Professor Claudiu Tiberiu ALBULESCU, PhD
E-mail: claudiu.albulescu@upt.ro
Department of Management
Politehnica University of Timisoara
Professor Stelian STANCU, PhD
E-mail: stelian_stancu@yahoo.com
Department of Economic Informatics and Cybernetics
The Bucharest University of Economic Studies
Associate Professor Eugenia GRECU, PhD
E-mail: eugenia.grecu@upt.ro
Department of Management
Politehnica University of Timisoara
Associate Professor Daniela Livia TRAȘCĂ, PhD
E-mail: daniela.trasca@ase.ro
Department of Economy and Economic Policies
The Bucharest University of Economic Studies

INFLATION, INFLATION UNCERTAINTY AND FUEL PRICES IN THE EU

Abstract. *We investigate the interactions between inflation, inflation uncertainty and fuel prices in the EU-28 countries, over the period 2005 to 2017. We compute the inflation uncertainty as the difference between the recorded level of inflation and one-year inflation forecasts. Our GMM results show a positive impact of inflation uncertainty and fuel prices on inflation. In addition, we show that diesel prices have a larger impact on inflation level compared with gasoline prices. Further, the increase in oil prices over the previous period, and the inflation targeting regime, have no significant influence on inflation. Our results are robust to different models and samples.*

Keywords*: inflation, inflation uncertainty, fuel prices, dynamic panel, EU countries.*

JEL Classification: E31, E37, C23

1. Introduction

In his Nobel lecture about the inflation-unemployment trade-off, Friedman (1977) hypothesizes that an increased inflation is associated with a higher inflation

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volatility and thus, with an increased inflation uncertainty.[1] Since then, a plethora of studies empirically investigate the nexus between inflation and its uncertainty, with mixed findings (see, for example, Lai et al., 2011; Khan et al., 2017). While a first portion of empirical works validates the Friedman-Ball hypothesis (e.g. Grier and Perry, 2000; Fountas, 2001; Thornton, 2008; Nasr et al., 2015), a second portion documents a bi-directional relationship between inflation and its uncertainty (e.g. Chowdhury, 2014; Albulescu et al., 2019). Panel data investigations are performed *inter-alia* by Daal et al. (2005), Stock and Watson (2007) and Caporale et al. (2012), with mixed findings also.

These results are largely influenced by the empirical methods used (linear or non-linear, time-series analysis or panel data models), by the control variables as stock price (Albulescu et al., 2017), oil prices (Mallik and Chowdhury, 2011; Bahr and Mallik, 2013), and especially by the way the inflation uncertainty is computed. It is surprising that the literature marginally considers the role of one of the main drivers of inflation, namely the fuel prices. Indeed, crude oil prices represent the main component of fuel prices. However, fuel taxes and oil companies' profit margins are equally important in the setup of fuel prices (Albulescu and Mutascu, 2021). At the same time, although complex empirical approaches are put forward to compute the inflation uncertainty (e.g. unobserved component models), it is near impossible to verify their accuracy given that uncertainty is related to the incapacity of market participants to correctly anticipate the price dynamics.

We therefore bring additional insights to the inflation-uncertainty nexus in the European Union (EU) countries, and make four contributions to the existing literature. We first consider the role of fuel prices in influencing the inflation-uncertainty relationship. Given that fuels prices represent an important cost-component of all goods and services, their increase automatically passes-through inflation. At the same time, a higher volatility of fuel prices influences the inflation uncertainty given that consumers' inflation expectations are correlated with the fuel prices. We consider fuel and not crude oil prices because fuel prices vary across countries and are influenced by both the behavior of oil companies and by the tax systems in place. In addition, we compare the role of gasoline and diesel prices, and we expect a larger influence of diesel prices on inflation, given that diesel prices directly pass-through transportation costs.

Second, different from most previous recent studies which measure inflation uncertainty relying on unobserved components models (Stock and Watson, 2007; Chan et al., 2013), we consider uncertainty as being the difference between the

[1] Ball (1992) formalizes the positive connection between inflation and its uncertainty (the Friedman – Ball hypothesis). Formulating a concurrent hypothesis, Cukierman and Meltzer (1986) state that inflation uncertainty leads to high inflation. Other pioneer studies advance opposite theories, documenting a negative relationship between inflation and its uncertainty (e.g. Holland, 1995).

recorded and the forecasted level of inflation.[2] We argues that uncertainty is mainly represented by the difficulty of market participants and authorities to correctly anticipate the future level of inflation.

Third, we place our analysis at the EU level, performing a panel data analysis over the period 2005-2017 (annual data), for 28 countries.[3] On the one hand, the case of EU countries is of great interest given the dynamics recorded by the fuel prices during the last decade. On the other hand, we rely on a General Method of Moments (GMM) approach to overcome several econometric problems such as endogeneity, persistence and unobserved heterogeneity among inflation, uncertainty, and fuel prices. For robustness purpose, we compare the results of a difference GMM model (Arellano and Bond, 1991), with the findings generated by a system GMM specification (Blundell and Bond, 1998).

Finally, we test for the role of an increase in fuel prices and for the role of monetary policy regime, in influencing the inflation-uncertainty relationship. To this end we construct two dummy variables, one for an increase in fuel prices and the other for the monetary policy regime in place. The first dummy variable takes value 1 if the fuel prices increase over the last period and 0 if they record a decrease compared to the previous period. Indeed, we expect that the inflation-uncertainty relationship is more influenced by an increase in fuel prices. This is because cost increases generate a higher uncertainty compared with cost decreases. The second dummy variable takes value 1 if the country has in place an inflation targeting regime, and 0 otherwise.[4] Afterwards we construct an interaction term between the first dummy variable and the fuel prices, and an interaction term between the second dummy variable and the inflation uncertainty. This way we are able to see if, and how an increase in the fuel prices and the inflation targeting regime will affect the relationship between inflation, inflation uncertainty and fuel prices.

The remaining of the paper present the literature review (Section 2), the data and methodology (Section 3), the results (Section 4) and the robustness analysis (Section 5). The last section presents the conclusions of the paper.

2. Literature review in brief

The relationship between inflation and its uncertainty is intensively investigated with opposite findings reported by the empirical literature (for a recent survey of the literature, please refer to Albulescu et al., 2019).

[2] A similar approach was implemented by Albulescu and Ionescu (2018) to compute the monetary policy uncertainty in the EU countries.
[3] Grecu et al. (2020) had a similar approach in testing the Friedman's (1977) second hypothesis, connecting the economic output with the inflation uncertainty.
[4] As Payne (2009) states, the inflation target contributes to a reduction in inflation uncertainty.

A first strand of the literature validates the Friedman (1977) – Ball (1992) hypothesis and report a positive, unidirectional causality from inflation to the inflation uncertainty. In this line, Grier and Perry (2000) investigate the US case using monthly data for the period 1948:07-1996:12. Relying on a Generalized AutoRegressive Conditional Heteroskedasticity (GARCH) approach, the authors show that US inflation positively impacts the inflation uncertainty. A similar result in reported by Fountas (2001), using a similar approach for the United Kingdom (UK) and covering a historical period running from 1885 to 1998. Thornton (2008) investigated the inflation-uncertainty nexus with a focus on an emerging economy, namely Argentina. The author also investigates the connection between inflation and its uncertainty in a GARCH-type framework, considering historical data from 1810 to 2005. The Granger causality tests indicate a one-way causality from the inflation to the inflation uncertainty. Approaching the South Africa's case, Nasr et al. (2015) use in their turn GARCH-type and MS-VAR models and discover that the level of inflation influences the inflation uncertainty during the period 1921:01-2012:12.

A concurrent strand of the literature discover that inflation uncertainty also impacts the inflation level. Consequently, a bi-directional relationship is reported by Fountas and Karanasos (2007) for the G7 countries for the period from 1957 to 2000. Using a similar GARCH approach to detect the inflation uncertainty and a Granger causality analysis, Chowdhury (2014) reports a bi-directional causality between inflation and inflation uncertainty in India, over the period 1954:04-2010:04. Similar results are reported in a wavelet framework by Albulescu et al. (2019), for the US. All in all, the mixed findings reported by the literature can be found both in the case of developed and emerging economies.

3. Data and methodology

Annual data on inflation and inflation forecasts, necessary to compute the inflation uncertainty, came from the Organization for Economic Cooperation and Development (OECD) database (OECD Economic Outlook).[5] The fuel, gasoline and diesel prices (in EUR/l) are extracted from the Weekly Oil Bulletin of the European Commission and are available starting with 2005 (the average annual data of these prices are considered). The dataset includes the EU 28 countries and covers the timespan 2005 to 2017.

To apply the GMM approach we first check the stationarity of our series (Table 1). We notice that the panel unit root tests indicate the absence of unit roots for inflation and its uncertainty, while for the fuel prices the findings are mixed. We therefore use the log returns of fuel prices (gasoline and diesel).

[5] Similar to Albulescu and Ionescu (2018), we consider a one-year forecasting horizon to compute the inflation uncertainty.

Table 1. Panel unit root tests

28 cross-sections	Levin, Lin & Chu t*	Im, Pesaran and Shin Z-t-tilde-bar	ADF - Fisher Inverse Chi-square P	ADF - Fisher Inverse Normal Z
i	-5.399***	-3.610***	92.60***	-3.904***
iu	-6.110***	-4.701***	122.980***	-5.7525***
fuel1		-2.032	51.407	-1.221
fuel2		-2.988	66.806	-2.588***

Notes: (i) the null hypothesis for all the tests is the presence of unit roots (the t test assumes common unit root process while the other tests assume individual unit root process); (ii) *, **, ***, mean stationarity (in level) significant at 10 %, 5 % and 1 %; (iii) i – inflation rate, iu – inflation uncertainty, fuel1 – gasoline retail prices, fuel2 – diesel retail prices.*

The GMM general specification for dynamic panel data is:

$$\Delta Y_{i,t} = \beta_1 \Delta Y_{i,t-s} + \beta_2 \Delta X_{i,t} + \Delta \mu_i + \Delta \varepsilon_{i,t} \qquad (1)$$

where: $Y_{i,t}$ is the dependent variable (inflation), $X_{i,t}$ is the vector of explanatory variables (inflation uncertainty and oil prices), μ_i are between-entity errors, $\varepsilon_{i,t}$ are within-entity errors.

The difference GMM estimator (Arellano and Bond, 1991) uses as instruments difference lagged values of variables. It supposes the absence of second-order autocorrelation:

$$E\left[Y_{i,t-s}(\varepsilon_{i,t} - \varepsilon_{i,t-1})\right] = 0, \text{ for } s \geq 2 \text{ and } t = 3, \dots, T, \text{ and} \qquad (2)$$

$$E\left[X_{i,t-s}(\varepsilon_{i,t} - \varepsilon_{i,t-1})\right] = 0, \text{ for } s \geq 2 \text{ and } t = 3, \dots, T. \qquad (3)$$

However, the lagged values of the retained explanatory variables are not reliable instruments for short-sample periods (Blundell and Bond, 1998). Therefore, the system GMM estimator, which include both differenced and level equations, might represents a solution to this issue. In this case, for variables in differences, the lagged values (in levels) are used as instruments. At the same time, for variables in levels, the differenced values are used as instruments. The additional moment conditions are:

$$E\left[(Y_{i,t-1} - Y_{i,t-2})(\mu_i + \varepsilon_{i,t})\right] = 0, \text{ for } s \geq 2 \text{ and } t = 3, \dots, T, \text{ and} \qquad (4)$$

$$E\left[(X_{i,t-1} - X_{i,t-2})(\mu_i + \varepsilon_{i,t})\right] = 0, \text{ for } s \geq 2 \text{ and } t = 3, \dots, T. \qquad (5)$$

3. Results

We first present the GMM results considering the gasoline prices (Table 2). We estimate three different models, and we compare the difference and system GMM specifications: (i) Model 1 tests the influence of inflation uncertainty and gasoline prices on the level of inflation; (ii) Model 2 investigates to what extent an increase in gasoline prices over the previous year influences the inflation; (iii) Model 3 search for the role of the inflation targeting regime.

We notice that the inflation uncertainty (iu) positively impacts the inflation level for all models, supporting thus the Friedman – Ball hypothesis. This result is very robust and remains unchanged for tall three methods and bot difference and system GMM approaches. Moreover, the impact of gasoline prices on inflation is positive and significant. For example, if we look to Model 1 results and to the difference GMM specification, an increase of 1% in the gasoline level leads to 1.33% increase in the general price level.

However, the increase in gasoline prices over the previous period (dum_f1×fuel1) has a positive impact on inflation only in the case of difference GMM specification (Models 1 and 2). This result, although not very robust, confirms the fact that gasoline price increases directly pass-through inflation.

Finally, although the sign of inflation targeting interaction dummy is the expected one (see Payne, 2009), the impact of inflation targeting regime (dum_it×iu) is not significant. The results are similar across the two specifications (difference and system GMM).

Table 2. GMM results for inflation, uncertainty, and gasoline prices (28 cross-sections)

28 cross-sections	difference GMM			system GMM		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
lag(1)	0.205***	0.214***	0.215***	0.187***	0.193***	0.194***
iu	1.006***	0.961***	0.978***	1.049***	1.020***	1.040***
fuel1	1.331***	0.923*	0.892*	1.321***	1.111***	1.058***
dum_f1×fuel1		0.409**	0.415**		0.202	0.213
dum_it×iu			-0.089			-0.100
c	0.693**	0.792***	0.807***	0.731***	0.782***	0.808***
observations	297	297	297	325	325	325
instruments	194	195	196	227	228	229

*Notes: (i) lag(1) is the first lag of the dependent variable; (ii) dummy variables are considered strictly exogenous; (iii) *, **, *** means significance at 10 %, 5 % and 1 %; (iv) iu – inflation uncertainty, fuel1 – gasoline prices, dum_f1×fuel1 – interaction dummy between fuel1 and dum_f1 (which takes value 1 if the gasoline* price *increases in t compared to t-1 and 0 otherwise), dum_it×iu – interaction dummy between inflation uncertainty and dum_it (which takes value 1 if the country has in place an inflation targeting regime and 0 otherwise), c – intercept.*

We next consider the role of diesel prices (Table 3). In this case the results are similar, showing that both inflation uncertainty and diesel prices positively influence the level of inflation in EU-28 countries. Compared with previous estimations, as expected, the diesel prices have a larger influence on inflation compared to gasoline prices. The interaction term also show that diesel price increases are important in explaining the level of inflation.

Table 3. GMM results for inflation, uncertainty, and diesel prices (28 cross-sections)

28 cross-sections	difference GMM			system GMM		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
lag(1)	0.201***	0.209***	0.211***	0.185***	0.189***	0.191***
iu	0.996***	0.960***	0.977***	1.037***	1.017***	1.035***
fuel2	1.500***	1.173***	1.135***	1.443***	1.300***	1.249***
dum_f2×fuel2		0.320*	0.330*		0.139	0.149
dum_it×iu			-0.089			-0.092
c	0.549**	0.634**	0.652***	0.612***	0.648***	0.674***
observations	297	297	297	325	325	325
instruments	194	195	196	227	228	229

*Notes: (i) lag(1) is the first lag of the dependent variable; (ii) dummy variables are considered strictly exogenous; (iii) *, **, *** means significance at 10 %, 5 % and 1 %; (iv) iu – inflation uncertainty, fuel1 – gasoline prices, dum_f1×fuel1 – interaction dummy between fuel1 and dum_f1 (which takes value 1 if the gasoline* price *increases in t compared to t-1 and 0 otherwise), dum_it×iu – interaction dummy between inflation uncertainty and dum_it (which takes value 1 if the country has in place an inflation targeting regime and 0 otherwise), c – intercept.*

4. Robustness analyses

Several robustness analyses are performed to check the validity of our results. We first exclude from our sample the countries which joined the EU after 2005, namely Bulgaria, Croatia, and Romania. This is because the prices were not completely liberalized in these countries during the analyzed period, issue that may influence the results. We obtain a new sample called EU-25. Second, we test the same relationship for the old EU members (EU-15), which have in place a more mature monetary system.

If we consider the case of EU-25 group of countries (Table 4), we clearly see that the inflation uncertainty influences the level of inflation, whereas the coefficient of elasticity is close to unit. This result confirms the main findings reported in section 3. In line with the main findings, the gasoline prices explain the inflation level. However, the interaction term between the first dummy variable and the fuel prices, is o longer significant for the difference GMM specification. As in the previous case, the inflation targeting regime has to significant influence on the inflation level in the EU countries.

These results are confirmed by the subsequent analysis, where the role of diesel prices is assessed in explain the inflation. Again, our results confirm the main findings and show that diesel prices, representing one of the main components of production and transportation costs, has a stronger impact on inflation than the gasoline prices do (Table 5).

Table 4. GMM results for inflation, uncertainty, and gasoline prices (25 cross-sections)

25 cross-sections	difference-GMM			system-GMM		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
lag(1)	0.163***	0.167***	0.167***	0.145***	0.139***	0.140***
iu	1.040***	1.022***	1.018***	1.074***	1.096***	1.097***
fuel1	1.214***	1.076**	1.072**	1.159***	1.298***	1.286***
dum_f1×fuel1		0.140	0.144		-0.140	-0.136
dum_it×iu			0.015			-0.011
c	0.805***	0.837***	0.839***	0.868***	0.838***	0.843***
observations	275	275	275	300	300	300
instruments	186	187	188	219	220	221

*Notes: (i) lag(1) is the first lag of the dependent variable; (ii) dummy variables are considered strictly exogenous; (iii) *, **, *** means significance at 10 %, 5 % and 1 %; (iv) iu – inflation uncertainty, fuel1 – gasoline prices, dum_f1×fuel1 – interaction dummy between fuel1 and dum_f1 (which takes value 1 if the gasoline* price *increases in t compared to t-1 and 0 otherwise), dum_it×iu – interaction dummy between inflation uncertainty and dum_it (which takes value 1 if the country has in place an inflation targeting regime and 0 otherwise), c – intercept.*

In this case also, the coefficients of the interaction terms between the dummy variables and fuel prices and inflation uncertainty respectively, are not significant.

Table 5. GMM results for inflation, uncertainty and diesel prices (25 cross-sections)

25 cross-sections	difference-GMM			system-GMM		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
lag(1)	0.159***	0.162***	0.163***	0.143***	0.136***	0.137***
iu	1.029***	1.013***	1.012***	1.064***	1.089***	1.093***
fuel2	1.360***	1.249***	1.244***	1.258***	1.406***	1.391***
dum_f2×fuel2		0.113	0.117		-0.152	-0.148
dum_it×iu			-0.001			-0.024
c	0.681***	0.708***	0.710***	0.770***	0.737***	0.744***
observations	275	275	275	300	300	300
instruments	186	187	188	219	220	221

*Notes: (i) lag(1) is the first lag of the dependent variable; (ii) dummy variables are considered strictly exogenous; (iii) *, **, *** means significance at 10 %, 5 % and 1 %; (iv) iu – inflation uncertainty, fuel1 – gasoline prices, dum_f1×fuel1 – interaction dummy* *between fuel1 and dum_f1 (which takes value 1 if the gasoline* price *increases in t compared to t-1 and 0 otherwise), dum_it×iu – interaction dummy between inflation uncertainty and dum_it (which takes value 1 if the country has in place an inflation targeting regime and 0 otherwise), c – intercept.*

The last set of robustness checks considers the case of old-EU member states. These states are also part of the EU monetary union and records a higher stability of the general level of prices compared with their eastern counterparts. Table 6 indicates that the inflation uncertainty still impacts the level of inflation, although the effect is smaller compared to the entire sample. These results might be explained by the fact that the level of uncertainty (that is the inflation forecasting errors) is reduced in the case of more developed EU countries. Curiously, the impact of gasoline prices on the inflation level in significant only in the case of Model 1, but the interaction term is always positive ad significant. This means that the increases of gasoline prices and not necessary the price level has an important impact of inflation in EU-15.

Table 6. GMM results for inflation, uncertainty and gasoline prices (15 cross-sections)

15 cross-sections	difference-GMM			system-GMM		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
lag(1)	0.140***	0.191***	0.191***	0.095***	0.149***	0.148***
iu	0.870***	0.624***	0.624***	0.969***	0.743***	0.765***
fuel1	1.410**	0.340	0.342	1.317***	0.510	0.480
dum_f1×fuel1		1.231***	1.228***		0.934***	0.915***
dum_it×iu			-0.004			-0.110
c	0.519	0.702**	0.701**	0.639***	0.751***	0.777***
observations	165	165	165	180	180	180
instruments	138	139	140	171	172	173

*Notes: (i) lag(1) is the first lag of the dependent variable; (ii) dummy variables are considered strictly exogenous; (iii) *, **, *** means significance at 10 %, 5 % and 1 %; (iv) iu – inflation uncertainty, fuel1 – gasoline prices, dum_f1×fuel1 – interaction dummy between fuel1 and dum_f1 (which takes value 1 if the gasoline* price *increases in t compared to t-1 and 0 otherwise), dum_it×iu – interaction dummy between inflation uncertainty and dum_it (which takes value 1 if the country has in place an inflation targeting regime and 0 otherwise), c – intercept.*

Finally, when we consider the role of diesel prices in explaining the level of inflation in EU-15, we obtain similar results to those reported for gasoline prices (Table 7). The inflation uncertainty explains the level of inflation and the results confirm once again the Friedman – Ball hypothesis. The coefficient level is sub-unitary, and this result confirms the fact that the inflation uncertainty has a smaller impact of inflation I the EU-15 compared with the findings recorded for the entire sample.

To sum up, we show that inflation uncertainty, as well as fuels prices, explain the inflation level in the EU countries. I the case of old EU members, the fuel price increases are more important for inflation compared to the level of fuel prices. Our findings are robust to different model specifications and the post-estimation tests confirm the lack of autocorrelation issues or instrument overproliferation problems.

Table 7. GMM results for inflation, uncertainty, and diesel prices (15 cross-sections)

15 cross-sections	difference-GMM			system-GMM		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
lag(1)	0.132***	0.188***	0.188***	0.089***	0.149***	0.149***
iu	0.842***	0.588***	0.589***	0.938***	0.697***	0.715***
fuel2	1.666***	0.535	0.531	1.436***	0.581	0.551
dum_f2×fuel2		1.230***	1.230***		0.958***	0.947***
dum_it×iu			-0.009			-0.088
c	0.325	0.553**	0.555**	0.527**	0.664***	0.688***
observations	165	165	165	180	180	180
instruments	138	139	140	171	172	173

*Notes: (i) lag(1) is the first lag of the dependent variable; (ii) dummy variables are considered strictly exogenous; (iii) *, **, *** means significance at 10 %, 5 % and 1 %; (iv) iu – inflation uncertainty, fuel1 – gasoline prices, dum_f1×fuel1 – interaction dummy between fuel1 and dum_f1 (which takes value 1 if the gasoline* price *increases in t compared to t-1 and 0 otherwise), dum_it×iu – interaction dummy between inflation uncertainty and dum_it (which takes value 1 if the country has in place an inflation targeting regime and 0 otherwise), c – intercept.*

5. Concluding remarks

We investigate the inflation-inflation uncertainty nexus in the EU countries, considering the role of fuel prices. We find evidence for the Friedman-Ball hypothesis. Further, we show that fuel prices positively influence the inflation level, while the diesel prices have a larger influence compared to gasoline prices. Finally, we posit that an increase in oil prices over the previous year, and an inflation targeting regime, have no significant influence on inflation when the EU-28 sample of countries is considered. However, the increases in fuel prices become important in explaining inflation for the EU-15 sample.

Our findings have two policy implications. First, in order to control for the general level of prices, the monetary authorities should reduce the inflation uncertainty. It means that by increasing the forecast accuracy, the authorities might contribute to a decrease of inflation level. Second, considering thee fuel prices dynamics represents a key issue in anticipating the level of inflation.

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