Comparing sticky prices and sticky information in a New Keynesian model based on forecast accuracy

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We estimate three different versions of a standard New Keynesian model that take into account various specifications of the Phillips curve, including sticky prices, sticky information and sticky prices and indexation. We compare these models based on their forecasting accuracy relative to output and inflation. For the case of output, the results are mixed as no specification is clearly favored. With respect to inflation, the sticky information and sticky prices with indexation models outperform the baseline model. The model with sticky prices and indexation also outperforms the sticky information model in the short run. The sticky information framework appears as having a limited value in improving the forecasting accuracy.

Keywords: Phillips Curve, Sticky Information, New Keynesian, monetary policy.
JEL Classification: C11, E31, E40.

1. Introduction

The standard New Keynesian model (NK from here), see Clarida, Gali and Gertler (1999) for a presentation of the canonical specification, although has addressed several issues, has some difficulties in replicating both the inflation persistence as well as the impact of monetary policy shocks. A solution to these difficulties was proposed by Mankiw and Reis (2002) who introduced the idea of sticky information and show that it can replicate the above mentioned puzzles. Since then, numerous studies have been carried on analyzing whether sticky information improves the performance of the New Keynesian Phillips curve, either in the partial equilibrium framework, or in general equilibrium.

In a partial equilibrium framework, Dopke et al. (2006) estimated the sticky information Phillips curve for four European economies, France, Germany, Italy and UK.

The general equilibrium approach is much older than the incorporation of sticky information into the Phillips curve, dating to the idea of Lucas (1972) who incorporated imperfect information into his model consisting in islands. Collard and Dellas (2003) was among the first studies that included the sticky information into the standard DSGE model.

A few studies compared the performance of DSGE models with sticky prices and sticky information. Trabandt (2006) showed that although the model with sticky information can reproduce the above mentioned features in data, the same performance can be reached when a model includes both sticky prices and indexation.

Paustian and Pytlarczyk (2006) extended the previous research by considering a medium size model as proposed by Smets and Wouters (2003). Surprisingly, they found that, in terms of posterior odds ratio, the sticky price version outperforms the sticky information specification.

Further evidences were found by Arslan (2008), who compared the response of a sticky information model and of a typical NK model with sticky prices to a cost push shock. The simulation shows that the sticky information framework leads to more realistic results.

Kiley (2007) performed a comparison between the sticky information NK model and the sticky price specification based on their ability to model inflation. His results indicate that when a hybrid component is included, the results of a NK model are improved.

The results in Mankiw and Reis (2002) were revisited by Keen (2007) who showed that their results are sensitive to the calibration of their model. The results depend on the degree of real rigidity as well as the way the monetary policy is specified.

Recently, new evidences against the sticky information framework were found by Carillo (2012) who, based on estimated VAR models on US data, showed that such a model leads to worse response following a productivity shock as compared with a standard NK model with inflation indexation and habit.

We can conclude that there is no definite answer on the usefulness of the sticky information framework and although the initial contributions have shown some advantages vis-a-vis the standard New Keynesian framework, later contributions have also indicated that when the New Keynesian model departs from the standard specification and it includes further features, then it can have a better performance than a NK model with sticky information.

In this paper, we compare three different New Keynesian models, one with sticky prices, one with sticky information and one with both sticky prices and indexation which we estimate on US data using a Bayesian methodology.

This study contributes to existing literature on this topic in a few ways. In contrast with previous approaches, we compare the different specifications for NK models based on their forecasting ability.

Although there is a growing literature regarding the ability of DSGE models to forecast as compared to alternative approaches, mostly VARs, see Rubaszek and Skrzypczyński (2008) or Guangling et al. (2009), or factor models, see Wang (2009) for a relevant example, there is a weak literature regarding what drives the ability of DSGE models to forecast, especially with respect to their specification (microfoundations). Among the approaches to address these shortcomings, we can enumerate Matthes and Wang (2012). However, they compare different models without precisely looking at what kind of micro foundations drives the accuracy of the different models.

This paper is organized as follows. The next section describes the models used within the paper. In the third section we present the data used in the estimation, the calibration and estimation of the three models and we discuss the resulting estimates. We compare the forecast accuracies for output and inflation for each of the models in the fourth section. In the last section we conclude and outline possible future developments.

2. Alternative New Keynesian Models

We present here the models used throughout the paper. We build on a typical sticky price New Keynesian model to which we consider two alternatives, namely a sticky information NK model as well as the augmentation of the baseline sticky price model with price indexation.

2.1. The New Keynesian Model with Sticky Prices

We use the model proposed by Rabanal and Rubio-Ramirez (2005) which was estimated on US data. Besides being known to work well, the baseline model together with its different versions has also been estimated for the case of Euro Area, see Rabanal and Rubio-Ramirez (2003).

The baseline model is an enhanced version of a typical New Keynesian model with sticky prices and thus is a reasonable starting point for our comparison exercise. The model assumes a closed economy and is a reasonable hypothesis given the large economy status of US economy. We present the model in its log linear form in the following equations:

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

$$y_t = a_t + (1-\delta) n_t \quad (2)$$

$$mc_t = w_t - p_t + n_t - y_t \quad (3)$$

$$mrs_t = \frac{1}{\sigma} y_t + \gamma n_t - g_t \quad (4)$$

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

$$w_t - p_t = w_{t-1} - p_{t-1} + \Delta w_t - \Delta p_t \quad (6)$$

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

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

$$ms_t = \varepsilon_t^m \quad (9)$$

$$\lambda_t = \varepsilon_t^\lambda \quad (10)$$

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

$$w_t - p_t = mrs_t \quad (12)$$

The first equation is a typical New Keynesian IS curve showing the drivers of output: expected output y_t, the real interest rate, r_t, minus inflation, the rate of change of prices p_t. The preference shocks g_t also drive the dynamics of output.

Equation (2) shows the linearized production function, where a_t stands for the technological process while n_t represents the hours worked.

The next equation, the third one, presents the relationship between marginal cost and nominal wage w_t. The marginal rate of substitution, mrs_t, and the hours worked are related in the fourth equation. The preference shocks have a role in this relationship too.

The monetary policy rule is described in equation (5). We have slightly modified the specification in Rabanal and Rubio-Ramirez (2003) by considering that there is smoothing process for the interest rate, in line with the findings in Clarida, Gali and Gertler (1999).

The real and the nominal wages are related in the sixth equation. Finally, dynamics for prices and wages are shown in equations (11) - (12). The baseline model assumes Calvo type sticky prices, see equation (11) for the specification of the New Keynesian Phillips curve. The parameter k_p is given by:

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

where $\bar{\varepsilon} = \frac{\bar{\lambda}}{\bar{\lambda}-1}$ is the steady state of ε, the elasticity of substitution for the different types of goods. The key parameter of the New Keynesian Phillips curve with sticky prices is Θ_p, which stands for the probability that prices remain the same in the current period.

Finally, the model is closed by specifying the shocks in equations (7) - (10). For productivity and preferences there is assumed that they follow AR(1) processes, while for monetary policy and supply shocks, we simply assume they are not correlated over time.

2.2. The New Keynesian Model with Sticky Prices and Indexation

We look first at a very used modification of the NK Phillips curve which consists in allowing for backward-lookingness. This extension has been proposed by Gali and Gertler (1999) who have shown that it can improve the modeling of inflation dynamics with respect to inflation inertia.

A standard specification for a NK Phillips curve with backward-lookingness is given below:

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

Where $k_p^{'} = \frac{k_p}{1+\beta\omega}$

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

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

The newly introduced parameter ω measures the degree of price indexation relative to the last period.

2.3. The New Keynesian Model with Sticky Information

We also consider the introduction of the sticky information hypothesis within the Phillips curve. By changing only the Phillips curve, we are able to compare the different specification of the Phillips curve within the same New Keynesian model.

In this case, the optimization decision by the firms is changed. The firms now maximize the expected profit in a monopolistic environment facing sticky information. We assume a rather standard specification as presented below:

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

The parameter that measures the degree of information stickiness is ψ. The higher the parameter, the larger the number of firms that update their information. Firms update their information every 1/ψ period.

3. The Estimation of the New Keynesian Models

3.1. Data

We use the data set proposed in the original paper by Rabanal and Rubio - Ramirez (2005). In doing so, one hand we are able to compare our results with theirs. At the same time, since this is not a replication exercise, we did not aim at obtaining perfectly similar results, which would have been hard given the sensitivity of the Bayesian estimation to the prior choices, see Del Negro and Schorfheide (2008). On the other hand, we are able to compare the introduction of sticky information with sticky prices and sticky prices and indexation within models which are well known and tested. Not at last, we provide an additional testing of the proposed model (at least for the cases of the sticky prices and sticky prices with indexation), by providing a comparison of forecast accuracies.

The dataset comprises also, besides the three key variables in any New Keynesian model, namely inflation, interest rate and the real output, the real wage, reflecting the inclusion of a wage decision in the model. The data sources are the Bureau of Labor Statistics for output, prices and wages and the FRED data base (based on the Board of Governors of the Federal Reserve System) for the interest rate.

The output is given by the output for the non-farm business sector, and the corresponding deflator as a measure of prices. The nominal wage is given by the compensation at hourly level for the nonfarm business sector. The interest rate, as it is usually done, is given by the federal funds rate.

The sample for the series lasts from the first quarter of 1960 to the last quarter of 2001. The sample size is reasonable long to perform both Bayesian estimations and forecasting. Before using the data series, all the series are demeaned as well as detrended based on a quadratic trend, as it was done in the original paper by Rabanal and Rubio-Ramirez (2005).

3.2. The Estimation of the New Keynesian models

We discuss in this section the procedure to estimate the models and the results. We estimate the model given by equations (1)-(12), as well as the two alternative specifications. The model is comprised from the following variables: y_t, a_t, r_t, Δp_t, Δw_t, n_t, mc_t, rw_t, mrs_t, g_t, λ_t şi ms_t representing the output, the total factor productivity, the interest rate, the inflation, the growth rate of nominal wage, the labor effort, the marginal cost, the real wage, the marginal rate of substitution, the preference shocks, the inflationary shock as well as the interest rate shocks.

Before estimating the models, some of the parameters were calibrated. We calibrated some of the parameters based on the results in the literature. For example, the discount factor β was calibrated at 0.99, while the γ parameter was set at 1. The parameter ε is also calibrated since, as it is argued in the original paper by Rabanal and Rubio –Ramirez (2005), this parameter cannot be estimated at the same time with the parameter θ that characterizes the degree of rigidity of prices, namely how often the producers update the prices.

The estimation paradigm is the Bayesian one, and it is argued in the literature that this is an adequate approach in dealing with structural models. We used two chains of Metropolis Hasting draws, each with a 200.000 length. The resulting estimations for each case are checked with respect to convergence results (based on Brooks-Gelman statistics), univariate and multivariate, as well as the acceptance rates that are ensured to lie between 20 and 40%, the optimal range.

The results of the estimations are presented in Annex 1, Table 1.1 for the standard New Keynesian model, Table 1.2 for the New Keynesian model with sticky information and Table 1.3 for the New Keynesian model with both sticky prices and indexation. We have reported the estimates for the full sample.

The first thing we remark is that the estimation is stable across the different specifications as the differences between the posterior means are rather minor. There is also, generally, a reasonable variation between the prior distributions and the posterior distributions.

The estimates of the Taylor rule are within the expected range and confirm the general results in the literature. The estimated coefficient for inflation is around 1.5, indicating an active monetary policy. The smoothing parameter for the interest rate is moderate, indicating a moderate monetary policy. The estimates are slightly lower than the ones in Rabanal and Rubio-Ramirez (2005). There are some larger differences as compared to the estimates in the original paper, when it comes to the output coefficient.

The estimation of θ_p suggests a moderate degree of price stickiness. There is larger price stickiness in the NK model that allows for price indexation. The price indexation is moderate to strong, the posterior mean being estimated at 0.65. The degree of sticky information is however pretty large, the firms updating their information every 9 periods (the inverse of the estimated value of the degree of sticky information ψ).

4. Comparing the forecasting accuracy of the estimated models

In this section we further analyze the results of the estimations based on the accuracy of the forecasts. We performed out-of-sample forecasts for each of the models. The forecasts were done in a recursive manner with an out-of-sample of 20 observations (the out-of-sample approach is the typical one in the DSGE literature), that is to five years, corresponding to a sample between Q1 1997 and Q4 2001. In order to check for the effect of the forecast horizon, we ran the forecasting exercises for different horizons, that is of 1 quarter, of 4 quarters and of 8 quarters.

A first measure to compare the forecast accuracies was based on the standard RMSE statistic as presented below. We denote the model by *j* each model, by *h* the forecast horizon, by τ_0 the beginning of the sample for forecast, namely 1997 Q1, by τ the τ-th prediction of a model for output for *h* steps in the future, and by $y^0_{i,\tau+h}$ the actual observation, while *i* is the variable of interest, then we can write:

$$RMSE(h,i,j) = \sqrt{\frac{\sum_{\tau=\tau_0}^{T-h}\left(y^0_{i,\tau+h} - E\left(y^j_{i,\tau+h} | T\right)\right)^2}{T-h}} \tag{16}$$

Given that the RMSE statistic is, generally, not sufficiently informative, we compute the forecast accuracies based on the Diebold Marion test that allows to discriminate between the computed RMSE of different models.

Annex 2 presents the RMSEs for each model for every corresponding forecast horizon. We have included the forecasts only for inflation and output. For the case of inflation, the choice is justified since we assume different specifications for the Phillips curve and thus we would expect the different specifications of the Phillips curve to significantly influence the dynamics and forecasts of inflation. We are also interested in checking the impact of the different specifications on the forecasting accuracy for output.

Table 1. Diebold Mariano test results for output

Forecasting Horizon	***M2 vs. M1***	***M3 vs. M1***	***M3 vs. M2***
1 step ahead	*-3.21*	*0.43*	*3.60*
4 steps ahead	*-1.54*	*-0.94*	*0.74*
8 steps ahead	*1.30*	*-1.39*	*-1.33*

Source: Own Computations

Table 2. Diebold Mariano test results for inflation

Forecasting Horizon	***M2 vs. M1***	***M3 vs. M1***	***M3 vs. M2***
1 step ahead	*6.26*	*1.69*	*-6.53*
4 steps ahead	*4.31*	*5.02*	*-3.60*
8 steps ahead	*3.11*	*5.65*	*-0.56*

Source: Own Computations.

The results of applying the Diebold-Mariano test are presented in Table 1 for inflation and Table 2 for output. We have compared not only the model with sticky information (named *M3* in the two tables) to the two models with sticky prices (*M1* is the baseline model, while *M2* is the model with both sticky prices and indexation), but we have also compared the model extended with indexation to the baseline model.

When looking at the results for output, we that the results are mixed across specifications and forecasting horizons, although we can observe that at lower forecast horizons, *1* and *4* steps ahead, the baseline model *M1* is better than the model with indexation *M2*, however at *8* steps the model augmented with indexation becomes better.

The results for inflation are, as we would have expected, much clearer. Both the extended model with indexation *M2* and the model with sticky information *M3* clearly outperform the baseline model at all forecast horizons. When models *M2* and *M3* are compared, the model with indexation *M2* outperforms the model with sticky information at least for *1* and *4* step ahead forecasts, and also has a lower RMSE at *8* steps ahead forecasts.

The results point to the fact that there is some utility in adopting the information stickiness, at least when comparing to the baseline model. However this advantage becomes less clear when richer specifications of a New Keynesian model are used, in our case, the price indexation, and generally confirm the latest findings on this issue.

5. Conclusion

We estimated three New Keynesian models which differ with respect to the specifications of the Phillips curve. Besides the standard sticky prices, we have also considered the introduction of indexation as well as sticky information.

The results of the estimations are generally in line with those from the literature, point to moderate sticky information and moderate to strong sticky information. The models were further compared based on the ability to accurately forecast output and inflation.

For the case of output, we have rather mixed results, no specification being clearly better than the other ones, although the baseline model appears to produce better forecasts in the short run compared to the model with indexation, while the model with indexation performs better in the medium run. This lack of definite results may come from the fact that the output dynamics are much more influenced by different structural parameters and rigidities.

There are clearer results when forecasting inflation. Better forecasts result when using sticky information as compared to the baseline model, but the sticky information model is outperformed itself when indexation is introduced. These results are in line with the latest findings in the literature that point to the fact that although there is some value of introducing sticky information, better results can be obtained with more complex specifications for the New Keynesian models with sticky prices.

The paper contributes to the growing interest on the role of imperfect information too and can be a starting point to future research on the role of imperfect information, learning and bounded rationality in obtaining accurate forecasts.

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ANNEX 1. Results of the estimation

Table 1.1.The results of the Bayesian Estimation for Sticky Prices Model

Parameters	*Mean Prior*	*Mean Posterior*	*Confidence Interval*	*Confidence Interval*	*Prior Distribution*	*Standard Deviation*
ρ_r	0.70	0.64	0.58	0.70	Beta	0.10
γ_π	1.50	1.56	1.43	1.69	Normal	0.10
γ_y	0.125	0.25	0.16	0.35	Normal	0.10
θp	0.70	0.46	0.42	0.50	Beta	0.15
e_a	0.05	0.005	0.043	0.005	Uniform	0.02
e_g	0.05	0.011	0.097	0.013	Uniform	0.02
e_ms	0.05	0.017	0.014	0.002	Uniform	0.02
e_lam	0.05	0.048	0.036	0.059	Uniform	0.02

Source: Own Computations

Table 1.2. The results of the Bayesian Estimation for Sticky Prices with Indexation Model

Parameters	***Mean Prior***	***Mean Posterior***	***Confidence Interval***	***Confidence Interval***	***Prior Distribution***	***Standard Deviation***
ρ_r	*0.70*	*0.65*	*0.58*	*0.71*	*Beta*	*0.10*
γ_π	*1.50*	*1.53*	*1.40*	*1.67*	*Normal*	*0.10*
γ_y	*0.125*	*0.28*	*0.18*	*0.37*	*Normal*	*0.10*
θp	*0.70*	*0.57*	*0.51*	*0.63*	*Beta*	*0.15*
ω	*0.70*	*0.65*	*0.46*	*0.84*	*Beta*	*0.15*
e_a	*0.05*	*0.005*	*0.042*	*0.005*	*Uniform*	*0.02*
e_g	*0.05*	*0.011*	*0.099*	*0.013*	*Uniform*	*0.02*
e_ms	*0.05*	*0.017*	*0.014*	*0.002*	*Uniform*	*0.02*
e_lam	*0.05*	*0.068*	*0.046*	*0.091*	*Uniform*	*0.02*

Source: Own Computations.

Table 1.3. The results of the Bayesian Estimation for Sticky Information

Parameters	***Mean Prior***	***Mean Posterior***	***Confidence Interval***	***Confidence Interval***	***Prior Distribution***	***Standard Deviation***
ρ_r	*0.70*	*0.62*	*0.55*	*0.69*	*Beta*	*0.10*
γ_π	*1.50*	*1.51*	*1.37*	*1.65*	*Normal*	*0.10*
γ_y	*0.125*	*0.27*	*0.18*	*0.36*	*Normal*	*0.10*
ψ	*0.50*	*0.12*	*0.10*	*0.14*	*Beta*	*0.15*
e_a	*0.05*	*0.005*	*0.047*	*0.006*	*Uniform*	*0.02*
e_g	*0.05*	*0.012*	*0.010*	*0.014*	*Uniform*	*0.02*
e_ms	*0.05*	*0.018*	*0.015*	*0.002*	*Uniform*	*0.02*
e_lam	*0.05*	*0.032*	*0.027*	*0.037*	*Uniform*	*0.02*

Source: Own Computations.

ANNEX 2. RMSEs of the forecasts with DSGE models

Table 2.1. Results for output

Forecasting Horizon	***Sticky prices***	***Sticky prices & indexation***	***Sticky information***
1 step ahead	*0.002676*	*0.003589*	*0.002625*
4 steps ahead	*0.005384*	*0.005632*	*0.005467*
8 steps ahead	*0.006499*	*0.006531*	*0.006531*

Source: Own Computations

Table 2.2. Results for inflation

Forecasting Horizon	***Sticky prices***	***Sticky prices & indexation***	***Sticky information***
1 step ahead	*0.002672*	*0.001396*	*0.002577*
4 steps ahead	*0.003870*	*0.003610*	*0.003805*
8 steps ahead	*0.004254*	*0.004233*	*0.004237*

Source: Own Computations.