What Drives Inflation in New Keynesian Models?

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Abstract

This paper estimates variants of a textbook small-scale New Keynesian model using only observations on inflation, inflation expectations and nominal interest rates. We ask if those variables alone can tell us something useful about the time series properties of real marginal costs, which are a major factor in the price setting decisions of firms in a New Keynesian model. We compare our estimates of marginal costs to a set of observable variables which could possibly proxy for marginal cost and find that labor share is most highly correlated with our estimates. However, there is substantial variation in our estimates that can not be explained by any of the observable variables we consider.

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1   Introduction

A textbook New Keynesian model predicts that inflation today depends on expected future inflation and a measure of real marginal costs that firms in the economy take into account when forming prices. In this paper we ask what data on inflation, nominal interest rates and inflation expectations tell us about this measure of marginal cost. Can those nominal variables alone help us decide which of several candidate variables that we observe in the data is most closely related to marginal cost and thus drives inflation in a standard New Keynesian model? We estimate a simple New Keynesian model using Bayesian methods and back out estimates of the unobserved measure of marginal cost, which we then compare to our candidate variables. The candidate variables we consider are either directly motivated by the New Keynesian model we use or broad measures of real economic activity that could a priori be assumed to be highly correlated with marginal cost.

2   Model

This section presents a benchmark New Keynesian based on An & Schorfheide (2007) in its log-linearized form, which will we use to estimate the model's parameters and the path of average marginal cost in the economy. Firms are monopolistically competitive and face a quadratic cost of adjusting prices. This leads to a forward looking New Keynesian Phillips curve of the following form, where all variables are measured as deviations from steady state:[1]

$$\pi_t = \beta E_t \pi_{t+1} + \kappa y_t, \tag{1}$$

where β denotes the discount factor. Note that here inflation π_t is written as a function of the output gap y_t, but it would be also be consistent with the underlying non-linear model to write inflation as a function of average marginal cost in the economy.[2] Log-linearizing the representative household's

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[1]The results presented in this paper are robust to assuming a hybrid New Keynesian Phillips curve instead.

[2]An alternative specification (which we do not pursue here) would be to write down a model with inventories, which would allow us to express inflation as a function of the marginal cost of sales. This approach has been pursued by Jung & Yun (2010).

consumption Euler equation gives the following equation:

$$y_t = E_t y_{t+1} - \frac{1}{\tau}(R_t - E_t \pi_{t+1} - E_t z_{t+1}), \tag{2}$$

where τ denotes the inverse of the intertemporal elasticity of substitution, z_t is a shock to the aggregate productivity, and R_t is the nominal interest rate. Following An & Schorfheide (2007), we consider two specifications for the monetary policy rule. First, we consider a specification where the central bank responds to the output gap:

$$R_t = \rho_R R_{t-1} + (1 - \rho_R)(\psi_1 \pi_t + \psi_2 y_t) + \epsilon_{R,t}, \tag{3}$$

where ρ_R is the central bank's interest rate smoothing parameter, ψ_1 the central bank's reaction parameter to inflation, ψ_2 the central bank's reaction to output gap, and $\epsilon_{R,t}$ the monetary policy shock. As an alternative, we also consider a policy rule in which the central bank responds to output growth:

$$R_t = \rho_R R_{t-1} + (1 - \rho_R)(\psi_1 \pi_t + \psi_2(\Delta y_t + z_t)) + \epsilon_{R,t}, \tag{4}$$

where ψ_2 now measures the central bank's reaction to the output gap. Finally, z_t is governed by an AR(1) process with Gaussian innovations,

$$z_t = \rho_z z_{t-1} + \epsilon_{z,t}, \tag{5}$$

while $\epsilon_{R,t}$ and $\epsilon_{z,t}$ are Gaussian white noise shocks.

3 Data

In the estimation of our model, we use quarterly US data from 1969:1 to 2010:4 on inflation based on the GDP deflator, median inflation expectations based on the same measure of inflation and the Federal Funds Rate. The data on inflation and inflation expectations is coming from the Survey of Professional Forecasters at the Philadelphia Fed. We chose a GDP deflator based measure because it allows us to use a longer time series than other measures. We aligned inflation expectations with other observables in such a way that the time t expectations are formed using the information available at time t (instead of an information set that already includes time t variables). All observables are seasonally adjusted. We chose not to include

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real variables such as capital, output, hours or consumption because those variables are either components of GDP or inputs into the production of GDP and could thus bias our results into the direction of candidate variables that are correlated with output. This consideration has also lead us to use a small scale New Keynesian model rather than a model in the tradition of Smets & Wouters (2007), which would have been very hard to estimate on the limited number of observables we use.

3.1   The Candidate Variables

We consider 6 variables which we will compare to the filtered estimate of marginal cost coming out of the estimation of our model:

1. logarithm of real GDP detrended using the Hodrick-Prescott filter

2. logarithm of real GDP detrended using a quadratic trend

3. real GDP growth

4. logarithm of labor share of real income

5. the unemployment rate

6. logarithm of the Aruoba-Diebold-Scotti index

Real GDP and the unemployment rate are taken from the St. Louis Fed's FRED database. The Aruoba-Diebold-Sciotti index (Aruoba, Diebold & Scotti (2009))is a measure of real business conditions based on a factor model and is available at the Philadelphia Fed website. Finally, the labor share is taken from the BLS.
Using labor share as a measure of real marginal cost follows Gali & Gertler (1999) and Sbordone (2005). That paper shows that labor share (or equivalently, real unit labor costs) has substantially different time series properties than common measures of the output gap. A similar conclusion is reached by Sbordone (2002) for nominal unit labor costs. All candidate variables are seasonally adjusted.

4 Estimation

We estimate our model using Bayesian methods. We use priors and estimation strategy similar to those used in An & Schorfheide (2007).[3] We estimate 4 different specifications: two different specifications for the policy rule and for each of those policy rule specifications we estimate the model with inflation expectations as an observable and without inflation expectations. The output gap specification without inflation expectation data is referred to as the benchmark specification. The measurement equations are

$$Inflation_t = \pi^{(A)} + 400\pi_t \tag{6}$$

$$Fedfunds_t = \pi^{(A)} + r^{(A)} + 4\gamma^{(Q)} + 400R_t \tag{7}$$

$$InflationForecast_t = \pi^{(A)} + 400E_t\pi_{t+1} + \epsilon_{\pi,t}, \tag{8}$$

where $\pi^{(A)}$ denotes the annual steady state inflation rate, $r^{(A)}$ the annual steady state nominal interest rate, $\gamma^{(Q)}$ the quarterly steady state technology growth rate, and $\epsilon_{\pi,t}$ the Gaussian white noise measurement error on the observed inflation expectation. Equation (8) is excluded from the specifications without inflation expectation data.

5 Results

5.1 Correlation Between Estimated Marginal Costs and Candidate Variables

Table 1 gives the correlation between the mean posterior filtered marginal cost coming out of our estimation and the candidate variables.[4] Labor share has the highest correlation coefficient in absolute value for all specifications. Different measures of the output gap as well as the unemployment rate and the Arouba-Diebold-Scotti index (ADS), on the other hand, have a very small correlation with our estimated measure of marginal cost. This confirms that the approach taken by Gali & Gertler (1999) and Sbordone (2005) when

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[3]Detailed prior and posterior moments of all parameters can be provided upon request.

[4]An alternative way to proceed would be to calculate the posterior distribution of these correlations, taking into account parameter uncertainty. For the sake of brevity and since the unobserved marginal cost is estimated relatively tightly we focus on the mean of the estimated marginal cost series in the following tables. Figure 1 highlights the role of estimation uncertainty.

choosing an observable to proxy for marginal cost still seems to be the best way to proceed even when considering more potential proxy variables. The inclusion of inflation expectations as an observable decreases the correlation. There are substantial differences in parameter estimates across the specifications. Figure 1 shows the time series plot of the posterior marginal cost series for the benchmark specification and the candidate variables we consider. The figure confirms that our estimated series moves closely with labor share.

5.2 Correlation Between Different Model-Based Measures of Marginal Cost

Next, we focus on the different model-based measures coming out of our estimation and investigate further how the different specifications affect our estimated measures of marginal cost. Table 2 shows the correlations across the different specifications for the mean posterior filtered marginal cost series. The differences across the estimated series (measured in terms of correlations) are tiny. Across policy rule specifications, the correlations are almost 1, indicating that different monetary policy specifications have no impact on dynamics of our estimate of marginal cost. Even the omission of inflation expectation data from our data set does lead to estimates of marginal cost that are highly correlated with our other estimates.

Figure 2 displays the autocorrelation structure as well as the cross correlation of our estimated marginal cost series with the observable candidate variables for the benchmark specification.[5] It shows that the correlation between our estimated marginal cost series and labor share is significant at the 95 % level for all lags that we consider. Interestingly, there is a significantly positive correlation between unemployment and lags of our estimated series, a fact that would be missed by just looking at contemporaneous correlations.

5.3 Regression Results Using Standardized Variables

Next, we standardize all variables to have mean zero and a unit variance and then regress the mean filtered marginal cost series on all candidate variables. Table 3 gives the results of those regressions. The results show that, in

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[5]The cross-correlation plots show $corr(mc_t, obs_{t+k})$, where mc_t is our estimated marginal cost series, obs_t is the relevant observable variable and k is the variable on the x-axis

contrast to the pair-wise correlation comparison, both labor share and the unemployment rate carry substantial information about the marginal cost estimate coming from the model. This is true even when controlling for the other available measures of marginal cost and real activity. These results suggest that the labor market is the major source of fluctuations in marginal cost. One important feature that this table highlights is the fact that even the best fitting regression only has an R^2 of less than 0.4. There is considerable variation in our estimates of marginal cost that can not be accounted for by a combination of all candidate variables we consider.
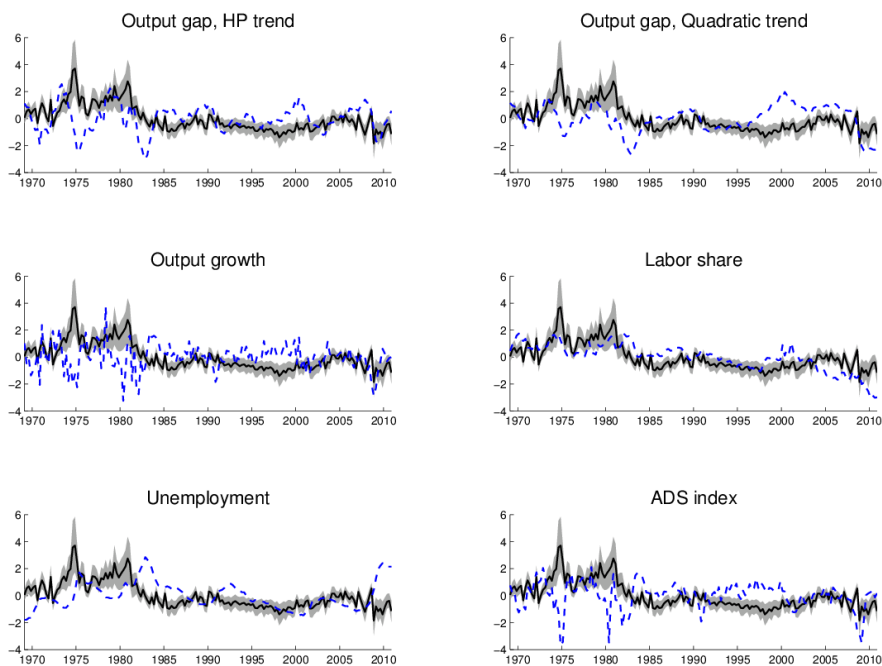
6   Conclusion

In this paper we estimated variants of a standard New Keynesian model using only information on nominal interest rates, inflation and inflation expectations. We then compare the estimated series of marginal costs for these specifications with several candidate variables that either have been used in the past to proxy for marginal cost or could reasonably be assumed to be closely related to marginal costs.

We find that, in line with Gali & Gertler (1999) and Sbordone (2005), labor share is the best proxy variable among the set of candidate variables we consider. This result should be useful for researchers who need an observable proxy variable for marginal cost in New Keynesian models. However, our results also highlight that one proxy variable alone (or even the entire set of proxy variables we consider) cannot capture the entire variation in marginal cost that we have estimated.
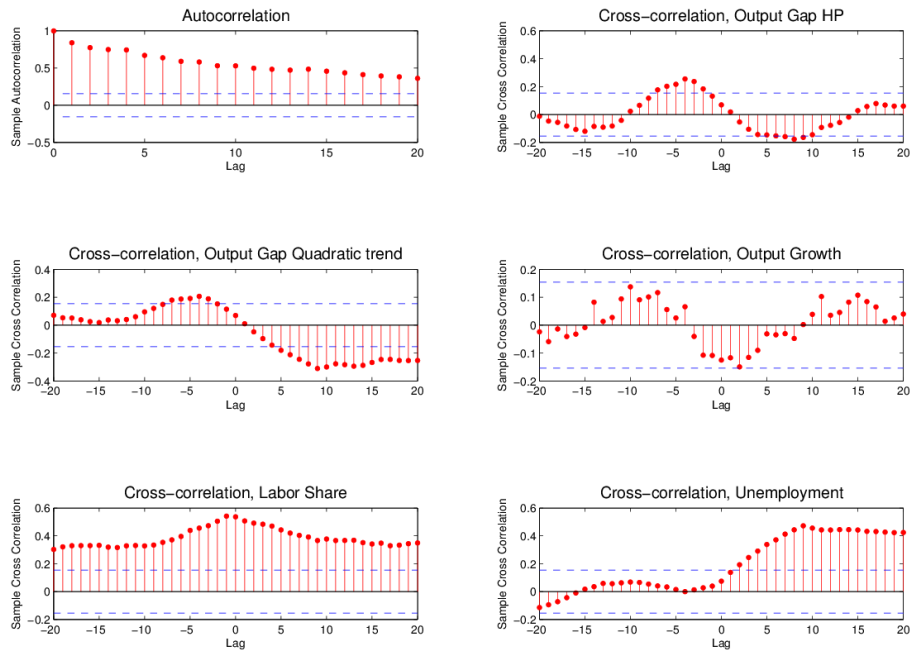
A Tables and Figures for the Main Text

Figure 1: Estimated marginal cost series

Dashed lines are candidate variables. Solid lines are posterior mean of the filtered marginal costs. Shaded area are associated 90 % probability bands. All variables are normalized to have zero mean and unit variance.

Figure 2: Autocorrelation and cross correlation for estimated marginal cost series

Dashed lines indicate 95 % confidence intervals of zero correlation.

Table 1: Correlation between estimated measures of marginal cost and candidate variables

| | No inflation forecast | | With inflation forecast | |
	Output gap	Output growth	Output gap	Output growth
Ouput gap hp	0.0693	0.0686	0.0241	0.0073
Ouput gap qtrend	0.0696	0.0696	0.0671	0.0655
Output growth	-0.1249	-0.1249	-0.1182	-0.1144
Labor share	0.5367**	0.5351**	0.4262**	0.3813**
Unemployment	0.0750	0.0749	0.0706	0.0682
ADS	-0.1266	-0.1266	-0.1229	-0.1202

** denotes rejection of the null hypothesis of zero correlation at 5 %.

Table 2: Correlation between different estimated measures of marginal cost

		No inflation forecast		With inflation forecast	
		Output gap	Output growth	Output gap	Output growth
No	Output gap	-	0.9999	0.9782	0.9597
inflation forecast	Output growth	-	-	0.9789	0.9607
With	Output gap	-	-	-	0.9971
inflation forecast	Output growth	-	-	-	-

Table 3: Regression results

	No inflation forecast		With inflation forecast	
	Output gap	Output growth	Output gap	Output growth
R^2	0.3752	0.3732	0.2562	0.2179
Output gap HP	0.1901	0.1881	0.0606	0.0128
	(0.1458)	(0.1460)	(0.1588)	(0.1629)
Output gap qtrend	0.3313	0.3336	0.4697	0.5150*
	(0.2273)	(0.2275)	(0.2412)	(0.2451)
Output growth	−0.0891	−0.0894	−0.1020	−0.1056
	(0.1308)	(0.1310)	(0.1454)	(0.1496)
Labor share	0.5155**	0.5135**	0.3804**	0.3271**
	(0.1126)	(0.1127)	(0.1213)	(0.1243)
Unemployment	0.5065**	0.5072**	0.5383*	0.5441*
	(0.1918)	(0.1922)	(0.2157)	(0.2232)
ADS	−0.1039	−0.1038	−0.0903	−0.0843
	(0.1773)	(0.1776)	(0.1971)	(0.2027)

The first row shows the regression R^2. Other entries are regression coefficients and their associated HAC standard errors (in brackets). * denotes significance at 10 %. ** denotes significance at 5 %.

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