5. P-STAR MODEL UNDER THE CURRENCY BOARD – THE CASE OF BULGARIA 1997-2008[1]

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Abstract

The paper deals with the P-star model in conditions of the Bulgarian economy operating under the currency board regime. The research period covers 11 years of stabilisation after the Bulgarian 1996/97 financial crisis. Our findings are twofold. First, the significant influence of the German inflation was detected as a result of anchoring the Bulgarian Lev. Second, the domestic price gap influence is showed to be statistically insignificant.

Keywords: P-star model, Bulgaria, inflation, price gap
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1. Introduction

Quantity theory of money is a traditional theory explaining the inflation. The basic principles of the theory were based on the proportionality assumption (price level proportionally reacts to the money stock changes) and assumption of money neutrality (i.e. real output is fully independent on the stock of money). However, later developed theories weakened both assumptions, the idea of the causal relation between money stock and prices development remained undisputed. When the Federal Reserve Board of Governors in Washington needed to develop a consistent model of inflation, Hallman, Porter and Small (1991) formulated P* (P-star) model based again on the traditional quantity theory of money. On contrary to the traditional approach, the authors distinguished between short-term and long- term periods of the inflation development. The methodology of the error-correction models was here also used.

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Within the model, the price gap (difference between the actual and equilibrium price levels) is correcting the actual price movements in the direction to restore equilibrium. On the other hand, the short-term inflation exhibits short-term memory pattern.

As the model was primarily formulated for the relatively closed U.S. economy, the authors neglected the role of foreign trade. This shortage was later eliminated by Kool and Tatom (1994) who formulated the model for five small- and medium-seized European economies. As these economies share major part of their foreign trade with Germany, the German price gap was also incorporated. The model showed improved results if compared to the Hallman et al. (1991) autarkic economy methodology.

Extending the P-star model to analyse and predict the inflation also in case of other economies, authors should face new methodological problems. As in the U.S. case the velocity of money was stable in the long run, there are some countries, where the velocity demonstrates increasing or decreasing trends. In the case of the small economies with the pegged currency exchange rate to the currency of the anchor economy, this becomes a typical case. We distinguish two typical cases of the trend velocity. First, the equilibrium velocity computed using the Hodrick-Prescott filter as proposed by Hoeller and Poret (1991) and Kool and Tatom (1994) in case of the identified stochastic trends in the original time series. On the other hand, Groeneveld (1995) used the Kalman filter in the similar situation. Second, the deterministic trend was treated in the case of the German economy (Tödter and Reimers, 1994).

Usage of the money aggregate becomes a subject of further fruitful discussion. As Tödter and Reimers (1994) and Gerlach and Svensson (2001) used the M3 aggregate, Hallman *et al*. (1991) used M2 and Anglingkusumo (2005) quantifying the model for Indonesia, used the M1. Tatom (1990) identified several specification errors in the M2-based P-star model and preferred to use the M1 as a more appropriate variable. On the other hand, Frait *et al*. (1998) showed that there are no significant distinctions in-between M1 and M2 aggregates.

The rest of the paper is organized as follows. In the second section, a short description of the currency board introduction in Bulgaria is given. The model is described in the third section. Data and P-star model for the Bulgarian economy based on the pre-crisis period is formulated in the fourth section. The fifth section brings the final results discussion.

2. The Currency Board in Bulgaria

In middle 90's, Bulgaria had failed more stabilisation attempts and the national economy faced enormous problems. Delaying of the structural reforms and political instability caused a financial as well as an economic crisis. The crisis culminated in 1996/97 when GDP contracted by 10 percent (in 1996) and falling tax incomes enforced the government to issue a considerable amount of the short maturity treasury bills with high nominal interest rates. In March 1997, the annual inflation achieved 2000 percent. The real liquidity contraction caused serious problems in the banking system, where 9 of 10 state banks (accounting for 80 percent of the banking sector) had negative capital. Protecting the domestic currency, the central bank depleted its currency reserves, which fall to the level covering less than 2 months of imports. On the other hand, the foreign debt to GDP ratio increased to almost 160 percent of GDP. The Bulgarian currency depreciated from lev 487 to lev 1.588 per $ 1 in the first quarter 1997.

In the end of 1996, the IMF mission initiated the first round of discussions regarding the currency board, which was really introduced in the middle of 1997. The anchor currency became Deutsche Mark (later Euro) with the exchange rate - lev 1.000 to DM 1. To increase the currency reserves, the credits of the International Monetary Fund, World Bank and G7 countries were accepted.

However, the currency board regimes differ in various countries, its main tools were fully applied in the Bulgarian case: fixed exchange rate between the domestic and the anchor currencies, their automatic convertibility, and limitation of issuing the high power money necessary fully backed up by disposable currency reserves. After that, Bulgaria reduced its annual inflation to 1 percent by the end of 1998 and rebuilt its currency reserves to more than $3 billion (covering 6 months of imports). The basic interest rate fell to 5.2 percent by the end of 1998 and the fiscal balance became positive. The following 10 years period was characterized by the gradual financial stabilization and improvement in all financial and economic indicators.

3. The Model

The HPS P-Star Model

Hallman *et al*. (1991) formulated the P-star model being motivated by the equation of the quantity theory of money

$$PY = MV, \tag{1}$$

where: P is a price level, M is a money stock, V is a money velocity and Y is a real output. Within the rudimentary version of the quantity theory of money, real output *Y* and money velocity *V* are assumed to be constant and price level *P* to be fully determined by the actual money stock. In the P-star model, we postulate this relation between money stock and prices only in the long-run, where equilibrium price level P* is given as

$$P^* = M \times V^*/Y^*. \tag{2}$$

Here, the potential product Y^* attracts the real product *Y*, the actual velocity V tends to approach the to the equilibrium money velocity *V** and money stock supply *M* is considered to be exogenous. Both equilibria (*Y**, *V**) are assumed to be determined independently, and, more importantly, both are independent of the money stock. Then, the equilibrium price level can be interpreted as money stock necessary to serve the unit potential product respecting the equilibrium money velocity. Here, the money stock influences exclusively the short term velocity *V* as well as the short term real product *Y*. Expressing (1) and (2) in logs and subtracting (2) from (1), we get a price gap as the percentage deviation of the actual price level from its equilibrium value as

$$GAP^D = p - p^* = (v - v^*) - (y - y^*), \tag{3}$$

where: small letters denote natural logarithms of the respective variables. Thus, the price gap is explained by the real factors related with the capacities utilization (output gap) as well as monetary factors given by surplus/deficit of money stock (velocity gap). It is assumed, the price gap has the tendency to be closed in the long-run, i.e. the periods with prevailing actual price level over its equilibrium value must be alternated with the periods of the lower than equilibrium prices. This concept leads to the idea of the econometric model with the error correction price gap component, which has the form

$$\Delta p_t = \alpha_0 + \alpha_1 GAP_{t-1}^D + \sum_{i=1}^{n} \beta_i \Delta p_{t-i} + u_t. \tag{4}$$

where: Δp_t denotes inflation in time *t*, u_t is a random term, regression coefficient α_1 denotes speed of the prices adjustment towards the equilibrium (coefficient is assumed to be negative), β_i are inflation short memory coefficients. Functioning of the model is based on the assumption that variables representing current velocity of money v, price level *p*, and real GDP *y* are integrated of order 1. As the v and *y* variables are non-stationary and if they contain stochastic trends, their equilibria would be expressed using the Hodrick-Prescott filter. On the other hand, the price gap GAP^D is assumed to be integrated of order 0.

As the above given model fully neglects the role of foreign trade, its application is restricted only for large and relatively autarkic economies. This form of the model was used by Kole, Leahy (1991) in case of Germany and Japan; Pallardo and Esteve (1999) in case of Spain and others.

The Kool and Tatom P-Star Extension

Kool and Tatom (1994) adapted the model for small open economies operating under the fixed exchange rate regime. These economies are often related to the larger „anchor" economy and the price development of the smaller domestic economy is mainly determined by the economic policy pursued by the anchor economy. The model is based on the long-run functioning of the law of one price under the fixed exchange rate regime as given in formula

$$P^{D*} = EP^{F*} / R^*, \tag{5}$$

where: P^{D*} is the equilibrium price level of the domestic economy determined by the equilibrium price level of the anchor economy P^F, *E* is a fixed nominal exchange rate and R^* is an equilibrium real exchange rate. As we assume that the law of one price works in long-run, there is a gap between the actual domestic price level and the equilibrium price level determined by the anchor economy

$$\begin{aligned} GAP^F &= (p - p^{D*}) = [p - (p^{F*} + e - r^*)] = \\ &= [p - (m^F + v^{F*} - y^{F*} + e - r^*)] \end{aligned} \tag{6}$$

where: small letters denote logs of the respective variables, *p* is an actual domestic price level and superscript ^{F} denotes the respective variables of the anchor economy. Kool and Tatom (1994) assumed that in case of the fixed exchange rate regime, the domestic authorities have limited power to influence the domestic money stock and the price level development will be influenced mainly by the price gap determined by the anchor economy. In this case, the model takes the form

$$\Delta p_t = \alpha_0 + \alpha_1 GAP_{t-1}^{D} + \alpha_2 GAP_{t-1}^{F} + \sum_{i=1}^{n} \beta_i \Delta p_{t-1} + u_t. \quad (7)$$

where: α_1 and α_2 are expected to be negative to enforce closing of the price gaps. Inclusion of both gaps into the model enables preserving the possible domestic price gap impact and avoiding the misspecification error. However, Kool and Tatom (1994) assume no statistically significant impact of GAP^D on the current inflation, on the other hand, they admit also some influence caused mainly by the capital mobility rigidities in the domestic economy. In case of both gaps, all respective time series are assumed to be integrated of order 1 and the Hodrick-Prescott filter is applied to quantify their equilibria. Here, the price level equilibrium is quantified according to the logarithmic form of the expression (5). As model (4) is nested in (7), the statistical insignificance of α_2 would reject the role of the foreign price gap GAP^F and the domestic price gap GAP^D would become the only significant factor. In this case, the Kool and Tatom extension would be proved to be non-relevant.

4. Data and the P-Star Model in Bulgaria

Quarterly time series covered time period 1997:1-2009:2, which characterizes the currency board regime in Bulgaria. The tail data (the first two quarters of 1997 and the last two quarters of 2009) were used to capture seasonality and further were not used. Data were collected from the Eurostat database (nominal and real GDP of both countries; Bulgarian M2 aggregate) and the databases of the National Bank of Bulgaria (nominal exchange rate BGN/EUR) and German Federal Bank (German M3 aggregate). As the time series of the GDP‘s were not seasonally adjusted, the classical multiplicative method was applied to remove the seasonal components. Then, the GDP deflators of both countries were obtained by division of the nominal and real GDPs. The GDP deflator was expressed as a base fixed index with the base period 2000:1. Downloaded M2/M3 aggregates were in the form of seasonally adjusted monthly time series and into the quarterly series form were transformed using the end-of–period method. Using (1), the money velocity was obtained by division of the nominal GDP and the respective money aggregate. After that, all time series were logarithmically transformed to stabilize variability and meet the form of the error correction models given in (4) and (7).

The potential product, the equilibria of both the price levels and money velocities play key role in the P-star model. In distinction to the HPS (1989) US data model (assuming the velocity to be stationary), we deal with the velocity exhibiting come kind of the trend. Different researchers faced this fact differently. Herrmann and Toedter (1990) used a simple estimated money demand function, in other cases the authors detected the deterministic trend, etc. On the other hand, most of the P-star papers describe the application of the Hodrick Prescott filter in measuring the equilibrium velocity. The similar situation is in determining the potential product. Some authors use the theoretical base of the Philips curve or approximate the potential product by real private consumption (Anglingkusumo, 2005). Again, most authors describe applications of the Hodrick-Prescott filter to determine also the potential product. Based on the above presented experience, we decided to use the Hodrick-Prescott filter in both, the equilibrium money velocity and potential product determination. Having quantified both measures, application of the logarithmic form of the formula (2) gives the equilibrium price level measure.

Figure 1

Domestic Price Gap

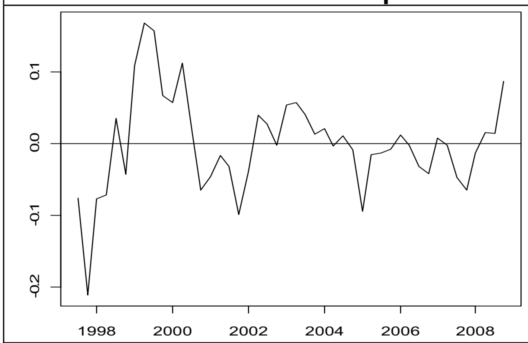
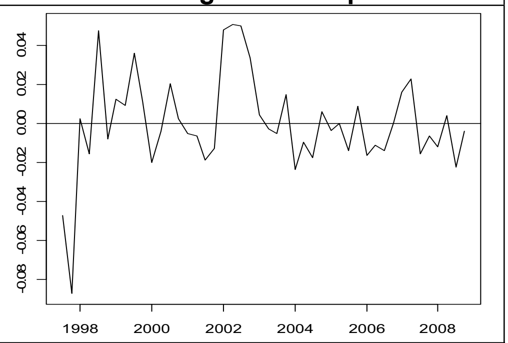


Figure 2

Foreign Price Gap



As the P-star model is presented in some kind of the error correction model (ECM) form, we tested all the empirical time series for the unit root using ADF and KPSS tests. Applying the Augmented Dickey Fuller (ADF) test, we followed the methodology proposed by Dolado, Jenkinson and Sosvilla-Rivero (1990). Number of lags was chosen according to the Schwarz information criterion. As the ADF statistics has low power in case of the "near unit root" situations, we made also the KPSS test, which zero hypothesis considers the time series to be stationary. The results are given in Table 1. In case of the real GDP's, money velocities of both countries and the real BGN/EUR exchange rate, the results proved to be in accordance with the theory – the time series were considered to be integrated of order 1 containing the stochastic trends. We did not perform the unit root tests in case of the nominal BGN/EUR exchange rate, as the currency board regime maintains the rate at the constant level with some just negligible deviations. The Bulgarian GDP deflator demonstrated strict decline during the researched period. Here, according to the results, statistically significant presence of deterministic trend not containing unit root (ϕ_1 *=27.577****, τ *=4.261****) was considered to be a realization of the statistical Type I. error caused by the misleading interpretation of the deterministic trend instead of the unit root specification. That is, why we decided to use the KPSS test respecting the presence of the deterministic trend. Here, the unit root hypothesis was accepted and we considered the time series to contain the unit root. The hypothesis on the presence of the integration of higher orders was rejected using the ADF test applied on the first differences of the respective variables. As all the differenced time series proved not to contain the unit root, all of the respective time series are considered to be I(1).

The price gaps were computed using equations (3) and (6). Here, in accordance with our expectations, both gaps proved to be stationary.

Table 1

Stationarity Tests of Relevant Time Series

Variable (in natural log form)	ADF		KPSS		ADF – 1st differences	
	type	τ_1/τ_2 – stat.	type	μ / τ - stat.	type	τ_l – stat.
GDP real /BG – y	C,1	1.147	C,3	1.235***	C,1	-5.921***
GDP real /DE – y^F	C,1	-1.135	C,3	1.127***	C,1	-3.606***
M3	C,1	-0.029	C,3	1.254***	C,1	-3.762***
M2 velocity /BG – v	C,1	0.564	C,3	1.192***	C,1	-4.899***
M3 velocity /DE – v^F	C,1	-0.026	C,3	0.996***	C,1	-3.852***
Real BGN/EUR – r	C,1	-0.191	C,3	1.255***	C,1	-6.270***
GDP defl. /BG – p	T,1	-4.261***	T,3	0.198**	C,1	-6.064***
GAP^D	C,1	-3.783***	C,3	0.067	-	-
GAP^F	C,1	-4.848***	C,3	0.114	-	-

Notes: Type – C-constant, T-trend, number of the lagged dependent variables.
,,*** means the 10%, 5%, 1% significance level, respectively.*
The stationarity tests were performed using the urca package of R software.

5. Final Results and Discussion

Since the correlation between the domestic and foreign-based price gaps was negligible, we decided to estimate model (7) containing both gaps simultaneously. The estimation results are given in Table 2. Here, to prevent the residuals autocorrelation, we included eight inflation lags that were successively eliminated based on the Akaike information criterion and remaining autocorrelation. In the final model, four lags remained and the fourth lag proved to be statistically significant. As the time series are of quarterly character, the resulting lags structure seems to be a demonstration of persisting seasonality. The final model does not exhibit any autocorrelation of the residuals (see Breusch-Godfrey statistics in Table 2), nor their heteroskedasticity (see Breusch-Pagan test statistics). The model seems to be well specified (see Ramsey RESET test) and estimated regression coefficients are stable (see Chow test). The adjusted coefficient of determination (0.42) was relatively high if compared with other published results (e.g. Wesche, 1998, demonstrated 0.36 for Netherlands, 0.28 for Belgium and 0.28 for Austria). Both price gaps regression coefficients contained the expected sign to correct the disequilibrium errors. The significance of the domestic price gap for the future inflation was insignificant, what is in accordance also with other published empirical results (e.g. the case of France and Belgium in Wesche, 1998) and our assumptions on the currency board regime. The findings are in line with the endogenity of the domestic money stock assumption (assumption generally accepted in case of the currency board) and show also that the application of the HPS model is inappropriate in case of the small economy operating under the fixed exchange rate regime. It means that the only significant determinants of the Bulgarian inflation are the relevant factors of the German economy, where the money stock is considered as the most significant one. In the estimated model, the foreign price gap was significant where about 28 percent of the foreign price gap is absorbed by the opposite price movements. On the other hand, the short term memory of the inflation proved to be also statistically significant.

Table 2

Regression Parameters

	Coefficients	t-value
const	0.0051	1.346
GAP^{D}_{t-1}	-0.0567	-1.364
GAP^{F}_{t-1}	-0.2836**	-2.150
ΔP_{t-1}	0.2067	1.368
ΔP_{t-2}	0.1927	1.374
ΔP_{t-3}	-0.0617	-0.5699
ΔP_{t-4}	0.3229***	2.777

R-squared 0.504475, Adjusted R-squared 0.417029
F(6, 34) 5.769009, p-value(F) = 0.000318
Log-likelihood 121.6014, Akaike criterion -229.2027
Schwarz criterion -217.2077
Breusch-Pagan test statistic – 4 lags: LM = 11.364822, p-value = 0.077735
Chi square test for normality: χ^2 *= 5.563 with p-value = 0.06194*
Breusch-Godfrey test statistic – 4 lags: LMF = 1.959400, p-value = 0.126
Ljung-Box Q' = 4.02525, p-value = 0.403
Ramsey RESET test: 1.1965, p-value = 0.315
Chow test for structural break at observation 2002:4
F(7, 27) = 0.451894, p-value = 0.8601

6. Conclusion

In this paper, the P-star model for the Bulgarian economy operating under the currency board regime was estimated. As expected, the significant influence of the German inflation as the consequence of the long-term functioning of the law of one price has been proved. On the other hand, the influence of the domestic price gap on the Bulgarian inflation was shown to be insignificant. The presented results are in line with the empirical research of the inflation transmission mechanism (as described by Yang, Guo and Wang (2004); Eun, Jeong (1999), Thams (2007) and others). The empirical research of the inflation transmission shows that the transmission process flows usually from the larger economy to the smaller one. This would be also the case of the Bulgarian economy as described in the paper. Besides the direction of the inflation transmission, we proved also the source of the imported inflation, which seems to be the money stock development in Germany.

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