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STICKY PRICES VERSUS STICKY INFORMATION. AN APPLICATION FOR ROMANIA

In this paper I compare New Keynesian models under different assumptions regarding the Phillips curves. I use three specifications of the Phillips curves, namely sticky prices, sticky prices with indexation and sticky information specification. I estimate the three models using Bayesian techniques. The degree of price stickiness is moderate, as is the degree of sticky information. The estimates of the Taylor rule are stable across the three models. The Bayesian comparison of the models favours the sticky information model. The results imply that the central bank in Romania should pay attention to the way the agents' expectations are formed.

Keywords: Phillips curve, sticky information, New Keynesian, monetary policy
JEL Classification: C11, E31, E40

1. INTRODUCTION

There are several studies on inflation dynamics for the Romanian economy, either in a classical econometric framework, for example Pelinescu and Ţurlea (2004), or DSGE[1] framework, like Caraiani (2008). However, inflation persistence was not studied almost at all. In this paper I study the inflation persistence in Romania using the DSGE framework.

The New Keynesian sticky prices models (NK, hereafter) initially appeared as successfully in replicating the stylized facts of real data. However, several studies showed that the New Keynesian Phillips curve cannot account for inflation persistence and for the impact of monetary policy shocks on the inflation.

Mankiw and Reis (2002) showed that the sticky information Phillips curve can account for three essential features of the data. Namely, it can reproduce the inflation inertia, it can replicate the fact that announced disinflations are contractionary, and it can reproduce the acceleration phenomena.

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[1] dynamic stochastic general equilibrium (DSGE)

Initial research was done in the partial equilibrium framework. We can notice the contributions of Khan and Zhu (2002), who estimated the sticky information Phillips curve for Canada, the US and the UK, or of Carroll (2003) who estimated the so-called epidemiological model of information transmission based on the US and European micro-data. Also, Dopke et al. (2006) estimated the sticky information Phillips curve for four European economies, France, Germany, Italy and the UK.

The first equilibrium approach to this problem can be traced back to Lucas (1972) who used his island model to show that imperfect information leads to monetary non-neutrality in the short run.

One of the first papers that considered a DSGE approach to the sticky information problem is that of Collard and Dellas (2003). They found the inflation response to the monetary policy shocks peaks in the first period or with just one lag.

Keen (2005) also considered a NK model with sticky information and money growth rule, and showed that the models need high real rigidity in order to replicate the persistence in the real data of inflation response to monetary policy shocks. He also showed that if the policy instrument is an interest rate then, in the NK model with sticky information, a monetary policy shock leads to an immediate response of inflation.

Trabandt (2006) showed that a DSGE model with sticky information can reproduce the three fore mentioned features of the data. However, he also found that such a result can also be reached by using a DSGE model with Calvo sticky prices and indexation. He showed that the two results can be produced under the hypothesis that firms pricing decisions are strategic complements, while Collard and Dellas (2003) and Keen (2005) used the strategic substitutes hypothesis for the pricing decisions of firms.

Several studies compared the sticky information and sticky prices approach, like Paustian and Pytlarczyk, Arslan (2007), Kiley (2007) or Molinari (2006).

While most of the previous DSGE models were simple, Paustian and Pytlarczyk (2006) used the medium-sized model of Smets and Wouters (2003) to test the sticky information hypothesis on Euro zone data. Based on posterior odds ratio, they found that the DSGE model with sticky Calvo specification for prices outperforms the alternative specification. Allowing for heterogeneity in prices and wages did not change the finding that the Calvo model performs better than the sticky information model.

In an original approach, Arslan (2007) presented a novel model with both sticky prices and sticky information firms estimated for US data. He showed

that this model outperformed the simple sticky prices or sticky information models. His estimation showed that most of the firms were of sticky prices type. He also showed that both sticky prices and sticky information hypothesis are important.

Kiley (2007) compared sticky prices and sticky models of inflation for the case of the US. He showed that the hybrid behaviour largely improved the behaviour of the model. In his opinion, the hybrid behaviour was not only compatible with the sticky information hypothesis, but outperformed the latter one in modeling inflation.

Molinari (2006) found mixed evidence about the sticky information hypothesis in US post-war data. On one hand he found that information was updated much more frequently than in the initial findings. At the same time, he also pointed that the sticky information hypothesis could help explain the time varying volatility of inflation.

These studies, either focused on the sticky information case, or focused on the comparison of the two hypotheses, do not offer a conclusive view. It rather seems that further studies should be carried out before dismissing any of the approaches. At the same time, it seems that the research was too much focused on the case of the US or Euro zone.

The DSGE approach to the modeling of inflation in CEE countries is still limited. However, one study is worth mentioning, both due to the number of countries used, and to the comparison of different types of Phillips curves in a NK framework, namely Di Bartolomeo et al. (2004). Although their focus was on monetary policy, they also extensively discussed two versions of NK Phillips curves, the basic forward looking NK Phillips curve and the hybrid type. Their research took into consideration eight of the accession countries at that time. They found that both forward looking and backward looking inflation expectations mattered. However, they did not compare the two types of Phillips curves in terms of the quality of their predictions.

This study contributes to the growing literature on this topic in a few ways. First of all, it estimates DSGE models under alternative assumptions regarding the Phillips curve for a CEE country, namely for Romania. Second, it compares, based on log marginal densities, the results for the sticky prices, sticky prices with indexation and sticky information models. It also discusses the implications for monetary policy of the Taylor rule estimations and of the impact of monetary policy shocks.

2. ALTERNATIVE NEW KEYNESIAN MODELS

In this section I sketch the NK model I use in my analysis. I start from the sticky prices case with Calvo specification, and then I describe the two extensions, namely the sticky prices with indexation and the sticky information case.

2.1. The New Keynesian Model with Sticky Prices

The model I use in this paper is the one that was used by Rabanal and Rubio-Ramirez (2005) to study the American economy, and also for the Euro zone, in Rabanal and Rubio-Ramirez (2003). The model considers a closed economy. This implies that characteristics like liquidity effect (which is a feature of the Romanian economy nowadays due to capital inflows), cannot be analyzed.

While studying a topic like monetary policy for a small open economy obviously requires an open economy model, the focus here is rather on the mechanism of the formation of prices. Although inflation may be determined by external shocks too, the focus in this paper is on its internal mechanism, namely if it is of a price rigidity type, or of an information rigidity type, as in the sticky information case.

The model is presented in the following equations:

$$y_t = E_t y_{t+1} - \sigma(r_t - E_t \Delta p_{t+1} + E_t g_{t+1} - g_t) \tag{1}$$

$$y_t = a_t + (1-\delta) n_t \tag{2}$$

$$mc_t = w_t - p_t + n_t - y_t \tag{3}$$

$$mrs_t = \frac{1}{\sigma} y_t + \gamma m_t - g_t \tag{4}$$

$$r_t = \rho_r r_{t-1} + (1-\rho_r)\left[\gamma_\pi \Delta p_t + \gamma_y y_t\right] + ms_t \tag{5}$$

$$w_t - p_t = w_{t-1} - p_{t-1} + \Delta w_t - \Delta p_t \tag{6}$$

$$a_t = \rho_a a_{t-1} + \varepsilon_t^a \tag{7}$$

$$g_t = \rho_g g_{t-1} + \varepsilon_t^g \tag{8}$$

$$ms_t = \varepsilon_t^m \tag{9}$$

$$\lambda_t = \varepsilon_t^\lambda \tag{10}$$

$$\Delta p_t = \beta E_t \Delta p_{t+1} + k_p mc_t + \lambda_t \tag{11}$$

$$w_t - p_t = mrs_t \tag{12}$$

The first equation represents the relationship between production, (y_t), and the real interest rate r_t represents the nominal interest rate, g_t stands for the preferences, p_t for the price level, while σ is the elasticity of intertemporal substitution E_t is the expectation operator, while Δ is the difference operator. The fact that the parameter σ is common to both real interest rate and the preference-shifter g_t, results from the assumptions regarding the utility function, where preferences are non-separable from consumption.

The second equation expresses the production function where a_t is the technological process, n_t the number of hours worked while δ stands for the capital retribution. The following equation shows the relationship between marginal cost and the nominal wage, w_t.

Equation (4) represents the relationship between the marginal rate of substitution and the hours worked; γ is the inverse of the labour supply elasticity with respect to the real wage. Equation (1) and equation (4) show that the preferences shocks influence both the Euler equation and the marginal rate of substitution.

The monetary policy is specified through a Taylor policy rule, where γ_π and γ_y are the long run responses of the monetary authority to the deviations of the inflation and the output gap from their steady state. I follow here Clarida, Gali and Gertler (1999), and introduce a smoothing parameter for the interest rate, ρ_r.

Equation (6) is a relationship between the dynamic of the real wage and the dynamic of the nominal wage and the inflation.

The last two equations, (11) and (12) express the wages and prices. Under the hypothesis of Calvo (1983) type rigidities for the prices, the equation for the dynamic of prices is given by (11), where:

$$k_p = \frac{(1-\delta)(1-\theta_p)(1-\beta\theta_p)}{\theta_p\left(1+\delta\left(\bar{\varepsilon}-1\right)\right)} \tag{13}$$

and $\bar{\varepsilon} = \frac{\bar{\lambda}}{\bar{\lambda}-1}$ is the steady state of ε, the elasticity of substitution for the different types of goods; Θ_p is the probability that prices stay fixed in the current period.

Equation (11) is the New Keynesian Phillips curve. The current inflation is determined by the expectations on future inflation, and real marginal cost and shocks on the prices mark-up.

Shocks are modeled in a standard way, see equations (7) to (10), with productivity and preferences following AR(1) processes. There are not major evidences in the DSGE literature about the fact that shocks specification could significantly alter the estimation.

2.2. The New Keynesian Model with Sticky Prices and Indexation

The first extension is that of the introduction of the backward perspective in the NK Phillips curve. The backward looking NK Phillips curve is given by the following relation:

$$\Delta p_t = \gamma_b \Delta p_{t-1} + \gamma_f E\Delta p_{t+1} + k_p^{'} mc_t + \lambda_t \tag{14}$$

where $k_p^{'} = \dfrac{k_p}{1+\beta\omega}$

$$\gamma_b = \frac{\omega}{1+\beta\omega}$$

$$\gamma_f = \frac{\beta}{1+\beta\omega}.$$

The degree of price indexation relative to the past period is measured by the parameter ω. The backward looking NK Phillips curve was proposed by Gali and Gertler (1999). They argued that lagged inflation is important in the dynamic of current inflation. This small extension improves the inertia of the inflation.

2.3. The New Keynesian Model with Sticky Information

For the case of the sticky information, the only equation that changes is, again, that of the Phillips curve.

The Phillips curve is now the result of the decision of the firms to maximize the expected profit in the circumstances of monopolistic

competition, given the fact that the information is sticky. The sticky information Phillips curve is given by:

$$\pi_t = \frac{\psi}{1-\psi}(mc_t) + \psi \sum_{j=0}^{\infty} (1-\psi)^j E_{t-1-j}(\pi_t + \Delta(mc_t)) + \lambda_t \quad (15)$$

The degree of information stickiness is measured by ψ. Firms update their information every 1/ψ period(s).

3. THE ESTIMATION OF THE NEW KEYNESIAN MODELS

3.1. The Estimation of the New Keynesian Model with Sticky Prices

In this section I estimate the model given by equations (1)-(12). The variables in the model are y_t, a_t, r_t, Δp_t, Δw_t, n_t, mc_t, rw_t, mrs_t, g_t, λ_t and ms_t which stand for production, total factor productivity, nominal interest rate, inflation, nominal wage growth rate, labor effort, marginal cost, real wage, the marginal rate of substitution, preferences, inflation shock and interest rate shocks.

The set of parameters to be estimated is given by $\{\sigma, \beta, \gamma, \theta_p, \varepsilon, \rho_r, \gamma_y, \gamma_\pi, \delta, \rho_a, \rho_g, \sigma_a, \sigma_m, \sigma_g, \sigma_\lambda\}$. Before applying the Bayesian estimation, several parameters are calibrated. The calibration is done according to the literature, following mainly previous studies for the Romanian economy, like Caraiani (2007a) and Caraiani (2007b), and also Rabanal and Rubio-Ramirez (2005): β is calibrated to 0.99, while γ is fixed to 1; ε is also calibrated since θ and ε cannot be estimated at the same time, as Rabanal and Rubio-Ramirez (2005) argue. The share of capital, δ, is fixed to 0.36.

The rest of the parameters are estimated, namely $\{\sigma, \theta_p, \rho_r, \gamma_y, \gamma_\pi, \rho_a, \rho_g, \sigma_a, \sigma_m, \sigma_g, \sigma_\lambda\}$, using Bayesian techniques. The data series used is the GDP, inflation rate, the interest rate and the wage rate, between 2000 and 2006. All the data is at a quarterly frequency. The GDP series is the quarterly GDP in 1995 constant prices. The inflation rate is given by the annualized monthly rate given by the harmonic consumer price index, the quarterly series being computed as the quarterly average. The interest rate is the refi (refinancing) rate and is computed as the quarterly average. The real wages are the average quarterly nominal wages which are deflated by the quarterly inflation rate. All the initial series were logged, de-seasonalized and then filtered with the Hodrick Prescott filter.

The Bayesian estimation was done through two chains of 150,000 Metropolis Hastings draws. The final acceptance ratio for the first block was of 27.8%, while for the second block it was of 27.7%. The multivariate statistics indicated that the convergence was achieved.

Table 1

The results of the Bayesian Estimation for Sticky Prices Model

Parameters	Mean Prior	Mean Posterior	Confidence Interval		Prior Distribution	Standard Deviation
γ_π	1.5	1.80	1.20	2.36	Normal	0.50
γ_y	0.125	0.12	-0.07	0.31	Normal	0.12
ρ_r	0.5	0.91	0.87	0.94	Uniform	0.28
ρ_a	0.9	0.79	0.64	0.94	Beta	0.1
ρ_g	0.9	0.64	0.39	0.92	Beta	0.1
θp	0.75	0.40	0.23	0.56	Beta	0.1
σ	0.67	0.28	0.16	0.37	Inverted Gamma	0.1
e_a	0.10	0.030	0.021	0.038	Inverted Gamma	Inf.
e_g	0.10	0.045	0.027	0.063	Inverted Gamma	Inf.
e_ms	0.10	0.019	0.014	0.024	Inverted Gamma	Inf.
e_lam	0.10	0.088	0.065	0.108	Inverted Gamma	Inf.

Source: own computations

The estimation of the Taylor rule shows a large value for the inflation coefficient. The coefficient related to the output gap is smaller than the estimates in the literature. Since the estimation period covers the preparation for the Inflation Targeting (IT, hereafter) regime adoption and the IT regime, this result confirms the fact that the National Bank of Romania followed first of all the stabilization of prices.

The estimation of θ_p suggests a moderate degree of price stickiness. The probability that the firms keep their prices fixed during the current period is of 0.40 implying that the firms, in average, change the prices every two quarters.

These findings can be tested against a recent microeconomic study about the behaviour of Romanian firm in setting their prices, namely in Copaciu et al. (2005). They realized an extensive study about what type of rule Romanian firms followed, the way the prices were formed and the size of price changes. For our study, it is more relevant that they found that, on average, firms used to change their prices 2 to 3 times during the considered year, 2005.

While this is a limitation, since we estimated the model using data for several years, their result is close to the estimation above, where the estimation implies that the firms, on average, change prices around two times during a year.

3.2. Estimating the New Keynesian Model under Sticky Prices and Indexation

In order to estimate the NK model with sticky prices and indexation, I calibrate the same subset of parameters. The parameters to be estimated using the Bayesian techniques are:

$$\left\{\sigma, \theta_p, \omega, \rho_r, \gamma_y, \gamma_\pi, \rho_a, \rho_g, \sigma_a, \sigma_m, \sigma_g, \sigma_\lambda\right\}$$

The estimations were done based on two chains of 150,000 Metropolis Hastings draws. The univariate and the multivariate statistics indicate that the convergence was achieved. The final acceptance ratio for the first block was of 25.13%, while for the second block it was of 25.16%.

Table 2

The results of the Bayesian Estimation for Sticky Prices with Indexation Model

Parameters	Mean Prior	Mean Posterior	Confidence Interval		Prior Distribution	Standard Deviation
γ_π	1.5	1.69	1.14	2.23	Normal	0.50
γ_y	0.125	0.14	-0.02	0.33	Normal	0.12
ρ_r	0.5	0.90	0.87	0.94	Uniform	0.28
ρ_a	0.9	0.82	0.68	0.97	Beta	0.1
ρ_g	0.9	0.62	0.38	0.89	Beta	0.1
θp	0.75	0.42	0.24	0.59	Beta	0.1
ω	0.75	0.69	0.52	0.86	Beta	0.1
σ	0.67	0.26	0.16	0.36	Inverted Gamma	0.1
e_a	0.10	0.031	0.021	0.040	Inverted Gamma	Inf.
e_g	0.10	0.048	0.030	0.066	Inverted Gamma	Inf.
e_ms	0.10	0.018	0.018	0.023	Inverted Gamma	Inf.
e_lam	0.10	0.058	0.058	0.074	Inverted Gamma	Inf.

Source: own computations

The second estimation leads to a lower, but close to the first estimation value of the inflation coefficient in the Taylor rule. The values of the interest

rate smoothing and output gap coefficient are approximately equal. Thus the Taylor rule appears as quite stable across the two estimations.

The probability of keeping the prices fixed is estimated at an approximately equal value to the previous estimation. The supplementary parameter of price indexation shows a high degree of indexation, as ω=0.69. This result contrasts with the finding of Di Bartolomeo et al. (2004) who estimated that most Romanian firms are forward-looking. However, Di Bartolomeo et al. (2004) fixed the price stickiness and the sample was between 1994 and 2002, so that the results are hard to be compared.

3.3. Estimating the New Keynesian Model under Sticky Information

For the sticky information Phillips curve I follow the same strategy for the estimation. The set of estimated parameters is given by:

$$\left\{\sigma, \rho_r, \gamma_y, \gamma_\pi, \psi, \rho_a, \rho_g, \sigma_a, \sigma_m, \sigma_g, \sigma_\lambda\right\}$$

The estimations were done based on two chains of 150,000 Metropolis Hastings draws. The univariate and the multivariate statistics indicate that convergence was achieved. The final acceptance ratio for the first block was of 25.0%, while for the second block it was of 25.1%.

Table 3

The results of the Bayesian Estimation for Sticky Information

Parameters	Mean Prior	Mean Posterior	Confidence Interval		Prior Distribution	Standard Deviation
γ_π	1.5	1.78	1.21	2.37	Normal	0.50
γ_y	0.125	0.15	-0.03	0.35	Normal	0.12
ρ_r	0.5	0.89	0.85	0.94	Uniform	0.28
ρ_a	0.9	0.75	0.59	0.91	Beta	0.1
ρ_g	0.9	0.69	0.43	0.94	Beta	0.1
ψ	0.25	0.48	0.36	0.60	Beta	0.1
σ	0.67	0.39	0.20	0.58	Inverted Gamma	0.1
e_a	0.10	0.028	0.020	0.035	Inverted Gamma	Inf.
e_g	0.10	0.039	0.023	0.055	Inverted Gamma	Inf.
e_ms	0.10	0.020	0.015	0.025	Inverted Gamma	Inf.
e_lam	0.10	0.103	0.071	0.133	Inverted Gamma	Inf.

Source: own computations

The inflation coefficient in the Taylor rule is closer to the first estimation. The estimates for the output gap and the interest rate smoothing parameter show similar values. The output gap coefficient is slightly higher than in the previous estimations. The Taylor rule appears as remarkably stable across the three estimates of the NK model suggesting that the specification is reasonable for the Romanian economy for the studied sample.

The information rigidity parameter, ψ, is estimated at 0.48. This implies that the firms update their information every two quarters.

3.4. Bayesian Comparison of the Models

While some of the previous studies on this topic considered the comparison of the models estimated using different econometric approaches, I focused in this paper only on the Bayesian approach. The recent research on macroeconometrics underscored the superiority of the Bayesian approach. Without entering a detailed presentation, it should be pointed out that this setting prior is a natural approach when estimating a macroeconomic model, due to our knowledge about the distribution of the parameters. At the same time, the calibration or the maximum likelihood approach are merely but two particular cases of the more general Bayesian approach, as this latter approach is a combination of calibration and maximum likelihood.

It is also interesting to compare the estimations in terms of posterior odds ratio. I present the log-marginal likelihoods in table. To check for the sensitivity of the results to the way expectations are formed in the sticky information case, I also estimate the sticky information model for two alternative cases. In one case, the agents use the expectations formed in the last two periods, while in the second case they use the expectations formed in the last six periods.

Table 4

Bayesian Comparison

Model	Log Marginal Likelihood	Log Bayes Factor
Sticky Prices	240.17	-
Sticky Prices with Indexation	240.56	0.39
Sticky Information 2 periods expectation formation	249.02	8.85
Sticky Information 4 periods expectation formation	249.28	9.11
Sticky Information 6 periods expectation formation	248.66	8.49

Source: own computations

We can use Jeffreys, (1961) thumb rule to discriminate between the models. According to this rule, a log-Bayes factor higher than two is decisive against the alternative model. Thus, it appears that the sticky information model outperforms both the Sticky Prices NK model and the Sticky Prices with Indexation NK model. Moreover, the introduction of indexation in the NK model with Sticky Prices improves the performance of the model very little.

As for the number of periods taken into account in forming expectations in the Sticky Information model, the results favour the four periods model, even if only marginally, both compared to the six and two periods model. At the same time, the version with two periods is better than that with six periods, but in the next section I will focus on the best version of the three. The results here underscore the necessity of the right evaluation of the formation of expectations in the Romanian economy and, more generally, in the CEE countries, by showing that frictions are not as much related to the firms' behaviour in the goods market as they are related to the way expectations are formed. The results are rather natural for a country where prices are volatile and change often.

4. THE IMPACT OF MONETARY POLICY SHOCKS

I discuss in this section the impulse response functions of the inflation, output and interest rate to the monetary shock for the sticky information model. I also compare the results of the model with the results from a typical three variable VAR consisting of inflation, interest rate and output which was estimated on quarterly data.

Annex 1 shows the impulse response functions in the VAR to an interest rate shock. We can notice a moderate persistence in the interest rate response. The positive effect lasts for about six quarters.

As for the output gap response, we can see that it reacts with a two quarter lag. The negative effect lasts for almost two years, which is a moderate persistence.

We can also notice a hump shaped response of inflation with reaches a peak after three quarters. The negative response of inflation last for about seven to eight quarters. The large confidence band also suggests the possibility of the price puzzle effect.

For the NK model, all the impulse response functions are drawn from 50,000 simulations. The simulations were based on calibrations of the parameters using the posterior mean of the Bayesian estimations.

In Annex 2 we can see the results of the impulse response function to the interest rate for the sticky information model. For this model the results are close to the VAR results in terms of persistence of the responses, however the impact on inflation takes slightly less than in the VAR model.

The model has difficulties in reproducing the hump shaped responses of inflation and output to the monetary policy shock. This may confirm Trabandt's (2006) finding that the hump-shaped impulse response functions are related more to the strategic complements feature of pricing decision of the firms. Obtaining a more realistic impulse response function may also require a more complex model, with wage rigidity, adjustments cost or habit formation. This topic is worth to be further studied, namely which factors contribute most to the formation of hump shaped type impulse response functions for a CEE country. At the same time, it remains an essential topic in the practical modeling of monetary policy, since the policy makers should have the best information about the timing of the maximum response of the macroeconomic variables to an interest rate shock.

5. CONCLUSION

Under the IT regime, which was adopted by the National Bank of Romania, the expectations of the private agents are essential to the effectiveness of monetary policy. This raises the issue of a correct understanding and modeling of the formation of expectations of private agents.

In the typical NK model, expectations influence the dynamic of current variables due to the forward looking feature of the Phillips curve and of the IS curve. But one alternative is to introduce the sticky information hypothesis and to derive the Phillips curve under this framework.

In this paper I showed that the NK model with sticky information clearly outperforms the standard sticky information NK model in terms of log Bayes factor in the case of Romania. At the same time, the NK model in any of the specifications cannot reproduce the hump shaped inflation and output response to the interest rate shock. However, this feature can be obtained either under different instrument rules, like money growth rule, as in Keen (2005), or under the hypothesis that firms pricing decisions are strategic

complements, as Trabandt (2006) showed. Future research for the Romanian economy should check the robustness of these results under different hypothesis regarding the DSGE model.

The results here imply that the monetary authority in Romania should give more emphases to the way households form expectations. The results also suggest that the sticky prices hypothesis should be tested before taken as granted.

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