Estimating structural changes of the Czech economy: How convincing are the symptoms of the economic crisis?

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Abstract. The goal of our contribution is to find possible changes in the Czech economy in the last fifteen years. We are concerned with the questions of stability of the relationships among the key economic variables. These relationships are expressed particularly by the dynamic Okun's law, Phillips curve, IS curve or the Taylor's rule. The cyclical development of the economy is based on the simultaneous estimation of the four (unobserved) natural rates potential output, NAIRU, equilibrium real interest rate and equilibrium real exchange rate. Unlike the mainstream (DSGE) models we use an alternative, non general equilibrium model without any strong restrictions on the parameter and model equations. Our results (among others) show that the significant changes of parameters are identified only in the period of the last economic downturn beginning the fourth quarter 2008 and that these changes influenced only a part of the key model parameters.

Keywords: recursive estimation, recursive forecast, natural rates, Bayesian estimation.

JEL classification: C53, E37
AMS classification: 91B55, 91B64

1 Introduction

The goal of our contribution is to find possible changes in the Czech economy in the last fifteen years. We are concerned with the questions of stability of the relationships among the key economic variables. We identify the cyclical development of the Czech economy within the framework of a dynamic monetary model with the exogenous foreign sector. The cyclical development of the economy is based on the simultaneous estimation of the four (unobserved) natural rates. Using recursive parameter estimates we are able to find and analyze important changes in parameter values which correspond to the structural changes of the Czech economy. We pay close attention to the period of the the economic crisis starting in the second half of the year 2008. Unlike the mainstream (DSGE) models we use an alternative, non general equilibrium model without any strong restrictions on the parameter and model equations.[1] That means it may provide better forecasting results (among other). These forecast abilities are tested using recursive forecasts. From this point of view we are able to show how precise are the predictions of the key economic variables (including natural rates) with respect to periods of sudden booms and recessions. The trajectories of the natural rates are treated as short-term (or medium-term) deviations from long-term potentials of the economy which represent best the economic dynamics and cycles.

Our contribution is structured as follows. The next section provides a simple variant of the dynamic monetary model which is used for our analysis. Section 3 explains used data, estimation techniques and basic parameters estimates. In Section 4, our estimates of unobserved states of the Czech economy are presented. Section 5 presents recursive estimates and forecasts which serve as a starting point for our analysis. Section 6 shows and comments unemployment dynamics during economic downturns. Section 7 concludes this contribution.

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[1]See Herber and Němec [3] for estimates of output gap in the Czech Republic using DSGE approach.

2 The Model

Our model is a modified version of the original model developed by Berg, Karam and Laxton [1]. We have extended this model by equations which represent unemployment dynamics. We have chosen this strategy because of successful estimation of similar (but smaller) model presented by Laxton and Scott [5] and estimated using the Czech data by Němec [6]. This smaller model does not contain the equations explaining the dynamics of real interest rate and real exchange rate and the monetary rule. Unlike Berg, Karam and Laxton we have attempted to explain movements in equilibrium real output, real exchange rate, real interest rate and equilibrium unemployment. It means that we have performed a simultaneous estimation of these unobserved economic variables.

Our model has five behavioral equations which expresses each variable in terms of its deviation from equilibrium. Our notation of the variables is self-explaining. Greek letter ϵ expresses appropriate shocks (demand shock, supply shock, monetary shock etc.) and the index "*" denotes equilibrium variables.

$$ygap_t = \alpha_1 ygap_{t-1} + (1-\alpha_1) ygap_{t+1} - \alpha_2 RRgap_{t-1} - \alpha_3 zgap_{t-1} + \alpha_4 ygapF_t + \epsilon_t^{ygap}, \quad (1)$$
$$\pi_t = \delta_1 E_t \pi 4_{t+1} + (1-\delta_1)\pi 4_{t-1} + \delta_2 \pi^m_{t-1} + \delta_3 ygap_{t-1} - \delta_4 \Delta z_t - \delta_5 \Delta ugap_t + \epsilon_t^{\pi}, \quad (2)$$
$$RS_t = \beta_1 RS_{t-1} + (1-\beta_1)[RR_t^* + \pi 4_t + \beta_2(\pi 4_{t+4} - \pi^*_{t+4} + \beta_3 ygap_t] + \epsilon_t^{RS}, \quad (3)$$
$$z_t = \gamma_1 z_{t+1} + (1-\gamma_1) z_{t-1} + (RR_t - RRF_t - \rho_t^*)/4 + \epsilon_t^z, \quad (4)$$
$$ugap_t = -\lambda_1 ygap_t + \lambda_2 ugap_{t-1} + \epsilon_t^{ugap}. \quad (5)$$

Equation (1) represents an aggregate demand or IS curve that relates the level of real activity (output gap, *ygap*) to expected and past real activity (output gaps), real interest rate gap, *RRgap*, the real exchange rate gap, *zgap*, and the foreign output gap, *ygapF*. The New Keynesian hybrid curve is represented by the equation (2) that relates annualized quarterly inflation (π) to past and expected inflation ($\pi 4$ represents four-quarter change in consumer price index – CPI), output gap, changes in exchange rate and unemployment gap (*ugap*). Equation (3) is monetary policy rule for setting the short-term (policy) nominal interest rate (RS) as a function of the output gap and expected inflation to achieve a target level for inflation, π^*. Equation (4) shows an uncovered interest parity condition for the exchange rate (z), where RR is the policy real interest rate, RRF is the foreign real interest rate a ρ^* is the equilibrium risk premium. The last equation (5) defines the dynamic Okun's law, where the unemployment gap depends on its past value and the current output gap.

Unobserved equilibrium variables are modelled as random walks. Potential output is augmented by a drift (growth rate, gy_t^*) and by a term which represents changes in equilibrium unemployment, NAIRU (Δu_t^*). This modification has improved identifiability of both the potential output and equilibrium unemployment (NAIRU).

$$y_t^* = y_{t-1}^* + gy_t^* - \phi \Delta u_t^* + \epsilon_t^{y^*}, \quad (6)$$
$$gy_t^* = gy_{t-1}^* + \epsilon_t^{gy^*}, \quad (7)$$
$$RR_t^* = RR_{t-1}^* + \epsilon_t^{RR^*}, \quad (8)$$
$$z_t^* = z_{t-1}^* + \epsilon_t^{z^*}, \quad (9)$$
$$u_t^* = u_{t-1}^* + \epsilon_t^{u^*}. \quad (10)$$

The gaps and real interest rate are naturally defined as follows:

$$ygap_t = y_t - y_t^*, \quad (11)$$
$$RR_t = RS_t - \pi 4_{t+1}, \quad (12)$$
$$RRgap_t = RR_t - RR_t^*, \quad (13)$$
$$zgap_t = z_t - z_t^*, \quad (14)$$
$$ugap_t = u_t - u_t^*. \quad (15)$$

For estimation purposes, AR(1) stochastic processes are defined for exogenous (observed) variables:

$$ygapF_t = \psi^{ygapF} ygapF_{t-1} + \epsilon_t^{ygapF}, \tag{16}$$

$$RRF_t = \psi^{RRF} RRF_{t-1} + \epsilon_t^{RRF}, \tag{17}$$

$$\pi 4_t = \psi^{\pi 4} \pi 4_{t-1} + \epsilon_t^{\pi 4}, \tag{18}$$

$$\pi_t^* = \psi^{\pi^*} \pi_{t-1}^* + \epsilon_t^{\pi^*}, \tag{19}$$

$$\pi_t^m = \psi^{\pi^m} \pi_{t-1}^m + \epsilon_t^{\pi^m}, \tag{20}$$

$$\rho_t^* = \psi^{\rho^*} \rho_{t-1}^* + \epsilon_t^{\rho^*}. \tag{21}$$

This model is structural because each of behavioural equations has an economic interpretation. It is general equilibrium model because the main variables are endogenous and depend on each other. It incorporates rational expectations. This model is not derived from microeconomic foundations (as compared to traditional stochastic general equilibrium models – DSGE) but the core equations are very similar to those arising from DSGE approach. We believe (in accordance with Berg, Karam and Laxton [1]) that *"this pragmatic approach to modelling represents the current state of the art in many policymaking institutions, where modellers embrace theory but do not feel compelled to marry it."*

3 Data and estimation techniques

We estimate the model of the Czech economy for the period of 1996:1 to 2009:4. The observed variables are logarithm of real output, unemployment rate, q-o-q and y-o-y CPI inflation, short-term nominal interest rate, real exchange rate, inflation target, import price inflation, foreign output gap and foreign real interest rate. All data are seasonally adjusted and prefiltered using Hodrick-Prescott (HP) filter applied on extended time series to avoid the problem with the turbulent dynamics of the latest observations. We have concentrated primarily on medium-term potentials of the economy and their dynamics. HP filter is the best way to remove the long-term trends (which are out of our concern) from the variables (the variables used are expressed as corresponding gaps). The data are from databases of the Czech National Bank and the Czech Statistical Office.

Param.	Prior (std.)	Post.	HPDI		Param.	Prior (std.)	Post.	HPDI	
α_1	.500 (.200)	.474	.428	.519	$\sigma^{\epsilon^{ygap}}$	.20 (1.0)	.362	.298	.428
α_2	.040 (.015)	.037	.026	.048	$\sigma^{\epsilon^{\pi}}$	1.50 (15.0)	3.049	2.557	3.519
α_3	.004 (.001)	.006	.004	.007	$\sigma^{\epsilon^{RS}}$	1.50 (7.0)	1.359	1.135	1.560
α_4	.050 (.025)	.039	.022	.055	$\sigma^{\epsilon^{ugap}}$	.40 (5.0)	.111	.083	.140
δ_1	.700 (.100)	.807	.697	.928	$\sigma^{\epsilon^{z}}$	2.50 (15.0)	1.265	.756	1.763
δ_2	.085 (.040)	.122	.049	.194	$\sigma^{\epsilon^{y^*}}$	.10 (6.0)	.099	.021	.215
δ_3	.100 (.050)	.090	.025	.156	$\sigma^{\epsilon^{gy^*}}$	.10 (1.5)	.057	.024	.090
δ_4	.040 (.020)	.035	.008	.062	$\sigma^{\epsilon^{RR^*}}$	.65 (5.0)	.380	.250	.516
δ_5	.450 (.200)	.448	.143	.748	$\sigma^{\epsilon^{z^*}}$	1.5 (5.0)	1.148	.361	2.089
β_1	.800 (.050)	.811	.762	.863	$\sigma^{\epsilon^{u^*}}$	.40 (5.0)	.121	.086	.152
β_2	1.500 (.200)	1.271	.981	1.540	$\sigma^{\epsilon^{ygapF}}$	.90 (4.5)	.789	.671	.908
β_3	.500 (.150)	.780	.536	1.026	$\sigma^{\epsilon^{RRF}}$	.40 (3.0)	.420	.356	.481
γ_1	.750 (.100)	.849	.750	.853	$\sigma^{\epsilon^{\pi 4}}$	1.20 (4.0)	1.306	1.105	1.503
λ_1	.250 (.050)	.178	.150	.207	$\sigma^{\epsilon^{\pi^*}}$	.10 (1.0)	.097	.082	.112
λ_2	.800 (.050)	.802	.750	.853	$\sigma^{\epsilon^{\pi^m}}$	6.50 (10.0)	3.886	3.284	4.472
ϕ	.500 (.100)	.520	.344	.685	$\sigma^{\epsilon^{\rho^*}}$	0.10 (2.0)	.074	.062	.085
ψ^{ygapF}	.970 (.010)	.950	.931	.970	ψ^{RRF}	.920 (.020)	.895	.863	.931
$\psi^{\pi 4}$	.920 (.015)	.901	.871	.929	ψ^{π^*}	.980 (.005)	.979	.971	.987
ψ^{π^m}	.700 (.100)	.758	.653	.855	ψ^{ρ^*}	.970 (.010)	.971	.957	.986

Table 1: Parameter estimates (full sample)

Parameters are estimated using Bayesian techniques combined with Kalman filtering procedures. All computations have been performed using Dynare toolbox [4] for Matlab. Some interesting technical details corresponding to recursive estimates and forecasts offer Christoffel, Coenen and Warne [2].

Our results (using full sample) are shown in Table 1. All parameters estimates have the correct (positive) sign. The most of the parameters are well identified using the data (especially standard deviations of the shocks). The aim of our paper does not us enable to comment each particular estimate. We will focus on some of them in the next sections. Nevertheless, we have to point out that these parameter values lead to acceptable dynamic properties of our model which have been verified by impulse-response function.

4 Estimates of unobserved states

Our first goal is to identify the periods of the booms and recessions in the development of the Czech economy. Using smoothed variables of the key unobserved states of the economy (see Figure 1), we are able to find three significant periods of economic downturn (see the grey bars in Figure 1). The first economic recession started (approximately) in the fourth quarter of 1997, the second slump of the economy has been found at the beginning of the second quarter of 2003 and the biggest fall of the Czech economy is connected with the last quarter of 2008. We understand the period of recession as a period with negative output gap.

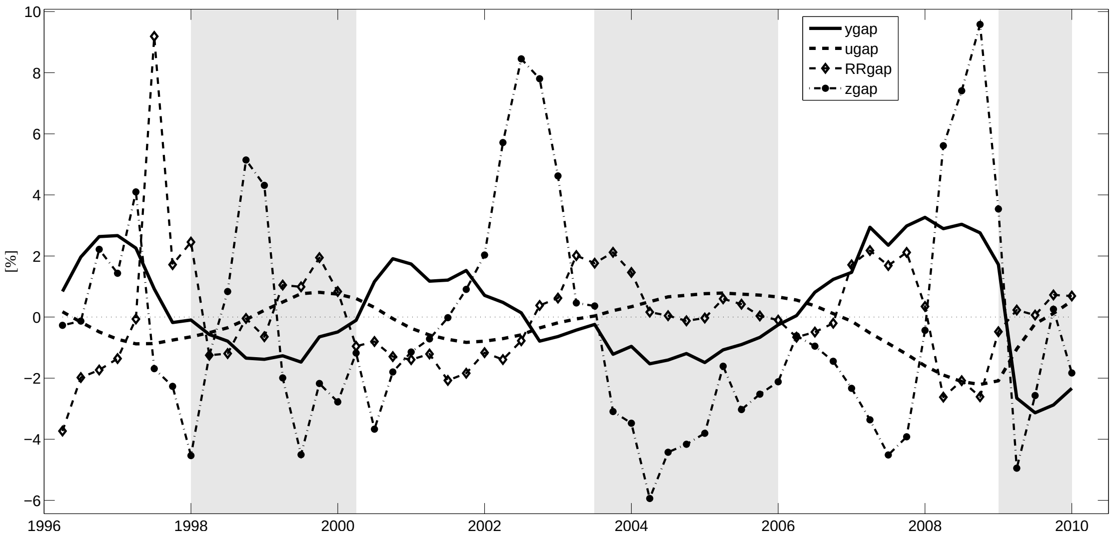

Figure 1: Output gap, unemployment gap, real interest rate gap and real exchange rate gap

5 Recursive estimates and forecasts

After identifying the periods of recessions, we are able to analyze influences of these changes on the model parameters. Figure 2 shows recursive estimates for the most influenced parameters. Unfortunately, the lack of data does not allow us to include the period of the first recession in 1997 into our analysis.

We can compare recursive estimates during the periods of two economic downturns. It is obvious that the downturn in 2003 was not accompanied by any important structural changes of model parameters. It seems that the source of crisis was solely internal overheating of the Czech economy. On the other hand, the economic fall in 2008 has been caused by exogenous factors which influenced some interesting structural parameters of our model as follows:

- Our estimates of standard deviations of both demand shock and shock of foreign output gap show a significant growth. We can see current slowdown of the Czech economy as a result of an immense fall in foreign output and domestic demand. This conclusion is supported by recursive estimates of parameters α_1 and α_4 which pointed out a decreasing effect of lagged output gap and an increasing influence of foreign output gap respectively.

- Parameters β_1 and β_2 describe the reaction function of monetary authority. In our case, we can see that the Czech National Bank has lowered the weight placed on inflation objectives (β_2). "Smoothing" parameter β_1 has suffered a mild increase. It means that monetary policy is more predictable and there is thus only a little "danger" of unexpected monetary shocks. From this point of view, a "no change" of parameters in 2003 reflects only a transitory character of the shocks occurred in this recession.
- An increasing influence of real exchange rate (γ_1) is associated with a higher volatility (uncertainty) in this variable. Economic agents have less confidence in past development of exchange rate in their decisions.
- The trajectories of parameters λ_1 and λ_2 represent remarkable changes in unemployment dynamics. At first we can find decreasing trend in the influence of output gap (from 2000 to 2007) and growing tendencies since 2007. This development is in accordance with hysteretic properties of the Czech unemployment (see Němec [6] and the effects of the negative and positive hysteresis). As for the lagged unemployment gap, there is an increasing influence since 2007 with a turning point at the end of 2008. At the beginning of the last recession there was a clear evidence of negative unemployment gap resulting from the lack of employees in the Czech economy. This negative gap has been closed as a result of the last economic slowdown.

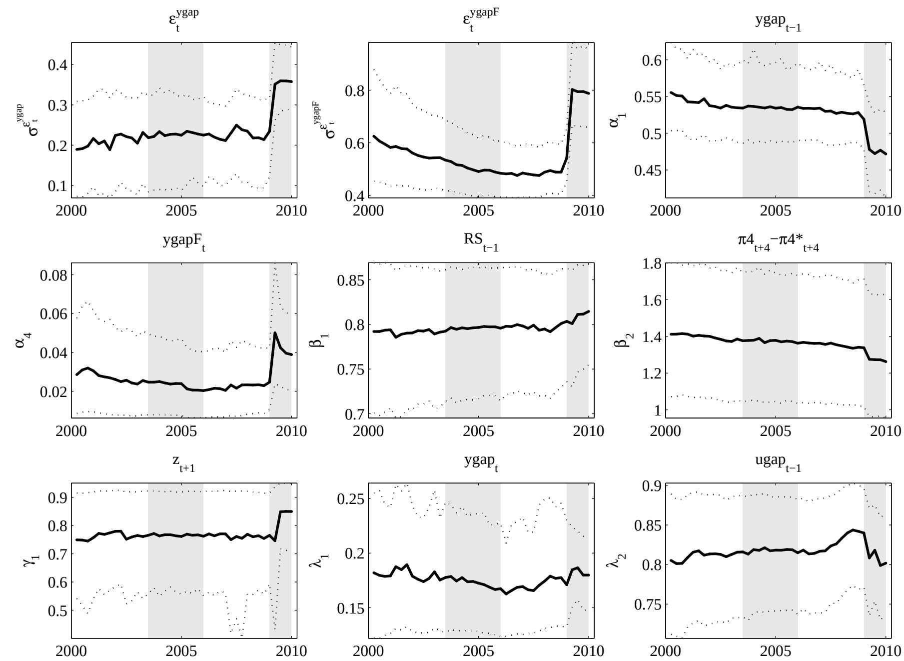

Figure 2: Recursive esimates of selected parameters

In order to verify the reliability of our results we have tested the accuracy of short-term out-of-sample forecasts. The accuracy of the forecasts of one- to four-quarters-ahead for the period 2000:2 to 2009:4 has been evaluated using the Theil U statistics. This statistics measures the ratio of the root mean square error (RMSE) forecasts generated by our model to the RMSE of naive (no change) forecasts:

$$U_k = \frac{\sqrt{\frac{1}{n_k}\sum_{t=17}^{T-k}(y_{t+k} - f_{t+k})^2}}{\sqrt{\frac{1}{n_k}\sum_{t=1}^{T-k}(y_{t+k})^2}},$$

where k is the forecast horizon (in our case, $k = 1, \ldots, 4$), y_{t+k} is the observed variable in time $t + k$, f_{t+k} is predicted value of the corresponding variable (based on estimates using all available data until time t) and n_k is the number of k-ahead forecasts. In our case, $t = 17$ means the observations of 2000:1 and $T = 56$ corresponds to the observation 2009:4.

A U value equal to one would suggest that the model forecasts are as good as naive. The statistics greater (or less) than one shows that the model forecast is worse (or better) than the forecasts from the "no change" model.

Our recursive forecasts with parameters and future shocks uncertainty are depicted in Figure 3. "Predicted" values are expert opinions about the future development of the key economic variables in 2010.

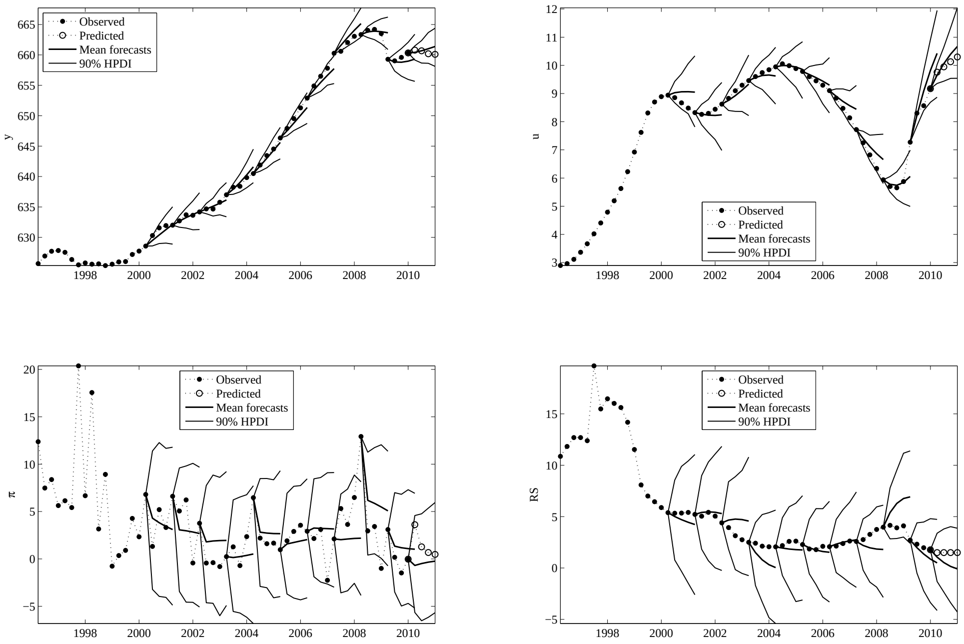

Figure 3: Recursive forecasts with parameters and future shocks uncertainty

Forecast horizon	y	u	π	RS
1 quarter ahead	0.6299	0.6444	0.8396	1.7047
2 quarters ahead	0.5502	0.6739	0.8607	1.7815
3 quarters ahead	0.4889	0.6536	0.8328	1.7733
4 quarters ahead	0.4430	0.6463	0.8161	1.7350

Table 2: Accuracy of recursive forecasts using Theil statistics

The conclusion from Table 2 are as follows:

- Log of real output (y): based on the Theil statistics for one to four-quarter ahead forecasts, our model outperforms the "naive" model. Our model is able to forecast real GDP pretty well.
- Unemployment rate (u): our model has a good ability to predict the future dynamics of the unemployment rate. This result speaks in favour of our model extending by the unemployment equation.
- CPI inflation (π): in this case, we have found a poor performance of our model to forecast future movements in inflation. There might be two reasons for this conclusion. The first one may reflect a weak specification of the Philips curve. The second one might result from the high variability of the inflation shocks (see Table 1).
- Nominal short-term interest rate (RS): our model performs very bad regarding the abilities to forecast the nominal short-term interest rate. There may be some explanations for this problem – high variability of the monetary shock and a difficult estimation of the monetary rule using observed data.

Overall forecast performance of our model seems to be good with regard to the uncertainty connected with the future realizations of corresponding shocks. Forecast abilities of the model are very similar in all periods (regardless the state of the economy – see Figure 3 and compare the particular turning points in observed and forecasted trajectories).

6 Unemployment dynamics

Figure 4 shows the relationship between the output gap and the unemployment gap. A relative stable relationship has been disrupted in 2007. This fact has been proved performing Chow tests for structural break at observation of the first and the second quarter of 2007. Corresponding test statistics were 3.2 (p-value 0.05) and 6.1 (with p-value 0.00) respectively.

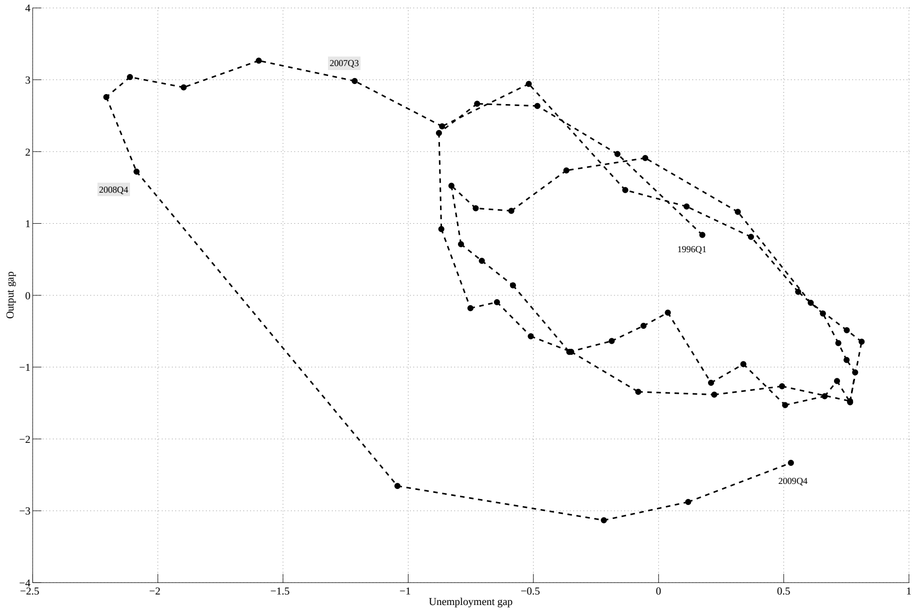

Figure 4: Dynamic Okun's law

The underlying story has been mentioned in the previous section. As a result of overheated economy and corresponding lack of employees, there was a significant fall of the Czech unemployment rate. The economic crisis at the end of 2008 cleared the labour market and dampened inflation pressures. As seen from the Figure 4, this tendency might be meant to be a return to equilibrium dynamics of unemployment.

7 Conclusion

This contribution does not pretend to be more than a short review of the main results associated with our detailed analysis of business cycles in the Czech economy. A key potential advantage of our approach we propose is that it uses a very flexible and pragmatic macroeconomic model. Leading ideas from foregoing results may be briefly summarized as follows:

- Using our pragmatic model, we are able to obtain reliable estimates of the equilibrium trajectories of the key economic variables. We have identified three periods of recession.
- Only some structural parameters are significantly influenced by the economic crisis beginning in the fourth quarter 2008. These parameters are connected with a high degree of openness of the Czech economy and with the changes in unemployment dynamics and in monetary policy. We have found no evidence for the structural changes during the economic slowdown 2003 – 2006.
- Our model is able to provide reasonable short-term (mean) forecasts of real output and unemployment. Uncertainty of future inflation and nominal interest rate is relative high as a consequence of high volatilities of the monetary and supply shocks.
- It is obvious that the global economic crisis plunged the Czech economy into an exceptionally deep recession in late 2008 which "fixed" negative tendencies in unemployment dynamics (represented by strongly negative unemployment gap).

Acknowledgements

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