An application of New Keynesian models to inflation in Croatia

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Abstract

Background: The inflation dynamics of Croatia is studied in the paper, with the review of applicable marginal cost proxies for the hybrid New Keynesian Phillips Curve (NKPC), and estimation of three specifications of the hybrid NKPC for Croatia. **Objectives:** The goal of this research is to examine the effect of labor's share of income, the price of energy, and the price of imports and other open economy factors in driving inflation in Croatia from the first quarter of 2000 to the fourth quarter of 2011. **Methods/Approach:** We use the generalized method of moments (GMM) estimator to empirically estimate three NKPC specifications. The J-stat and Cragg-Donald F-test are used to test for overidentification and for weak instruments, respectively. **Results:** We find that the marginal cost proxy for the energy-augmented specification is statistically significant and quantitatively the largest, whereas those for the other two are statistically significant, but quantitatively negligible. **Conclusions:** The results provide an empirical contribution both to the literature on inflation in Croatia and the literature of the NKPC in a small open economy. We can conclude that the price of energy has been the strongest driver of inflation, whereas the open economy factors we tested have had very little influence.

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Introduction

The modelling of inflation in the short run is an area of macroeconomics where answers are both urgently needed yet difficult to obtain. They are urgently needed because accurate forecasts of short-run inflation are vital for effective monetary policy; however, there are as yet no forecast methods that perform equally reliably in all situations. Phillips curve forecasts (in their current form, i.e. those forecasts that rely on a real activity variable such as unemployment, the output gap, or real marginal costs) appear to achieve better results than any other currently used method (Stock and Watson, 2008).

The New Keynesian Phillips Curve (NKPC) has been the focus of a great deal of recent research in inflation forecasting, and (consequently, to some degree) it is now a part of the monetary policy toolset for many countries. Having evolved from A.W. Phillips' relation of unemployment to inflation, the NKPC, in the form it takes today, relates a real activity such as the output gap or real marginal cost to inflation. That real activity variable is arguably the most disputed and most actively researched aspect of the NKPC, and the definitive form of the relation is far from being a settled issue.

This study's aim is to contribute to the literature by examining the causes of inflation in Croatia and by estimating the NKPC for a small open economy with corrected measures of marginal cost; most empirical NKPC studies have been carried out for large and highly developed countries, using the labor share

of income as a proxy for marginal cost, which has shown to be problematic (Wolman, 1999, Rudd and Whelan 2005, 2007). It is particularly problematic for a small open economy, and several approaches have been developed in response, most notably those by Leith and Malley (2003) and Dabušinskas and Kulikov (2007). We empirically test these approaches, and also review other promising approaches that could not be adapted for modeling the case of Croatia, with a discussion of what makes them an approach worth considering and what is problematic in adapting them to the Croatian economy.

First, we describe our specifications of the NKPC and briefly discuss the issues surrounding proxies of real marginal cost. Second, we describe our data set and methodology. Third, we present our results using the generalized method of moments (GMM) estimator. Fourth, we discuss alternative approaches to adjusted marginal cost that are promising but could not be adapted for the purposes of this study, and we conclude with a review of the study and a discussion of the possible directions of future research.

Theoretical Framework

To estimate the NKPC for a given economy, a model of price setting in that economy is necessary. In this paper, we will use the model of price adjustment introduced by Calvo (1983), the most widely used model in the NKPC literature.

This model assumes an economy with monopolistically competitive firms that are perfectly identical, except for the differentiated products they produce, and for their pricing history. Each identical firm faces the same constant price elasticity of demand for its differentiated product. Some firms, whose proportion is given by $(1-\theta)$, adjust prices in period t, and that probability is independent of the firm's pricing history up to period t. The pricing decisions are formulated as a monopolistic competitor's profit maximization problem, given a stream of expected future marginal costs and given the ability to set a frictionless optimal markup over marginal costs. For the sake of simplicity and brevity, we only provide the closed form of the NKPC with Calvo model pricing in this paper, and not the full derivation. In addition to the original description of the pricing structure in Calvo (1983), the full derivation is available in, among others, Galí and Gertler (1999) and in Leith and Malley (2003) for an open economy model. After including a discount factor β, the NKPC is given by

$$\pi_t = \beta E_t \pi_{t+1} + \lambda mc_t^r \tag{1}$$

Where

$$\lambda = \frac{(1-\theta)(1-\theta\beta)}{\theta} \tag{2}$$

and where π_t is the rate of inflation in period *t*, $E_t\pi_{t+1}$ is the expected rate of inflation of the period *t+1* in period *t*, and mc_t^r is real marginal cost in period *t*.

The NKPC can also be expressed with the output gap (the difference between real and potential output) substituted for marginal costs (Galí, 2002). But this choice is becoming increasingly deprecated, primarily because in empirical data the output gap leads inflation for a given period, rather than the other way around as the NKPC implies; because of this, real marginal cost is typically used in the literature instead of the output gap (Mazumder, 2010).

However, accurate measurement of real marginal cost is one of the most problematic areas of NKPC research (Mazumder, 2010). We shall give an overview of this, including the measures we use to attempt to obtain a better fit for the NKPC, and we will present a longer discussion of recently proposed alternatives. We now turn to the NKPC specification that is the most widely used in the literature, and that we shall also use in this study.

Hybrid new Keynesian Phillips curve

The so-called hybrid NKPC, which incorporates a lagged inflation term, was introduced by Galí and Gertler (1999), and its specification is as follows:

$$\pi_t = \gamma_f E_t \pi_{t+1} + \gamma_b \pi_{t-1} + \lambda mc_t^r \quad (3)$$

Where

$$\lambda \equiv (1-\omega)(1-\theta)(1-\beta\theta)\phi^{-1}$$

$$\gamma_f \equiv \beta\theta\phi^{-1}$$

$$\gamma_b \equiv \omega\phi^{-1}$$

$$\phi \equiv \theta + \omega\left[1-\theta(1-\beta)\right] \quad (4)$$

In the hybrid NKPC, there is a fraction of firms, given by *1- ω*, that behave exactly like all firms in Calvo's model. The remaining firms in the economy, given by *ω*, set their prices using a backward-looking rule of thumb. This rule is defined by two features: (1) there are no persistent deviations between that rule and optimal behavior; and (2) the price decision for period t depends only on information from t-1 and earlier. Firms described by *ω* set their price according to $p_t^b = p_{t-1}^* + \pi_{t-1}$, where p_{t-1}^* is the average price level set in the round of price adjustments at *t-1* (note that, in this way, the backward-looking firm indirectly takes into account information about the future, since the average price level includes prices of forward-looking firms). When *ω=0*, that is, when there are no backward-looking firms in the economy, the hybrid NKPC converges to the conventional NKPC form.

Real marginal cost and our approach (Model (3))

Since real marginal cost cannot be observed, a proxy must be found. Following Galí and Gertler (1999), who assumed a Cobb-Douglas production function, the choice of proxy has in recent literature overwhelmingly fallen on labor's share of income (or, equivalently, real unit labor costs). The empirical results obtained since then, from diverse data sets, have led to this choice of proxy being strongly criticized (Wolman, 1999; Rudd and Whelan 2005; 2007) on the grounds that only using labor's share of income fails to create a good fit for the NKPC. The studies cited do not go so far as to assert that the theoretical basis must be scrapped, but they strongly affirm that labor's share alone is inadequate and that, for the given specification of the NKPC, a better proxy for real marginal cost must be found.

This has provided the stimulus for a spate of research. A number of alternative measures have been proposed, the most promising of which may be those of Muto (2009) and Bratsiotis and Robinson (2009), who developed successful frameworks of labor adjustment costs, and capital and labor marginal costs, respectively; a full discussion of those frameworks is one of the subjects of following part oft he paper. However, Muto (2009) does not use GMM, only OLS and NLS.

Energy-augmented hybrid new Keynesian Phillips curve (Model (5))

Dabušinskas and Kulikov (2007), in their empirical analysis of inflation in Estonia, Latvia and Lithuania, use two different NKPC specifications that are of interest to us. The first is what they refer to as the energy-augmented Phillips curve, and which explicitly includes the price of energy in its measure of marginal cost, given by:

$$\hat{mc}_t^r = \hat{s}_t - (1-\mu s)(\rho - 1)(\hat{p}_t^E - \hat{w}_t) \quad (5)$$

where μ is the markup, *p* is a measure of the elasticity of substitution between labor and imported intermediate goods, *s* is labor's share of income, and $(\hat{p}_t^E - \hat{w}_t)$ is the price of energy relative to wages. All hatted variables represent log-deviations from their steady state (μ and *p*, of course, are constants).

Open economy hybrid new Keynesian Phillips Curve (Model (6))

The second model considered is an expansion of the hybrid NKPC into an open economy hybrid NKPC in which intermediate goods are taken into account for marginal cost (Leith and Malley, 2003). In this model, real marginal cost depends on the domestic wage rate relative to the price of imported intermediate goods, the price of domestic intermediate goods relative to the price of imported intermediate goods (as the producers of final goods substitute domestic labour as an input with imported intermediate goods, according to the elasticity of their substitution *p*), and the output gap.

λ is replaced with $\tilde{\lambda}$, and the additions to the NKPC are given by:

$$\tilde{\lambda} \equiv \frac{(1-\theta)(1-\theta\beta)\zeta_t}{\theta}$$

$$\zeta_t \equiv \frac{1}{\psi_t \mu - 1}$$

$$\psi_t = \frac{1}{1-\alpha_t} \tag{6}$$

where $1-\alpha_t$ is the output share of labor and of imported intermediate goods, given by $1-\alpha = \mu\frac{s+i_t^s}{1+i_t^s}$, and real marginal cost is given by

$$mc_t^r = \hat{s}_t - (\psi - 1)\left(\frac{i_t^s}{1+(1-\psi_t)i_t^s}\right)\hat{y}_t -$$
$$-\left((1-\rho)\frac{i_t^s}{s+i_t^s} + \rho\left(\frac{i_t^s}{1+(1-\psi_t)i_t^s}\right)\frac{s_t}{s_t+i_t^s}\right)(\hat{w}_t - \hat{p}_t^f) +$$
$$+\left(\frac{i_t^s}{1+(1-\psi_t)i_t^s}\right)(\hat{p}_t^d - \hat{p}_t^f) \tag{7}$$

where i_t^s is the share of imported intermediate goods in output, $\hat{y}_t$ is the output gap, ($w_t - p_t^f$) is the difference between the wage level and the price of foreign goods, and ($p_t^d - p_t^f$) is the difference between the price of domestic goods and foreign goods. Since the steady-state labor share, s, and the steady-state share of intermediate inputs in GDP, i^s , rise in our sample data, and following the treatment in Leith and Malley (2003), we allow this steady-state ratio to vary depending on the period. In all respects other than these, this specification is identical to the hybrid NKPC.

Having defined our theoretical framework, we now turn to the description of our data and methodology, followed by the presentation of our results.

Methodology

Our sample consists of 11 years of quarterly data for Croatia, beginning with 2000Q1 and ending with 2010Q4. Data are sourced from Eurostat, the Croatian National Bank and the Croatian Bureau of Statistics, and (for the price of Brent Crude oil) the U.S. Energy Information Administration. All time series data are seasonally adjusted, either by Eurostat or by the author and all variables that are hatted in a given equation are represented in the model as log-deviations from their steady state (for which we take the sample mean).

Inflation, π_t , is the GDP deflator. The difference between the price of energy and wages in equation (5), $(\hat{p}_t^E - \hat{w}_t)$, is the logarithmic difference of the price of Brent Crude oil on European markets (adjusted by the USD/HRK exchange rate for the period) minus nominal wages. The labour income share, $\hat{s}_t$, is the ratio

of employee compensation to GDP, and the output gap, $\hat{y}_t$, is obtained by detrending real GDP with the Hodrick-Prescott filter. The difference between wages and domestic prices, ($\hat{w}_t - \hat{p}_t^f$), is the logarithmic difference between nominal wages and the GDP deflator, and that between domestic and foreign prices ($p_t^d - p_t^f$) is the logarithmic difference of the GDP deflator and the import deflator. The steady-state share of imported intermediate goods in GDP, i_t^s, consistently rises in our sample and is thus allowed to be time-varying, and since data on imports of intermediate goods are unavailable for Croatia, we follow the rule-of-thumb adjustment of Dabušinskas and Kulikov (2007) and assume that 50% of imported goods are intermediates; we use this assumption since this is currently the sole precedent for such a rule-of-thumb adjustment in the literature, and Dabušinskas and Kulikov have achieved acceptable results. The rising steady-state value is obtained by applying the Hodrick-Prescott filter. Following relatively common choices in the literature (see, e.g., Mihailov, Rumler and Scharler, 2011; Dabušinskas and Kulikov, 2007), we set the discount factor β to 0.98, the markup μ to 1.2, and the elasticity of substitution ρ to 0.5.

Results

Table 1 shows the resuls obtained for our three models: the hybrid NKPC, (model (3)), described by (3) and (4) with real marginal cost equal to the labor share of income, the energy-augmented hybrid NKPC, (model (5)), described by (3) and (4) with its real marginal cost given by (5), and the open economy hybrid NKPC, (model (6)), described by (3), (4) and (6) with its real marginal cost given by (7). All calculations were made according to the formulas, with the time series listed previously used where appropriate in the formulas.

Table 1
Empirical hybrid NKPC models for Croatia, 2000Q1 to 2010Q4

	Structural Parameters		**Reduced-form Parameters**			**Statistical Tests**	
	θ	ω	γ_b	γ_f	λ	J-stat	Cragg-Donald F-stat
Model (3)	0.9152 (0.0077)	0.3858 (0.0006)	0.4992 (0.0050)	0.5058 (0.0047)	0.0162 (0.0042)	1.5108	8.8010
Model (5)	0.9090 (0.0092)	0.3878 (0.0000)	0.4911 (0.0004)	0.5487 (0.0004)	0.0434 (0.0003)	1.0009	4.8044
Model (6)	0.9565 (0.0059)	0.3768 (0.0005)	0.4997 (0.0048)	0.5067 (0.0046)	0.0098 (0.0030)	1.3364	7.9744

Note: Standard errors are in parentheses. The instrument set includes both the current value and two lags of the marginal cost series; and four lags of the GDP deflator, of wage growth, of the output gap, and of the import deflator. The GMM estimation uses Newey-West weighting matrices with a Bartlett kernel.

Source: Eurostat, Croatian National Bank, Croatian Bureau of Statistics, U.S. Energy Information Administration and author's calculations

The hybrid NKPC open economy model appears to have less explanatory power for inflation than either the conventional hybrid NKPC or the energy-augmented NKPC, since the value of λ, the coefficient of the marginal cost variable, is lower in the hybrid NKPC open economy model. It is possible to speculate extensively on the reasons for this, and we offer two possible explanations. Croatia's relatively low consumption (as a component of GDP) and low exports, and the fact that its service sector makes up approximately two thirds of its GDP, suggest that the cost of labor may make up much of marginal cost, and imported intermediate goods have a negligible influence. It is also possible that the rule of thumb we adopted due to insufficient data (the assumption that 50% of imported goods are intermediate inputs) may yield inaccurate results.

The λ value of the energy-augmented NKPC (5) is, as increasingly predicted in the literature, higher than model (3), the conventional NKPC that takes into account for marginal cost only the labor share of income. Note that γ_f is also higher in Model (5): this is in line with the theoretical prediction that, as marginal cost becomes a more significant driver of inflation, forward expectations will play a larger role and so the forward-looking component will have more influence.

The proportion of backward-looking firms, ω, at close to 40% is near the range found in Krznar's (2011)