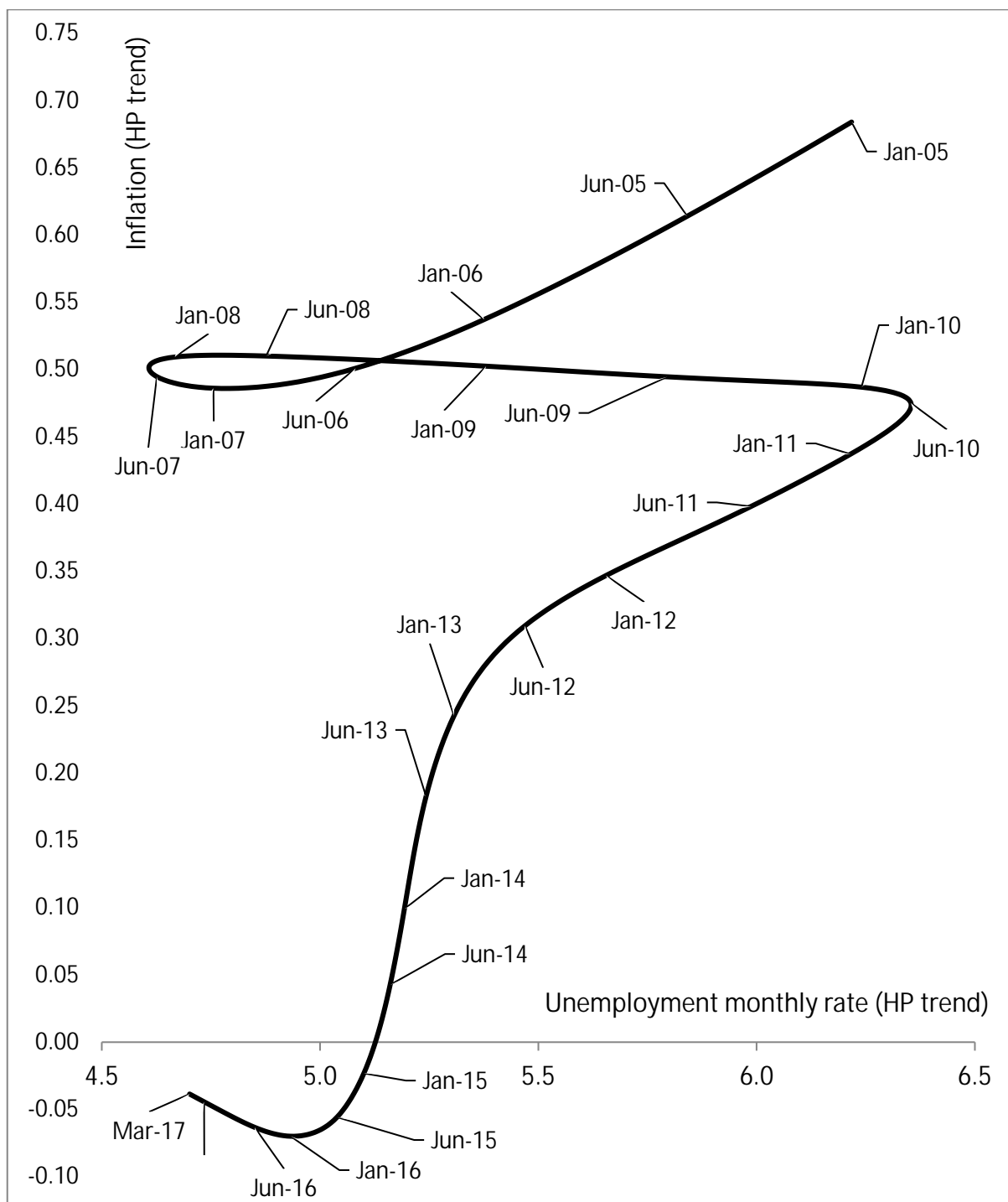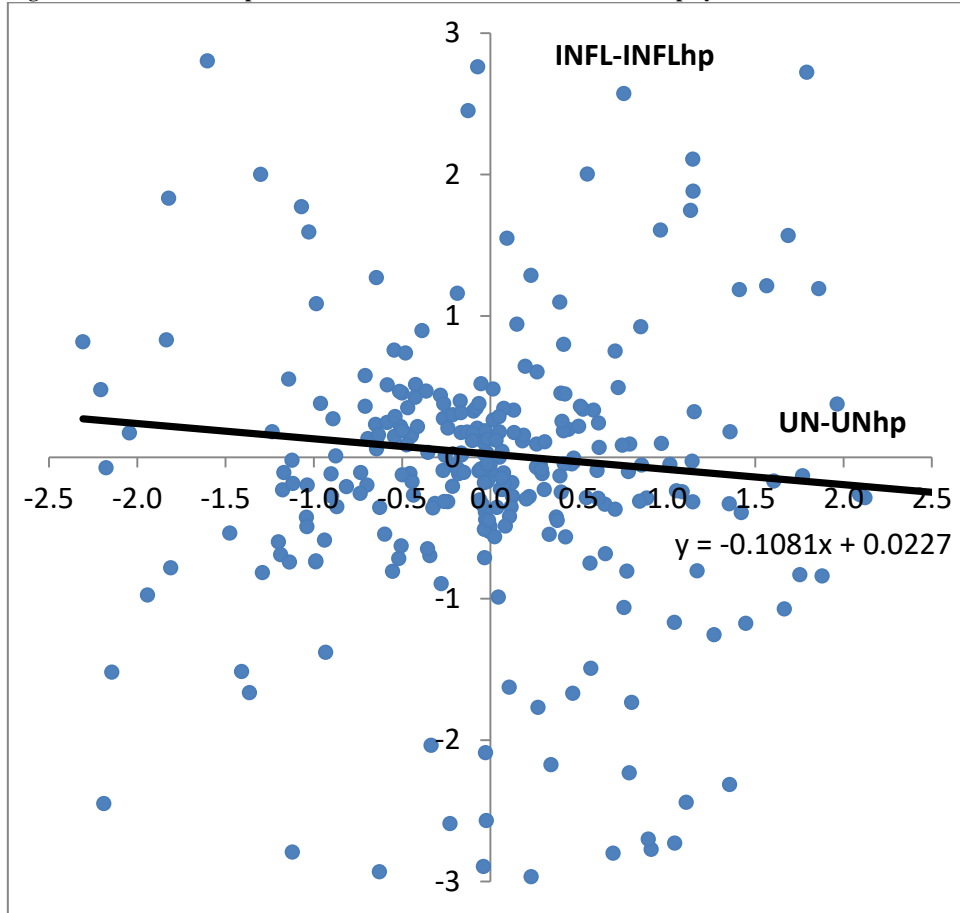Figure 9. HP-trend of the *Inflation* in relation to the HP-trend of the *Unemployment rate* – detailed graphic (monthly data, 2005-2017, March)

Source: An extract from the dynamics presented in Figure 1 (1995-2017 period)

Figure 10. The relationship between the deviations of Inflation and Unemployment rate from their trends

4. Econometric model

The previous figure suggests a weak relationship between inflation and unemployment, a relationship which is, as sign, in line with the theoretical expectation. To analyse the link between inflation and the unemployment rate we used, as a first approach, the standard model described by the neo-classical version of the Phillips curve:

$$\pi_t = \pi_t^e - \beta(u_t - u_t^e) + v_t.$$

where π_t is the inflation at the month t, u_t is the unemployment rate at the month t, π_t^e symbolises the expected inflation, u_t^e represents the expected rate of unemployment (natural rate of unemployment - NAIRU) and v estimates the random innovations in supply. Concretely, we have estimated the inflation by the relationship $INFL_t = CPI_t - 100$, where CPI is consumer price index.

The trend of inflation (INFLhp) was calculated by applying the HP filter on INFL variable and, the same, for expected unemployment we have HP-filtered the unemployment rate. So, the econometric model is:

$$INFL_t - INFLhp_t = a_0 + a_1 \cdot (UN_{t-4} - UNhp_{t-4}) + v_t,$$

where the innovations v_t was defined as an ARMA process. Also, we included in the model two DUMMY variables (for May, 1993[1], symbolised by D_{93M05} and March, 1997[2], symbolised by D_{97M03}). The unemployment

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[1] Government Decision No. 206 of May 7, 1993 on measures to further liberalization of prices and tariffs.
[2] Inflation induced by the strong rise in the leu / dollar exchange rate

gap has the greatest relevance in inflation model if we take a four months delay. In these circumstances, the model is:

$$INFL_t = a_0 + a_1 \cdot (UN_{t-4} - UNhp_{t-4}) + a_2 \cdot INFLhp_t + a_3 \cdot D_{1993M05} + a_4 \cdot D_{1997M03} + e_t$$

where e_t is ARMA(2,2)

If a Phillips relationship exists, between the unemployment and inflation, then the coefficient a_1 is significant and negative. We have dropped the constant term from the model because this coefficient is not econometrically significant. The results of the model are the following:

$$INFL_t - INFLhp_t = -0.344 \cdot (UN_{t-4} - UNhp_{t-4}) + 21.983 \cdot D_{93M05} + 18.072 \cdot D_{97M03} + e_t,$$
$$(1 + 1.102 \cdot L - 0.567 \cdot L^5) \cdot e_t = (1 - 0.494 \cdot L + 0.382 \cdot L^2) \cdot \varepsilon_t$$

All the coefficients are significant at standard level (2.3% for a_1 and less than 1% for everyone else), the ARMA process is stationary and invertible. The results are detailed in Annex 3. The coefficient of unemployment gap ($\hat{a}_1 = -0.344$) is significant and with the expected sign if we consider this gap with a 4-lag. Under the shown circumstances, the results do not reject the hypothesis of a relationship between inflation and unemployment, with the shape described by the Phillips curve. But, the main problem of this specification of Phillips curve is that the ARMA terms control only for serial correlation, while the errors remain heteroskedastic. In the presence of heteroskedasticity, the estimators are still unbiased and consistent, but the estimators lose the efficiency so that the t-statistics are misleading (Jula & Jula, 2017, pp. 202-236).

In a second approach, we have included in the model the inflation inertia, which derives from "assumptions of adaptive expectations and price rigidities in general" (Iordache, Militaru, & Pandioniu, 2016, p. 15). We have kept, as a benchmark, the expected inflation (INFLhp). As in the previous model, we have dropped the constant term, because this coefficient is not econometrically significant. And, likewise, the unemployment gap has the greatest relevance if we take a four months delay. Therefore, the model is:

$$INFL_t = a_1 \cdot INFL_{t-1} + a_2 \cdot (UN_{t-4} - UNhp_{t-4}) + a_3 \cdot INFLhp_t + e_t.$$

We used White version of least squares method, in order to control for heteroskedasticity. The results are the following:

$$INFL_t = 0.393 \cdot INFL_{t-1} - 0.386 \cdot (UN_{t-4} - UNhp_{t-4}) + 0.626 \cdot INFLhp_t + v_t,$$

where v_t is the residual variable. All the coefficients are significant at standard level: 3.9% is in the right-hand tail area for (negative) a_2 coefficient under the null hypothesis, 2.8% is in the left-hand tail area for (positive) a_1 coefficient, and less than 1% for (positive) a_3 coefficient). The errors are not serial correlated, at least until the lag 12 (Breusch-Godfrey Serial Correlation LM Test) and the White method allows to obtain heteroskedasticity-consistent estimates of the error variances and the corresponding robust t-statistics. The results are detailed in Annex 4.

The coefficient of unemployment gap ($\hat{a}_2 = -0.386$) is significant and with the expected sign if we included this variable with a delay of four months. As in the first model, the results do not reject the hypothesis of a relationship between inflation and unemployment, with the shape described by the Phillips curve. The unemployment gap coefficient is comparable with the one detected in the first model.

Conclusion

The purpose of our study was the analysis of the relationship between the unemployment rate and the inflation so that we have looking firstly on the significance of the coefficient that evaluates the linkage between the two variables. We found that the econometric analysis of unemployment rate and inflation, in Romania, during the period between 1992 and 1997 (March) do not reject the assumption that the relationships between these variables show a shape like the one described by the Phillips curve theory.

In a first model, we started from the hypotheses that the trend of inflation can be obtained through applying the HP filter on that variable and, the same, for unemployment trend (as estimating benchmark unemployment)

we had filtered (HP) the unemployment rate. The unemployment gap was calculated as a difference between the registered unemployment rate and their trend. In the second model, we adopt the assumption of an inflation inertia (the assumption of adaptive expectations) and keep the inflation trend as a benchmark for inflation dynamics. In both models, the unemployment gap has the greatest relevance in inflation model if we take a four months delay. The data support the hypothesis of a relationship between inflation and unemployment, with the shape described by the Phillips curve, and the coefficients of the unemployment gap are both negatives and econometrically significant. They are comparable (as a dimension) between the two specifications of the Phillips curve model: the coefficient of unemployment gap is -0.344 in the model where the errors follow an ARMA(2, 2) process and -0.386 in the model which includes the inflation inertia.

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Annexes

Annex 1. Unit Root Tests on Unemployment Rate

Unit Root Test	Null Hypothesis	Test statistic	Critical value (5% level)	Decision
Augmented Dickey-Fuller	unit root	-4.315	-3.989	I(0)
Phillips-Perron	unit root	-3.821	-3.425	I(0)
Kwiatkowski-Phillips-Schmidt-Shin	stationarity	0.138	0.146	I(0)

Note: The unit root tests were applied through test equations which include the constant and the trend (linear), as exogenous.

The t-statistic test values are below the 5% standard level for both tests (for the ADF, it is lower than the significance threshold of 1%, namely 0.34% and for PP test, it is 1.67%). This means that we do not accept the unit root hypothesis for the analysed series. For robustness, we also calculated the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test for stationarity. The result confirms the above conclusion: we do not reject the

hypothesis of stationarity for unemployment series, if we include both the constant and the linear trend in the test equation.

Annex 2. Unit Root Tests on Inflation

Unit Root Test		Null Hypothesis	Test statistic	Critical value (1% level)	Decision
Augmented Dickey-Fuller		unit root	-7.337	-3.988	I(0)
Phillips-Perron		unit root	-11.478	-3.988	I(0)
Kwiatkowski-Phillips-Schmidt-Shin		stationarity	0.287	0.216	I(1)
Elliott-Rothenberg-Stock DF-GLS		unit root	-4.736	-3.471	I(0)
Elliott-Rothenberg-Stock Point Optimal		unit root	2.446	3.998	I(0)
Ng-Perron	MZa	unit root	-38.801	-23.800	I(0)
	MZt	unit root	-4.380	-3.420	I(0)
	MSB	unit root	0.113	0.143	I(0)
	MPT	unit root	2.485	4.030	I(0)

Note: The unit root tests were applied through test equations which include the constant and the trend (linear), as exogenous.

Except for the KPSS test, all other tests reject the unit root hypothesis (the t-statistic test values are below the 1% standard level for these tests). This means that we do not accept the unit root hypothesis for the analysed series. The Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test does not confirm the above conclusion, namely, if we reject the hypothesis of stationarity for inflation series, then the error is less than 1%. As consequently, we have also turned to other unit root tests: the value calculated for Elliott-Rothenberg-Stock Point Optimal (ERS) test statistic was 2.446 (in the model with linear trend), bellow the critical value for 1% level (3.998). Accordingly, we reject the unit root. The same, for Elliott-Rothenberg-Stock DF-GLS test statistic, the calculated value was -4.736, below the critical one (-3.471 for 1% level). Moreover, all the Ng-Perron test statistics where below the critical values, at 1% level of signification. Therefore, we reject the hypothesis of unit root for the inflation series, between 1991 and 2007 (March).

Annex 3: Phillips curve for Romanian unemployment gap and inflation, ARMA model

Dependent Variable: INFL-INFL_HP

Method: ARMA Maximum Likelihood (OPG - BHHH)

Sample: 1992M05 2017M03

Included observations: 299

Convergence achieved after 101 iterations

Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
UN(-4)-UNhp(-4)	-0.344375	0.150543	-2.287557	0.0229
@ISPERIOD("1993m5")	21.98274	0.877071	25.06381	0.0000
@ISPERIOD("1997m3")	18.07199	1.187510	15.21839	0.0000
AR(1)	1.102433	0.117267	9.401058	0.0000
AR(2)	-0.567298	0.077053	-7.362399	0.0000
MA(1)	-0.494377	0.115156	-4.293097	0.0000
MA(2)	0.381584	0.074070	5.151688	0.0000
SIGMASQ	2.015087	0.085874	23.46556	0.0000
R-squared	0.714718	Mean dependent var		0.006703
Adjusted R-squared	0.707856	S.D. dependent var		2.662181

S.E. of regression	1.438918	Akaike info criterion	3.594485
Sum squared resid	602.5110	Schwarz criterion	3.693493
Log likelihood	-529.3754	Hannan-Quinn criter.	3.634112
Durbin-Watson stat	1.951427		
Inverted AR Roots	.55-.51i	.55+.51i	
Inverted MA Roots	.25+.57i	.25-.57i	

Annex 4. Phillips curve model with inflation inertia

Dependent Variable: INFL

Method: Least Squares

Sample (adjusted): 1992M05 2017M03

Included observations: 299 after adjustments

White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
INFL(-1)	0.392785	0.204721	1.918633	0.0560
UN(-4)-UNhp(-4)	-0.386079	0.217937	-1.771517	0.0775
INFL_HP	0.625992	0.185253	3.379120	0.0008
R-squared	0.609954	Mean dependent var		2.218763
Adjusted R-squared	0.607319	S.D. dependent var		3.840121
S.E. of regression	2.406384	Akaike info criterion		4.604110
Sum squared resid	1714.042	Schwarz criterion		4.641238
Log likelihood	-685.3144	Hannan-Quinn criter.		4.618970
Durbin-Watson stat	2.086681			

Breusch-Godfrey Serial Correlation LM Test: $20.717 < 21.026 = \chi^2(0.05; 12)$