\begin{aligned}\mathcal{L} = E_0 \sum_{t=0}^{+\infty} \frac{\beta^t}{c_t} \Bigg\{ &\left(\frac{p_t(k)}{p_{t-1}(k)}\right)^{1-\psi} y_t - w_t l_t(k) - \frac{\phi}{2}\left(\frac{p_t(k)}{p_{t-1}(k)} - 1\right)^2 c_t \\ &- \frac{r a_t}{q(\theta_t)}[l_t(k) - (1-s)l_{t-1}(k)] + \Lambda_t(k)\left[a_t l_t^{\alpha}(k) - \left(\frac{p_t(k)}{p_{t-1}(k)}\right)^{-\psi} y_t\right]\Bigg\}\end{aligned} \tag{5.30}$$

where Λ_t is the Lagrange multiplier on production function 5.24 in period t.

The first order conditions yields the firm's labor demand and the Phillips curve.

$$\begin{aligned}&\frac{\partial \mathcal{L}}{\partial l_t(k)} = 0 \Rightarrow \\ &\Lambda_t \alpha l_t(k)^{\alpha-1} = \frac{w_t}{a_t} + \frac{r}{q(\theta_t)} - \beta(1-s)E_t\left[\frac{r_t}{q(\theta_{t+1})}\frac{c_t}{c_{t+1}}\frac{a_{t+1}}{a_t}\right]\end{aligned} \tag{5.31}$$

The aggregate labor demand has the following form

$$l_t^d = \left[\frac{1}{\Lambda_t \alpha}\left[\frac{w_t}{a_t} + \frac{r}{q(\theta_t)} - \beta(1-s)E_t\left[\frac{r_t}{q(\theta_{t+1})}\frac{c_t}{c_{t+1}}\frac{a_{t+1}}{a_t}\right]\right]\right]^{\frac{1}{\alpha-1}} \tag{5.32}$$

$$\begin{aligned}&\frac{\partial \mathcal{L}}{\partial p_t(k)} = 0 \Rightarrow \\ &\frac{p_t(k)}{p_t} = \frac{\psi}{\psi-1}\Lambda_t(k) + \frac{\phi}{\psi-1}\frac{c_t}{y_t}\left(\frac{p_t(k)}{p_t}\right)^{\psi} \\ &\left[\beta E_t\left[\left(\frac{p_{t+1}(k)}{p_t(k)} - 1\right)\frac{p_{t+1}(k)}{p_t(k)}\right] - \left(\frac{p_t(k)}{p_{t-1}(k)} - 1\right)\frac{p_t(k)}{p_{t-1}(k)}\right]\end{aligned} \tag{5.33}$$

In the symmetric equilibrium, the relations $p_t(k) = p_t$ and $\Lambda_t(k) = \Lambda_t$ hold, therefore I first substitute $\left(\frac{p_t}{p_{t-1}} - 1\right)$ for π_t and I rewrite 5.33 as

$$1 = \frac{\psi}{\psi-1}\cdot\Lambda_t + \frac{\phi}{\psi-1}\frac{c_t}{y_t}\left[\beta E_t\left[\pi_{t+1}(\pi_{t+1}+1)\right] - \pi_t(\pi_t+1)\right]$$

Next, I multiply the expression above by $(\psi - 1)$ and rearrange to obtain

$$1 = \frac{\psi}{\psi-1}\Lambda_t + \frac{\phi}{\psi-1}\frac{c_t}{y_t}\left[\beta E_t\left[\pi_{t+1}(\pi_{t+1}+1)\right] - \pi_t(\pi_t+1)\right]$$

$$\Leftrightarrow \psi - 1 + \phi\frac{c_t}{y_t}\pi_t\cdot(\pi_t+1) = \psi\Lambda_t + \phi\cdot\frac{c_t}{y_t}\cdot\left[\beta E_t\left[\pi_{t+1}(\pi_{t+1}+1)\right]\right]$$

$$\Leftrightarrow \pi_t(\pi_t+1) = \frac{1}{\phi}\frac{y_t}{c_t}[\psi\Lambda_t - (\psi-1)] + \beta E_t\left[\pi_{t+1}(\pi_{t+1}+1)\right] \tag{5.34}$$

Λ_t is expressed from the firm's labor demand 5.31 and then plugged into 5.34 in order to get an expression for the intermediate good firms optimal condition.

$$\pi_t(\pi_t+1) = \frac{1}{\phi}\frac{y_t}{c_t}\left[\frac{\psi}{\alpha a_t l_t^{\alpha-1}}\left(w_t + \frac{a_t r}{q(\theta_t)} - \beta(1-s)\frac{c_t}{c_{t+1}}\frac{a_{t+1}r}{q(\theta_{t+1})}\right) + (1-\psi)\right] + \beta E_t\left[\pi_{t+1}(\pi_{t+1}+1)\right] \tag{5.35}$$

Since the labor market is a combination of private and public employment, also the aggregate labor demand is a sum of private and public labor demand.

$$n^d = l^d + g \tag{5.36}$$

5.1.5 Wage schedule

For the wage schedule I use the same concept as in section 4.1.1.3 where partially rigid wages exist and the aggregated wage schedule has the following form:

$$w_t = w_0 a_t^{\gamma} \tag{5.37}$$

5.1.6 Monetary policy

The gross nominal interest rate rule is set as

$$r_t = \frac{1}{\beta}(1+\pi_t)^{\mu_\pi(1-\mu_R)}(\beta r_{t-1})^{\mu_R} \tag{5.38}$$

where π_t is the time t inflation rate, μ_π measures the monetary policy to inflation response and μ_R is the interest rate smoothing parameter. I assume steady state inflation $\bar{\pi} = 0$ and steady state interest rate $\bar{r} = \frac{1}{\beta}$.

5.1.7 Government budget constraint and resource constraint

The number of workers employed in public sector in time period t is g_t. Government is exposed to hiring costs similarly to private sector $\frac{r a_t}{q(\theta)}[g_t - (1-s)g_{t-1}]$. Public wages are equal to private wages w_t. Each period the government is obliged to repay its debt from the previous period which costs $r_{t-1} \cdot b_{t-1}$ and a new debt b_t is produced. Public income is given by the labor taxation.

$$n_t \cdot \tau_t\, w_t + \frac{b_t}{p_t} = g_t w_t + \frac{r a_t}{q(\theta)}[g_t - (1-s)g_{t-1}] + \frac{r_{t-1}}{p_t} b_{t-1} \tag{5.39}$$

After plugging in (5.5) and the expression for firm's profits (5.29) the budget constraint becomes

$$y_t = c_t\left(1+\frac{\phi}{2}\pi^2\right)+\frac{ra_t}{q(\theta)}[n_t-(1-s)n_{t-1}] \tag{5.40}$$

The meaning behind the equation 5.40 is that the produced output is either consumed by households or spend on new employees recruitment or price adjustment mechanism.

5.2 Equilibrium

In the symmetric equilibrium relations $y_t(k) = y_t$, $n_t(k) = n_t$, $l_t(k) = l_t$, $p_t(k) = p_t$ holds and thus the set of stochastic processes

$$\{w_t, \theta_t, n_t, l_t, \pi_t, c_t, y_t, r_t, a_t\}_{t=0}^{+\infty}$$

satisfies the following system of equations

- the wage schedule
$$w_t = w_0 a_t^{\gamma} \tag{5.41}$$

- the quasi-labor supply
$$n_t = (1-s)n_{t-1} + (1-(1-s)n_{t-1})f(\theta_t) \tag{5.42}$$

- the aggregate labor demand
$$n_t = (1-\zeta)l_t + \zeta g_t \tag{5.43}$$

- the intermediate good firms optimal condition
$$\begin{aligned}\pi_t(\pi_t+1) =& \frac{1}{\phi}\frac{y_t}{c_t}\left[\frac{\psi}{\alpha a_t l_t^{\alpha-1}}\left(w_t+\frac{a_t r}{q(\theta_t)}-\beta(1-s)\frac{c_t}{c_{t+1}}\frac{a_{t+1}r}{q(\theta_{t+1})}\right)+(1-\psi)\right] \\ &+\beta E_t\left[\pi_{t+1}(\pi_{t+1}+1)\right]\end{aligned} \tag{5.44}$$

- the Euler equation
$$1 = \beta E_t\left[\frac{r_t}{1+\pi_{t+1}}\frac{c_t}{c_{t+1}}\right] \tag{5.45}$$

- the monetary policy rule

$$r_t = \frac{1}{\beta}(1 + \pi_t)^{\mu_\pi(1-\mu_R)}(\beta r_{t-1})^{\mu_R} \tag{5.46}$$

- the production function

$$y_t = a_t \cdot l_t^\alpha \tag{5.47}$$

- the resource constraint

$$y_t = c_t \left(1 + \frac{\phi}{2}\pi^2\right) + \frac{ra_t}{q(\theta)}[n_t - (1-s)n_{t-1}] \tag{5.48}$$

- the labor productivity process

$$a_t = \rho a_{t-1} + \epsilon_t \tag{5.49}$$

5.3 Data and calibration

Data used for calibration of parameters are the same Czech time series for vacancies, unemployment level and unemployment rate, new hires, employment, output and wages as were used and already described in detail in the section 4. Parameters which have already appeared and been calibrated in chapter 4 are now calibrated equally. Those which have not yet been used previously are calibrated in this section.

5.3.1 Known parameters

The parameters which have been estimated or calibrated previously are listed in the table 5.1.

5.3.2 New parameters

The intermediate goods substitution elasticity ψ is calibrated to 11 which is a fairly standard value found in related literature (Michaillat (2014)). The discount factor β is set to 0.99 Aliyev *et al.* (2014). The parameters introduced by the monetary policy rule are: the responsiveness of monetary policy to inflation denoted by μ_π and the interest rate smoothing parameter μ_R which are set respectively to values 1.5 and 0.52 Štork *et al.* (2009). The Rotemberg

symbol	interpretation	value	source
ρ	productivity autocorrelation	0.9968	own calculation
σ_z	standard deviation of productivity	0.0034	own calculation
s	separation rate	0.0024	Hobijna & Şahin (2009)
η	job-filling elasticity	0.7825	own calculation
$\bar{u}$	steady state unemployment rate	0.07143	own calculation
$\bar{n}$	steady state employment rate	0.9308	own calculation
α	production function parameter	0.53	Aliyev *et al.* (2014)
$\bar{\theta}$	steady state labor market tightness	0.1343	own calculation
$\bar{a}$	steady state labor productivity	1	normalization
γ	elasticity of wages	0.7	Haefke *et al.* (2008)

Table 5.1: DSGE model parameters calibrated in the chapter 4

price adjustment cost ϕ is set to a standard value of 50 Bergin *et al.* (2007). The parameter ζ denotes the share of employees working in public sector. According to OECD (2009) for the Czech Republic this share was equal to 12.8% in 1995 and 12.9% in 2005 which makes it relatively stable over time and thus I can assign to ζ the value 0.129. The steady state public employment rate is computed as $\bar{g} = \zeta\bar{n} = 0.1200$ and private employment rate as $\bar{l} = (1-\zeta)\bar{n} = 0.8107$. I will recalibrate the steady state wage w_0 using the firms' labor demand 5.31 in steady state to get $w_0 = 0.5267$ which yields the recalibrated per-period vacancy cost as $r = 0.3205 \cdot w_0 = 0.1688$. The matching coefficient is recalibrated as well using the equality relation for steady state unemployment inflows and outflows $f(\bar{\theta})\bar{u} = \bar{n}s$ where $f(\bar{\theta}) = \frac{\bar{h}}{\bar{u}}$ and $\bar{h} = \omega\bar{\theta}^{-\eta}$. Combining these three relations yields $\omega = \frac{s\bar{n}\bar{\theta}^{\eta-1}}{\bar{u}}$ and after plugging in numerical values I get the matching efficiency equal to 0.0409 which is very close to the mean value of matching efficiency estimates obtained in section 3.

5.4 Results

The model focuses on determining the difference between public hiring and firing during an economic slowdown. I run the simulation using the software Dynare three times in total - once without public response and then with public hiring and finally with public firing as a response to negative labor productivity shock. This approach allows me to assess the impacts of public employment on the economy through impulse responses. The simulation period is 400 weeks.

First, I simulate the model without any intervention from the government.

symbol	interpretation	value	source
ψ	intermediate goods substitution elasticity	11	Michaillat (2014)
β	discount factor	0.99	Aliyev *et al.* (2014)
μ_π	monetary policy response to inflation	1.5	Štork *et al.* (2009)
μ_R	interest rate smoothing parameter	0.52	Štork *et al.* (2009)
ϕ	price adjustment cost	50	Bergin *et al.* (2007)
ζ	public employment share	0.129	OECD (2009)
w_0	steady state wage	0.5267	own calculation
r	per-period vacancy cost	0.1688	$0.3205w_0$
ω	matching efficiency coefficient	0.0409	own calculation
$\bar{g}$	steady state public employment rate	0.1200	own calculation
$\bar{l}$	steady state private employment rate	0.8107	own calculation

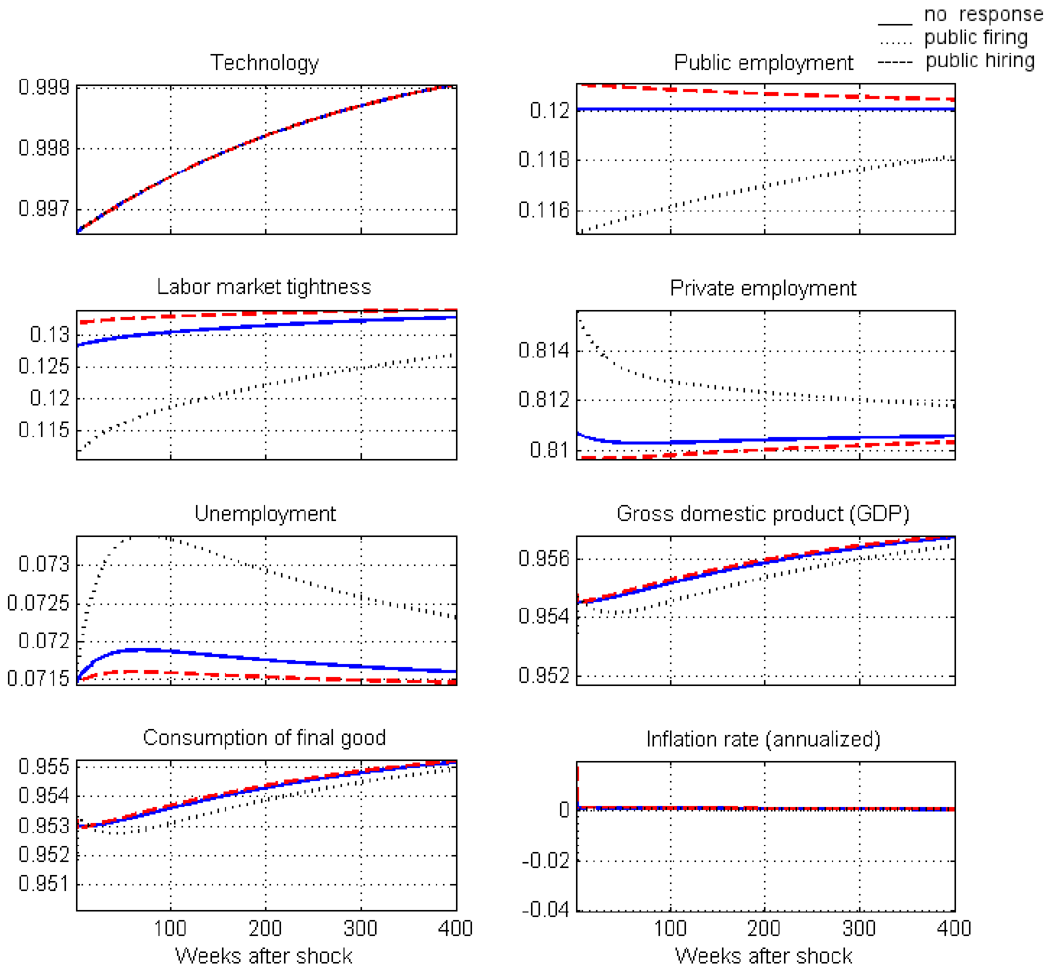
Table 5.2: Remaining DSGE model parameters calibration

The public hiring remains constant after the shock and each period is equal to the number of previously separated $s\bar{g}$ public sector workers so as to maintain their number $\bar{g}$ constant over time. The figure 5.1 depicts impulse response function of labor productivity, public employment, labor market tightness, private employment, unemployment, gross domestic product, consumption and inflation rate in this order. The solid line represents the simulation with constant public hiring and thus constant public employment. The negative shock to labor productivity induces a decrease in wage. However, since wages cannot adjust completely to a decreased labor productivity due to their rigidity, firms are forced to diminish the number of offered vacancies and thus labor market becomes less tight. Private employment thus declines and reaches its trough after 50 weeks. Consequently, unemployment increases and reaches its peak after 50 weeks after the shock. The gross domestic product is computed as a sum of output plus government expenses composed of public workers wage cost and public hiring costs.

$$gdp = y_t + g_t w_t + \frac{ra_t}{q(\theta)}[g_t - (1-s)g_{t-1}]$$

The reaction of GDP is induced by the fall of labor productivity and output. After the initial decline it converges slowly back to its steady state. The behavior of the household consumption of final good copies the behavior of GDP. The inflation rate stationary value is set to 0 and the technology shock influences its behavior only marginally.

The second simulation represented by the dashed line introduces a reaction of the government to a technology shock consisting of hiring an additional



Source: author's computations.

Figure 5.1: Impulse responses to the negative labor productivity shock

0.1% of workers at the time of the shock. After the first period, the public hiring law of motion remains in the form $g_t = s\bar{g} + (1-s)g_{t-1}$. Consequently, the public employment increases. the public hiring creates new vacancies which add up to private vacancies and result in a tighter labor market than in the previous case. With the tighter market comes higher recruitment costs for the private sector firms forcing them to reduce hiring which creates a deeper downswing of private employment than in the previous case and crowding out effect occurs. Despite this effect the overall unemployment increases less than in the previous case without the public employment thus neutralizing the negative impact on private employment. Due to the minimal size of hiring shock the behavior of GDP and consequently consumption is very similar to the first simulation.

The third simulation represented by the dotted line introduces a government reaction to the technology shock consisting of firing 0.5% of workers at the time of the shock. The reason why public firing shock is greater than public hiring is that the Czech government steadily decreases the number of its employees. The number went from 178 574 in 2001 to 164 678 in 2005 and to 159 854 in 2010 (Ministry of the Interior (2011)). The average separation rate in public sector is thus 1.2%. However, I use only half the value due to scaling reasons. After the first period the public hiring law of motion remains in the form $g_t = s\bar{g} + (1-s)g_{t-1}$ and other firing besides exogenous job separation sg_t does not occur anymore. The initial firing shock causes the public employment to drop from its steady state 0.1200 to less than 0.116. The next consequence of public firing is that no public vacancies are created at the time of negative technology shock to compensate for the private vacancy loss. This results in a sharp drop in the labor market tightness. A lowered labor market tightness brings lower recruitment costs for the private sector and thus firms are able to increase their hiring. Despite this positive effect the overall unemployment increases far more than in the previous case with public hiring thus neutralizing the positive impact on private employment.

5.5 Summary of results

The chapter 5 presented a New Keynesian DSGE model with search and matching frictions and public employment. The model was based on Michaillat (2014) but a significant alteration was made. The author focuses only on the public hiring and compares its effects on the model variables separately after a positive and after a negative technology shock and then proceeds to compute fiscal multipliers. Due to the Czech government long term goal to diminish the public sector size, I decided to adjust the model accordingly.

The model driving force is the negative labor productivity shock since the focus is on public employment effects during the economic slowdown. The simulation is run three times. Firstly without the public response when the government keeps the public employment stable over time. The second simulation consists in an unexpected hiring of additional 0.1% of workers at the time of the shock. The result is that the overall unemployment in the economy decreases despite private employment crowding out. The last simulation includes an unexpected firing of 0.5% of workers at the time of the shock. As shown, during the last decade the Czech government has been steadily diminishing the number of public jobs. Every year approximately 1.2% of public job are destroyed. The positive effect on the private employment is mitigated by large drop in the labor market tightness and consequently 50 weeks after the shock the overall unemployment reaches its peak with an increase of more than 0.15% comparing to the steady state.

The results suggest that the public hiring as an unemployment policy tool could be successfully employed during an economic slowdown to mitigate the overall unemployment since the public employment crowding out effect is neutralized. Also, the model results show that the negative effect of the persisting public jobs destruction policy used over the last decade outweigh possible advantages such as savings on government expenditures.

Chapter 6

Conclusion

This thesis examined the condition of the Czech labor market with particular focus on unemployment over the last 15 years. The overview of the literature related to the Czech labor market suggested that the transformation process from central planning to market economy brought significant changes of the labor market structure and also an increase in unemployment rate at the beginning of the previous decade. However, as it was found out the high unemployment rate was not due to mismatch between workers and jobs but rather due to the insufficient labor demand and the still ongoing transition process.

The second chapter aimed at investigation the structural changes in the Czech labor market over the last 15 years by estimating the matching function parameters with the fixed effects model. The results show that before 2004 the Czech economy had still been transforming and the mismatch between jobs and workers had not been significant. After 2004, the mismatch began to behave in accordance with the economic growth. During robust economic growth periods the mismatch was high and induced by structural changes in the labor market. Conversely, during periods of economic slowdown the mismatch between jobs and workers was not very problematic.

The third chapter defined two components of unemployment - cyclical and structural and focused on determining their behavior with regard to the economic growth. The DSGE model with incorporated labor market block and search and matching frictions yielded a result that the overall unemployment and its cyclical component gradually increase after a negative technology shock, while structural component diminishes. This is due to the fact that during the economic slowdown the gross marginal profit of firms, which is tied to the labor productivity, is lower and thus firms terminate a portion of existing worker-job matches and also they are not prone to open enough vacancies. In order to determine the behavior and size of the two unemployment components during the last 15 years a nonlinear rational expectations model was employed. The results are in line with the results from the chapter 2. After 2004, three economic slowdown and three robust growth periods occurred. During a robust growth of the economy the cyclical unemployment diminished while the structural increased which is confirmed by the high mismatch level in the labor market. During an economic slowdown the situation was exactly the opposite. The results suggest that a government policy targeted towards unemployment mitigation should take the ongoing condition of the economic growth into consideration. Wage subsidies or a direct employment seem to be an appropriate tool during the economic slowdown whereas placement services should be preferred during the robust growth periods.

The last chapter examined the public employment, which is one of the suggested policy tools suitable during an economic slowdown which. As it was shown, the Czech government has been focusing on cutting public expenditures and consequently the size of public sector and number of public jobs, rather then on public hiring. The DSGE model with the government block was used to compare the effects of public firing with potential benefits of public hiring after a negative labor productivity shock. The result is that despite the private employment crowding out effects caused by even a very low percentage of workers hired by the government, the overall unemployment is diminished and therefore the public hiring might be an effective tool to reduce unemployment during economic slowdown periods.

This thesis examined the effectiveness of one particular unemployment policy. However, the variety of possible policy tool is rather rich and their effects on the labor market with regard to the economic growth are worth focusing on. Also, the models throughout the chapters used the exogenous separation rate but the decision of destroying a worker-job match might presumably be given endogenously, as some studies have pointed out recently. Therefore, future research of the labor market dynamics in the Czech Republic should focus on these issues as well.

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