An Analysis of Inflation Dynamics based on an Empirical Improved Proxy for Real Marginal Cost Gap in the New Keynesian Phillips Curve

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***Abstract*—The paper study an alternative proxy for real marginal cost gap in the hybrid New Keynesian Phillips Curve in order to improve the empirical results and to provide a more detailed insight into the causes of inflationary process. The improved proxy distinguishes two types of inflation pressures coming from the real economy, one associated with the decreasing returns to production factors and the other one related to the position of real wage costs relative to their equilibrium level. Apart from testing the relative performance of an improved proxy of real marginal cost, the empirical analysis aims to evaluate the degree of inertia, the impact of forward looking expectations and the inflationary pressures steaming from real economy. To achieve these goals it is estimated a reduced form hybrid New Keynesian Phillips Curve for Romania and other three new Member States which present similarities between them: Czech Republic, Hungary and Poland.**

***Index Terms*—Inflation dynamics, new member states, hybrid new Keynesian Phillips curve, GMM estimation.**

I. Introduction

The New Keynesian Phillips Curve has become a standard framework for the analysis and forecasting of short and medium term inflation. All macroeconomic models used by central banks or other monetary institutions incorporate a certain type of Phillips Curve. Moreover, a wide range of empirical analyses demonstrate that the Phillips Curve can be successfully used as a tool for forecasting inflation. A specific feature of this economic relationship refers to the fact it includes through its determinants variables describing real economic activity. Because the corresponding theoretical concept describing inflationary pressures coming from real economy, i.e. real marginal cost, is an unobservable variable and it is not statistically available at aggregate level, there is much controversy in the literature regarding the choosing of the appropriate proxy. There is a large literature advocating the poor relationship between real activity and inflation from statistically point of view, when the measure of real activity is the output gap. The basic New Keynesian Phillips Curve includes a theoretical relation between inflation and real marginal cost derived from an optimization process, assuming staggered price setting by forward looking, monopolistically competing firms. In their well-known empirical analysis, [1] use an aggregate proxy for marginal cost instead of a simple output gap measure and find an economically and statistically significant effect of real activity on inflation rate in the U.S. economy. However, the results were conditional on the measure of marginal cost used. Reference [2] shows that the real marginal cost measure based on real unit labour costs also capture the pattern of Euro area inflation. One possible explanation could be related to the fact that this proxy directly accounts for the influence of both productivity and wages pressures on inflation and these economic variables tend to commove. A simple proxy of real marginal cost as a measure of the output-gap may be a weak approximation. Reference [3] argues that the presence of labour market frictions, in the form of real or nominal wage rigidities, may cause an inertial behaviour of real marginal cost. This may be one of the reasons why real marginal cost doesn't move proportionately to a measure of output-gap. References [2] and [4] find evidences in support of a better fit of the hybrid version of the New Keynesian Phillips Curve in case of inflation dynamics. References [5]-[7] derived the hybrid variant of the curve including in the derivation process a form of dynamic price indexing. References [8] and [9] demonstrate that the introduction of wage rigidity and allowing for matching frictions, as defined by [10], in a new Keynesian model manage to explain a significant part of the inflation persistence observed in the data. Reference [11] examines an anti-cyclical behaviour of real wages in the Czech economy and concludes for an extension of the central bank's core prediction model in order to include the effect of real wages on price inflation. Reference [12] argues that the labour share is not an ideal measure of real marginal cost because it is countercyclical whereas marginal cost is likely to be pro-cyclical. Reference [13] studies the decomposition of inflation based on a New Keynesian Pricing Equation into two components: fundamental inflation, defined as the discounted expected future real unit labour cost and a residual. They find large differences between actual and fundamental inflation for the period 1999 – 2011 which could emphasize the incompleteness of the proxy variable used for the real marginal cost in the Phillips Curve.

There are numerous concerns related to the specification and estimation of the New Keynesian Phillips Curve. One important issue concerns the appropriate measure of inflation expectations which should be used in the specification. Most

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empirical studies in line with [1] considered as a proxy for the expected inflation the realized future inflation data and address the endogeneity using the GMM estimator. Other more recent studies including [14]-[17] use data extracted from the inflation surveys and, consequently, do not impose rational expectations. For example, [17] analyse the mechanism of price expectations formation in the Romanian economy based on data from the survey conducted by the European Commission for consumers, emphasizing the role of wages in the economic agents' expectations formation. Another issue of debate is related to the suitability of the GMM methodology in order to address the endogeneity problems. Reference [18] argues that the GMM approach provides weak identification that can induce a bias towards the forward-looking term. Reference [19] claims that the significance of the real marginal cost depends on GMM instruments choices and, hence, the approach is not robust. Considering the sensitivity of the estimation results to instruments, [20] advocate that some of the instruments may be directly used as regressors. A majority of empirical studies on the New Keynesian Phillips Curve aim at the euro area, US or other major economies. However, since the Phillips Curve has become a standard framework for the analysis of short and medium term inflation, it is of special interest to test if it is supported by the data of small and open economies as well.

This paper provides a theoretical and empirical argumentation in support of an improved proxy of real marginal cost designed to replace a simpler measure of output gap or a measure based only on costs of labour. The rest of the paper is organized as follows. Section 2 presents the derivation of the hybrid New Keynesian Phillips Curve distinguishing between two alternative inflationary sources coming from real economic activity. In section 3 is described the methodological approach used to conduct the empirical analysis and the results of the estimates are presented. Section 4 concludes.

II. The New Keynesian Price Equation with an Improved Proxy of Real Marginal Cost

The New Keynesian Phillips Curve (NKPC) is based on the seminal work of [21] and [22] and is explicitly derived from an optimization process, assuming staggered price setting by forward looking, monopolistically competing firms. As a result of the optimization process, current inflation is related to future expected inflation and real marginal cost. Also, the parameters of the NKPC are directly linked to the behaviour of agents and are thus exempt from the Lucas critique. The hybrid version of the NKPC is due to [1] and it additionally incorporates inflation inertia in order to explain the linking between nominal and real variables.

In model setting, along with some important premises referring to monopolistic competition, nominal rigidities and some degree of price indexation it is considered that a representative firm, from a continuum of measure one, produces goods, $Y_t(j)$, using a two-input Cobb-Douglas technology:

$$Y_t(j) = \varepsilon_t^a \cdot \left(K_t(j)\right)^{\alpha} \cdot \left(L_t(j)\right)^{\beta} \quad (1)$$

where α is the capital income share and β is the labour income share; ε_t^a is a domestic, stationary, technology shock; K_t capital; and L_t labour. If the production function presents decreasing returns to production function, the sum of coefficients α and β is less than one. The representative firm produces a specific variety of domestic good combining capital and labour and taking the wage rate and the rental rate of capital as given. The price setting decision is similar to [22] but includes also an indexation mechanism of produced good price to its previous period inflation rate. Firms that do not receive the price-optimization signal, considered to be in a constant and exogenous chosen proportion which is equal to ξ, automatically update their previous period price $P_{t-1}(j)$ by indexation to the previous period good inflation rate π_{t-1}. So, a domestic good firm which is not re-optimising its price in a given period will set it following this rule:

$$P_t(j) = \pi_{t-1} \cdot P_{t-1}(j) \quad (2)$$

According to this rule, in any future period $t+i$, a firm that re-optimised last time its price in period t, will set it according to:

$$P_{t+i}(j) = \pi_{t+i-1} \cdot \ldots \cdot \pi_t \cdot P_t^{opt}(j) \quad (3)$$

where $P_t^{opt}(j) = P_t^{opt}$ represents the optimal price chosen by all firms adjusting in period t taking into account that they face the same optimization problem. The cost minimisation problem faced by the representative firm which produces a certain amount of domestic good, subject to the technology restriction (1), result in the following expression:

$$\frac{K_t(j)}{L_t(j)} = \frac{\alpha}{\beta} \cdot \frac{W_t}{R_t} \quad (4)$$

Equation (4) indicates that the capital-labour ratio depends on input shares and factor prices.

Substituting the capital-labour ratio in the production function expression can be obtained, in a row, the demand for labour and capital inputs, as functions of total production, relative prices and factor shares. Using the cost and demand for labour and capital inputs functions, the expression for the marginal cost is derived, as a function of technology shock, relative prices and factor shares. The expression is the same for all firms. Consequently, the cost function can be rewritten as: $C_t(j) = MC_t \cdot Y_t(j)$ which shows that the marginal cost MC_t equals average cost at the optimum decision point. Nominal profits can be expressed in terms of marginal cost as: $\Pi_t(j) = \left(P_t(j) - MC_t\right) \cdot Y_t(j)$ and the profit maximization problem is then given by:

$$\max_{P_t^{opt}} E_t \sum_{i=0}^{\infty} \left(\beta \cdot \xi\right)^i \cdot \Lambda_{t+i} \cdot \left(P_{t+i}(j) - MC_{t+i}\right) \cdot Y_{t+i}(j) \quad (5)$$

where $\Lambda_{t+i} = \frac{\lambda_{t+i}}{P_{t+i}}$ and λ_{t+i} is the marginal utility of an additional unit of wealth available to consume or invest.

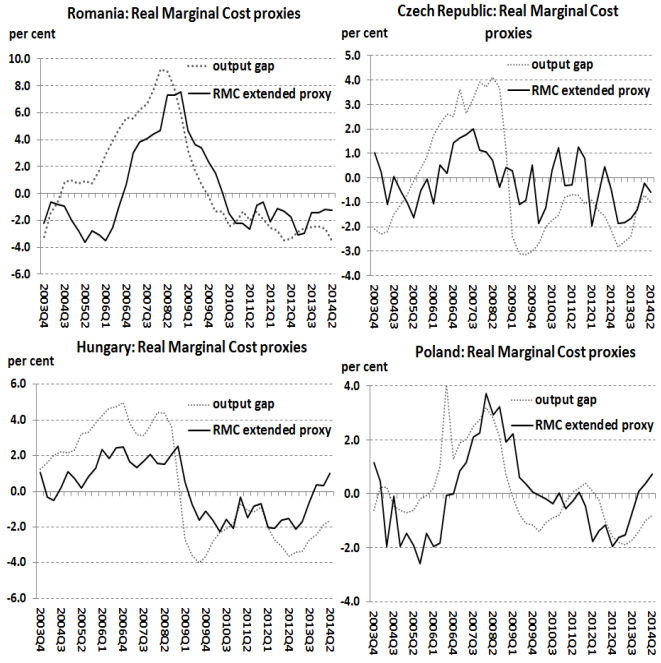
The demand curve for the goods is given by:

$Y_t(j)=\left(\frac{P_t}{P_t(j)}\right)^{\frac{\mu}{\mu-1}}\cdot Y_t$ where μ is the good price mark-up. Considering (3) and (4) and optimising (5) with respect to P_t^{opt} the first order condition for the price set by the adjusting firms is obtained. The aggregate price index will be a weighted average of the optimised price and the indexed price set by the firms which do not optimised their price in period t, with the fractions $1-\xi$ and ξ respectively. After log-linearization, a hybrid version of the new Keynesian Phillips curve for aggregate inflation is obtained. The real marginal cost is proxied by a combination between deviations of factor prices around the steady-state:

$$\pi_t=\frac{\beta}{1+\beta}\cdot\pi_{t+1}+\frac{1}{1+\beta}\cdot\pi_{t-1}+\frac{(1-\xi)\cdot(1-\beta\cdot\xi)}{\xi\cdot(1+\beta)}\cdot \cdot\left[-\varepsilon_t+\alpha\cdot r_t+\beta\cdot w_t\right] \quad (6)$$

This form of real marginal cost suggests identification of a richer approximation than a simple measure of real Gross Domestic Product deviation from its trend level or a measure based only on costs of labour. The output gap, which is largely used as a proxy for real marginal cost in the New Keynesian Phillips Curve, is only one part of the theoretical concept for this type of inflationary pressures, which approximates the impact of firms' real marginal costs on the production prices.

Such an improved real marginal cost proxy can distinguish between a possible different cyclical behaviour of real wages and output, which may be determined by higher rigidity of nominal wages compared to prices. Fig. 1 presents the two alternative proxies for real marginal costs in case of the four New Member States included in the analysis.



Sources: Eurostat, national banks databases, author calculations

Fig. 1. Alternative proxies for real marginal costs in case of four new member states.

Moreover, the improved proxy of the real marginal cost gap distinguishes at least two types of inflation pressures coming from the real economy. One is associated with the decreasing returns to production factors which determine marginal costs to rise simultaneously with the increase of production volume. The other one is related to the position of real wage costs relative to their equilibrium level. For example, if the real wage gap is positive, it has an inflationary effect determined by the increasing price of production. The first type of inflation pressure, which arises from the volume of production, can be proxied by a measure of output gap and the second one, arising from the cost of the production factor of labour, by the real wage gap. This improved proxy of real marginal cost provides a more detailed insight into the inflationary pressures coming from the real economy than a simple one variable approximation. At the same time, it is possible to take into account the hypothetical rather anti-cyclical behaviour of real wages caused by higher stickiness of nominal wages compared to prices.

Nevertheless, central banks encounter several obstacles in their way to achieve price stability. For example, price rigidities in wages means that even if monetary policy acts in order to reduce inflation, some wage contracts are not affected by this kind of actions in the short term. Therefore, there are some costs – such as a rise in unemployment or a decline of the output – achieving and maintaining price stability in the short run, induced by wages that are unlikely to adjust due to price rigidities. All in all, monetary policy has a decisive part in anchoring inflation expectations in order to reduce and maintain a low level of inflation. This kind of outcome will nevertheless create the premises for sustainable economic growth and will definitely foster economic activity.

In this context, the analysis of inflation determinants is highly important as it aims to determine the factors that might exert inflationary pressures both in the short and in the long run.

III. Empirical Results

In this section, the reduced form of the hybrid new Keynesian Phillips curve presented in equation (6) is estimated, using the enriched proxy of real marginal cost described in Section 3, in the case of four Central and Eastern European (CEE) countries with certain similarities regarding the process of euro are integration: Poland, Hungary, Czech Republic and Romania. Quarterly data for the core measure of inflation, output gap, real GDP and wages in the business sector for the period 2000Q1 – 2014Q3 was obtained from the websites of the central banks and from Eurostat's database. The core measure of inflation excludes from the overall CPI basket a number of components exogenous in terms of the scope of monetary policy action, which are different in each case. In Czech Republic the monetary policy relevant inflation is defined as headline inflation adjusted for first-round effects of changes to indirect taxes, in Poland and Hungary the core inflation excludes from headline consumption basket food and energy prices while in Romania the corresponding measure excludes from the CPI basket a number of sub-components as administered prices, volatile prices of vegetables, fruit, eggs and fuels, tobacco and alcohol prices.

The income share of labour is calibrated close to compensation of employees to total gross value added ratio, using data from national accounts, according to standard usage both in the literature and central banking practice, at least in the above mentioned countries. The sum of the coefficients α and β is restricted to one. Diminishing returns occurs at least in the short run when one factor is fixed (e.g. capital). Standard theoretical derivations of New Keynesian framework assume that the capital stock of each firm is constant or exogenously given, being independent of the firm's pricing decision. However, reference [23] shows that the empirical specifications largely used in the literature are not compromised by reliance on this assumption. As in [2], semi-structural parameters are estimated using generalized method of moments (GMM). Generalized Method of Moments (GMM) framework is employed due to measurement and simultaneity issues. Assuming that the anticipation of inflation for next period is formed under rational expectations, the forecast error is uncorrelated with past information. Since there is likely that the real marginal cost proxy to be an inexact approximation and some current information to be unavailable at the time that expectations are formed, lags of dependent and independent variables are used as instruments. The orthogonality condition, for the reduced form model, is given by:

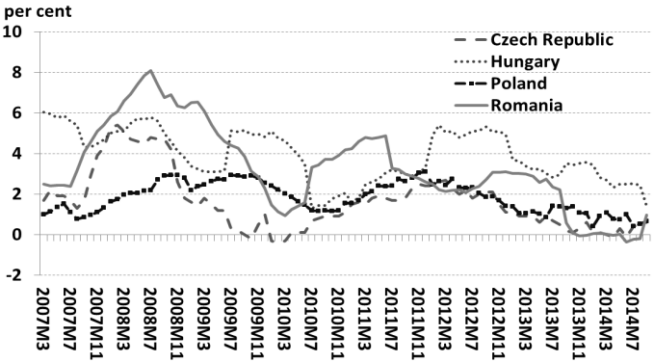
$$E_t\left\{\left[\pi_t - c_1\cdot\pi_{t+1} - (1-c_1)\cdot\pi_{t-1} - \right.\right.$$
$$\left.\left. -c_2\cdot\left(\alpha\cdot y_t - \beta\cdot w_t\right)\right]\cdot z_{t-1}\right\} = 0 \quad (7)$$

where y_t is a measure of output gap and w_t represents the gap of real wage in the business sector. The instruments used in the estimation have been chosen in each case individually, since there is likely that the inflation dynamics to pose country-specific features. In order to test the validity of the over-identifying restrictions the J-test is used.

Apart from testing the relative performance of an improved proxy of real marginal cost, the empirical analysis aims to evaluate the degree of inertia, the impact of forward looking expectations and the inflationary pressures steaming from real economy. To achieve these goals, it is estimated a reduced form hybrid New Keynesian Phillips Curve for Romania and the other three New Member States. In the specific literature were estimated Phillips curves for different inflation measures: GDP deflator, consumer price index inflation (CPI inflation), import price inflation and producer price inflation.

In what regards the current analysis, as explained variable it is used a monetary policy relevant inflation rate specific for each country because it excludes from total CPI basket different components with volatile prices. It is the common view of practitioners and theoreticians that volatile prices depend mainly on factors exogenous to the economy and, hence, distort CPI inflation especially if they have an important contribution to the basket. The role of monetary policy is important in the case of controlling excess demand. Especially in an inflation targeting environment, the central bank should curb excess demand using the monetary policy inflation rate. Consequently, the effectiveness of the monetary policy is determined by the effectiveness of the monetary policy transmission mechanisms. In case of Czech Republic the monetary policy relevant inflation is defined as headline inflation adjusted for first-round effects of changes to indirect taxes, in Poland and Hungary the core inflation excludes from headline consumption basket food and energy prices while in Romania the corresponding measure excludes from the overall CPI a number of prices as: administered prices, volatile prices (of vegetables, fruit, eggs and fuels), tobacco and alcohol prices.

Fig. 2 presents the monetary policy relevant inflation rates in the case of the four New Member States included in the analysis.



Sources: Czech national bank, central bank of Hungary, central bank of Poland, Romanian national bank.

Fig. 2. Monetary policy relevant inflation rate in four new member states.

The main results of the estimations are reported in Table 1 together with some additional statistics. Compared with the simpler approach where as a proxy for real marginal cost is used the output gap, the improved specification is characterized by a greater adjusted R-squared. For testing the better performances of the new specification, it is also compared with the simpler approach for forecasting purposes. For out of sample tests the period 2000Q1 – 2012Q3 is used for estimations and the remaining of the interval, until 2014Q3 is then used to gauge the out-of sample forecast performance of the two version of the Phillips curve. The both in-sample and out-of-sample forecasting performance have improved in terms of root mean squared errors when compared with the simpler version of the Phillips curve based only on output gap as a proxy for real marginal cost.

The inflation inertia coefficient is relatively high in case of Romania and Hungary showing the fact that the persistence component is an important factor in explaining inflation dynamics. Romania, and in a less extent Hungary, have experienced high inflation rates in early 2000's and started the disinflationary process later than its peers. These probably affected the inflation expectations formation mechanism which is still highly adaptive. Other countries, characterized by low and stable inflation rates for a longer period of time managed to firmly anchored inflation expectations through the conduct of monetary policy, benefitting from a much smaller contribution of inertia to inflation. As suggested by the data, from the four country included in the analysis, the disinflationary process from Czech Republic is the less inertial.

In addition, the theoretical unit-sum restriction imposed by the model on the coefficients of lagged inflation and expected

future inflation cannot be rejected by the Wald test at 1 per cent significance level. This proves the fact that the data sustain the principle of neutrality.

TABLE I: ESTIMATION RESULTS OF THE NEW KEYNESIAN PHILLIPS CURVE FOR FOUR NEW MEMBER STATES

	Coefficient on expected future inflation (c_1)	Coefficient on lagged inflation (c_2)	Coefficient on real marginal cost (c_3)
Poland			
Estimated value	0.57	0.4	0.02
Standard error	$(0.08)^{***}$	$(0.07)^{***}$	$(0.01)^{*}$
$\overline{R^2}$	0.74		
Hungary			
Estimated value	0.51	0.45	0.05
Standard error	$(0.014)^{***}$	$(0.12)^{***}$	$(0.02)^{**}$
$\overline{R^2}$	0.51		
Romania			
Estimated value	0.56	0.48	0.02
Standard error	$(0.0065)^{***}$	$(0.01)^{***}$	$(0.00)^{***}$
$\overline{R^2}$	0.71		
Czech Republic			
Estimated value	0.71	0.31	0.10
Standard error	$(0.11)^{***}$	$(0.10)^{***}$	$(0.05)^{**}$
$\overline{R^2}$	0.59		

Notes: *Significant at 10 per cent level; **Significant at 5 per cent level; ***Significant at 1 per cent level.

An important feature of these economies refers to the high share of administered prices in the consumption basket. In 2014, items with administrate prices have a proportion in the harmonized consumption basket of roughly 10.7 per cent in case of Czech Republic, 17.4 per cent in Hungary, 14.3 per cent in Poland and 14.4 per cent in Romania. The necessity of aligning the price of certain goods such as heat energy, gas, electricity to levels agreed with European Union still necessitates price adjustments with a significant impact on CPI inflation. Also, the discretionary way in which administrated prices are set, induces volatility in the evolution of CPI inflation. It is the common view of practitioners and theoreticians that regulated prices as well as volatile food and fuels prices depend mainly on factors exogenous to the monetary policy control, and hence, distort CPI inflation especially if they have an important contribution to the basket.

Furthermore, a characteristic of CEE economies is represented by the vulnerability to supply shocks. This mainly refers to the importance of the oil and unprocessed food prices in the overall CPI basket. The higher the share of fuel and food is in the consumption basket, the more significant effect does a sharp rise in these prices have on headline inflation. This effect is especially significant since monetary policy cannot efficiently restrain inflation pressures resulting from a surge in raw material prices. The only effect the monetary policy has is on the second round effects generated by these inflationary pressures on both forward and backward looking expectations of economic agents. The analysed economies have consumption baskets that comprise high shares of goods whose prices cannot be effectively influenced by monetary policy measures, as items with administered prices, food, fuels or products on which excise duty is levied.

Typically, inflation expectations are modelled as a combination between forward looking and backward looking expectations. However, the proportion given to the forward and backward looking components is extremely important. The more significant is the backward looking part in formation of inflation expectations, the more persistent inflation will be and, hence, monetary policy will be less effective in reducing the inflation rate. The credibility of monetary policy also plays a significant role in formation of inflationary expectations. A higher weight on forward looking expectations is an indicative that wage- and price-setters are confident in the ability of the central bank in achieving its goal, while more backward looking expectations have the exact opposite meaning. From this point of view the inflation expectation in case of Czech Republic suggest a higher credibility of monetary policy ability to control inflation shocks compared with its peers.

IV. CONCLUSION

This paper provides a theoretical and empirical argumentation in support of an improved proxy of real marginal cost designed to replace a simpler measure of output gap or a measure based only on costs of labour. The improved proxy distinguishes two types of inflation pressures coming from the real economy, one associated with the decreasing returns to production factors which determine marginal costs to rise simultaneously with the increase of production volume and the other one related to the position of real wage costs relative to their equilibrium level. In this way it is offered a more detailed insight into the inflationary pressures coming from the real economy. The empirical results showed an improved performance of the New Keynesian Phillips Curve when the new proxy of the real marginal cost gap is used. The richer approach provides also a more insightful interpretation of inflation pressures arising from the real economy. Apart from testing the relative performance of an improved proxy of real marginal cost, the empirical analysis aims to evaluate the degree of inertia, the impact of forward looking expectations and the inflationary pressures steaming from real economy employing Generalized Method of Moments (GMM) framework due to measurement and simultaneity issues. The inflation inertia coefficient is relatively higher in case of Romania and Hungary when compared with Czech Republic and Poland showing the fact that the persistence component is a more important factor in explaining inflation dynamics in the case of the first two economies.

Determining the causes of inflation is particularly important in case of the New Member States of European Union as they attempt to fulfil the Maastricht criteria in the view of acceding to the European Monetary Union. As an emerging economy there are some specific features which characterize the disinflationary process in case of inflation targeting countries from Central and Eastern Europe (CEE-IT).

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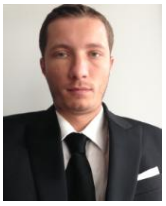

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