The New Keynesian Phillips Curve for Austria – An Extension for the Open Economy

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Following the empirical breakdown of the traditional Phillips curve relationship, the baseline New Keynesian Phillips Curve (NKPC) theory was formulated in the 1990s. Unlike the traditional Phillips curve, it derives from a theoretical model that is based on microeconomic principles. It expresses current inflation as a function of expected future inflation, past inflation and a measure of firms' marginal cost. The NKPC serves to estimate the model's structural parameters that capture price-setting behavior in an economy. This study estimates the NKPC using Austrian data. As Austria is a fairly open economy and the NKPC was initially formulated for a closed economy, the theoretical model is extended to include open-economy aspects and is then estimated in various specifications. The extended NKPC proves to explain inflation developments in Austria since 1980 quite accurately. The estimation of the structural parameters shows that around 30% of all Austrian firms change their prices every quarter, indicating that overall, prices are constant for an average of roughly ten months. Moreover, between 30% and 50% of all firms follow a backward-looking rule of thumb in setting their prices. Compared to the other euro area countries, this price duration represents an average, whereas the degree of backward-looking behavior in price setting is above average. However, the NKPC is not found to be as suitable for forecasting purposes as time-series models, as none of the inflation forecasts based on the NKPC model was able to outperform a naive forecast (unchanged inflation rate over the forecast horizon).

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1 Introduction

1.1 The New Keynesian Phillips Curve – Background and Derivation

The New Keynesian Phillips Curve (NKPC) is currently arguably the most commonly used inflation dynamics model in modern macroeconomics. The NKPC is derived from New Keynesian theory, whose most important assumptions are a market governed by monopolistic competition and short-term price rigidity. The baseline NKPC was developed in several contributions in the 1990s in the New-Keynesian literature[1] and represents inflation (π_t) as a function of future inflation (π_{t+1}) and firms' marginal cost (mc_t).

$$\pi_t = \gamma_f E_t(\pi_{t+1}) + \kappa(mc_t) \qquad (1)$$

For empirical applications, some contributions make suitable assumptions for the labor market to proxy marginal cost with a real economic activity variable, such as the output gap.

$$\pi_t = \gamma_f E_t(\pi_{t+1}) + \lambda(y_t - y_t^*) \qquad (2)$$

Hence, the only difference between the formulation of the new and the traditional Phillips curve lies in the fact that the former relies on future, rather than past, inflation to determine current inflation. However, the two concepts differ fundamentally, as the new Phillips curve is derived from a theoretical model with rational ex-

[1] *For an overview of the literature, see Goodfriend and King (1997).*

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pectations that is based on microeconomic principles.

The empirical evaluation of the Phillips curve shown in equation (2) undertaken in the early new-Keynesian literature was not very successful: Frequently, estimates of the output gap coefficient λ were only negative or not significant. In a seminal article, Galí and Gertler (1999) introduced two features into the NKCP that markedly improved the empirical explanatory power of the model. The authors extended the pure forward-looking model by adding past inflation as an explanatory variable in the Phillips curve equation (π_{t-1}). Further, they used real unit labor costs rather than the output gap as an empirical proxy for the (unobservable) marginal cost. The resulting formulation is generally referred to as the hybrid NKPC, as it displays features of both the traditional and the new Phillips curve:

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

At this point, it should be noted that the parameters of the Phillips curve equation (γ_f, γ_b, κ or λ) are represented in reduced form in equations (1) through (3). These parameters are themselves combinations of the structural parameters resulting from the underlying theoretical model. The theoretical model is based on the assumption of firms maximizing profit in a monopolistic competition market; they face a demand function with constant elasticity of demand. Firms' price-setting behavior is assumed to be subject to the restrictions formulated by Calvo (1983) on the modeling of price rigidity: Each firm is allowed to adjust its price in any given period with a certain (fixed) probability of $1-\theta$, which means that θ represents the probability of a firm not adjusting its price in this period. In addition to Calvo price setting, Galí and Gertler (1999) assume that a certain fraction of firms, ω, sets prices according to a rule of thumb, whereas the remainder, $1-\omega$, sets prices optimally. Firms that use the rule of thumb pursue a backward-looking approach, basing their prices on the optimum price in the last period and then updating it with past inflation. After solving the maximization problem under the given assumptions, the equation for the inflation rate may now be written in its structural form:

$$\pi_t = E_t \frac{\theta\beta}{\Delta}\pi_{t+1} + \frac{\omega}{\Delta}\pi_{t-1} + \frac{(1-\theta)(1-\omega)(1-\theta\beta)}{\Delta}\left[mc_t\right] \quad (4)$$

with β as the discount factor of firms' future profits, and $\Delta=\theta+\omega[1-\theta(1-\beta)]$. The variables in the equation are defined as deviations from their steady state values; in other words, the equation is specified in linearized form.

The NKPC has been estimated numerous times for various countries both in its reduced form (equation (3)) and in a structural form, using empirical data. The parameters estimated in equation (4) represent the structural factors of a country's price-setting process underlying the model, with θ frequently being interpreted as the parameter of price rigidity and ω indicating the degree of intrinsic inflation persistence.

1.2 The New Keynesian Phillips Curve for Austria

The NKPC has not been estimated with Austrian data so far in the existing literature. As Austria is a fairly open economy, the extension of the Phillips curve model to include open-economy aspects is especially relevant for Austria. In this contribution, the existing model of the hybrid NKPC is extended by the introduction of international trade as well as intermediate inputs. Thus, the model also captures the effects of import prices and the price of intermediate inputs on firms' marginal costs and ultimately inflation. The structural parameters of the model are then estimated and interpreted in various specifications, using Austrian quarterly data from 1980 to 2003. In particular, we identify the specification with the highest explanatory power for the analyzed period and compare the estimated degree of price rigidity of the closed economy specification with that of the open economy specification to establish whether they differ. Moreover, the forecasting performance of the extended NKPC for Austrian inflation from 2003 to 2006 is examined and compared with that of a naive forecast.

This study is structured as follows: Section 2 presents the extension of the NKPC model, which accounts for open-economy effects, and describes the empirical approach to estimating the model. The estimation results of the model's structural parameters along with some measures of fit for the individual specifications are presented and discussed in section 3. Section 4 contains an evaluation of the NKPC's forecasting performance, and section 5 concludes.

2 Extending the New Keynesian Phillips Curve to the Open Economy

2.1 The Model

For the sake of brevity, we refrain from deriving the extended model step by step, but discuss only the changes in the assumptions to account for an open economy and present the resulting Phillips curve. Rumler (2006) contains detailed information about the derivation of the Phillips curve for open economies.

The starting point is the hybrid NKPC known from the literature presented in equation (4).[2] The hybrid NKPC reflects the optimality condition of firms' price-setting in a general equilibrium model, expressing current inflation as a function of expected future inflation, past inflation and a measure of firms' marginal cost. In recent years, this function has been empirically tested for various countries in innumerable contributions; the empirical evidence has proved to be quite mixed. In a number of large industrial economies, the hybrid NKPC – which uses real unit labor cost as a proxy for marginal cost – has been able to deliver a good explanation of inflation dynamics over the past two decades.[3] However, a number of other empirical studies have shown that especially in small, open economies, the standard NKPC model is not always suited to explaining inflationary developments during the past decades.[4]

[2] *The theoretical model underlying the hybrid NKPC is described in detail in Galí and Gertler (1999) and in Galí et al. (2001).*

[3] *See e.g. Galí and Gertler (1999) as well as Sbordone (2002) for the U.S.A., Galí et al. (2001) and McAdam and Willman (2003) for the euro area and Jondeau and Le Bihan (2005) for the large EU countries.*

[4] *See Balakrishnan and López-Salido (2002), Bårdsen et al. (2004), Freystätter (2003) and Søndergaard (2003).*

One reason for the low empirical explanatory power of the NKPC for some countries is that real unit labor costs are not sufficiently representative of firms' total cost. For many firms, the cost of intermediate inputs plays just as important a role and should therefore be taken into consideration in the proxy for marginal cost. However, it must be noted that a large fraction of intermediate inputs are imported, which means they are subject to different – often more dynamic – price developments than domestic intermediate inputs. Taking these considerations into account yields an empirically more relevant proxy for the marginal cost variable of the Phillips curve, which contains not just unit labor costs but also the prices of imported and domestically produced intermediate inputs.

Therefore, the NKPC model is extended by two production factors in addition to domestic labor, namely imported as well as domestic intermediate inputs. Moreover, open-economy aspects are built into the model by incorporating international trade both at the final demand and at the intermediate input level. Thus, the model accounts for the fact that the firm-specific demand function and the marginal cost depend also on foreign variables.[5]

Maximizing future discounted profits of a representative firm assuming Calvo pricing – with the restriction that part of the price-setting firms follow a backward-looking rule of thumb – yields a hybrid NKPC (linearized) for this open-economy model.

$$\pi_t = E_t \frac{\theta\beta}{\Delta}\pi_{t+1} + \frac{\omega}{\Delta}\pi_{t-1} + \\ + \frac{(1-\theta)(1-\omega)(1-\theta\beta)}{\left[\varepsilon(\phi-1)+1\right]\Delta}\left[mc_t\right] \qquad (5)$$

with θ representing the part of firms that do not adjust their prices in a given period, β the steady-state discount factor, ω the fraction of firms following the backward-looking rule of thumb, ε the elasticity of demand and $\Delta = \theta+\omega[1-\theta(1-\beta)]$. The main difference between the open-economy NKPC and the standard model in equation (4) is the marginal-cost expression (in square brackets), which now contains a number of additional variables:

$$mc_t = \begin{bmatrix} \hat{s}_{nt} - (\phi-1)\dfrac{\bar{s}_{m^d}+\bar{s}_{m^f}}{1+(1-\phi)\left(\bar{s}_{m^d}+\bar{s}_{m^f}\right)}\hat{y}_t + \dfrac{\bar{s}_{m^f}}{1+(1-\phi)\left(\bar{s}_{m^d}+\bar{s}_{m^f}\right)}\left(\hat{p}_t^d - \hat{p}_t^f\right) - \\ \left[(1-\rho)\dfrac{\bar{s}_{m^d}}{\bar{s}_n+\bar{s}_{m^d}+\bar{s}_{m^f}} + \rho\dfrac{\bar{s}_{m^d}}{1+(1-\phi)\left(\bar{s}_{m^d}+\bar{s}_{m^f}\right)}\dfrac{\bar{s}_n}{\bar{s}_n+\bar{s}_{m^d}+\bar{s}_{m^f}}\right]\left(\hat{w}_t - \hat{p}_t^d\right) - \\ \left[(1-\rho)\dfrac{\bar{s}_{m^f}}{\bar{s}_n+\bar{s}_{m^d}+\bar{s}_{m^f}} + \rho\dfrac{\bar{s}_{m^f}}{1+(1-\phi)\left(\bar{s}_{m^d}+\bar{s}_{m^f}\right)}\dfrac{\bar{s}_n}{\bar{s}_n+\bar{s}_{m^d}+\bar{s}_{m^f}}\right]\left(\hat{w}_t - \hat{p}_t^f\right) \end{bmatrix} \qquad (6)$$

[5] *Similar Phillips curve models that take open-economy aspects into account can be found in the contributions of Leith and Malley (2003), Batini et al. (2005), and Razin and Yuen (2002).*

with, s_n, s_{m^d} and s_{m^f} representing shares of labor (n), domestic intermediate inputs (m^d) and imported intermediate inputs (m^f) in total domestic production, ρ denoting the elasticity of substitution between the input factors, and $\phi = \frac{(\varepsilon-1)\left(1+\bar{s}_{m^d}+\bar{s}_{m^f}\right)}{\varepsilon\left(\bar{s}_n+\bar{s}_{m^d}+\bar{s}_{m^f}\right)}$.

The variables, w, p^d and p^f, in turn, represent the prices of the input factors labor (wages), domestic and imported intermediate inputs. Hatted variables denote deviations from the steady state, and barred variables represent steady-state values.

Equation (6) shows that unlike in the standard model, marginal cost is not just a function of real unit labor cost, s_n, but also of the relative prices of the three production factors (1) domestic labor and domestic intermediate inputs (real wages), $w–p^d$, (2) domestic labor and imported intermediate inputs, $w–p^f$, and (3) domestic and imported intermediate inputs (the terms of trade), $p^d–p^f$. The weights with which the relative prices of the three production factors enter marginal cost are determined by their steady-state shares and the elasticity of substitution between them.

Hence, this general formulation of the open-economy NKPC nests the existing formulations for closed economies and for open economies exclusive of domestic intermediate inputs: if the share of domestic intermediate inputs in production is set at $s_{m^d}=0$, we obtain the open-economy Phillips curve model of Leith and Malley (2003); if we additionally set the share of imported intermediate inputs at $s_{m^f}=0$, the model yields the standard closed-economy specification of equation (4).

2.2 Empirical Approach

In a next step, the structural parameters of the NKPC presented in equations (5) and (6) are estimated for Austrian data from the first quarter of 1980 to the second quarter of 2003. Data from the third quarter of 2003 to the second quarter of 2006 are used to evaluate the NKPC's forecasting performance. As the estimation equation contains rational expectations (first term on the right-hand side of equation (5)), and a correlation between the error term and the regressors is therefore to be expected, an estimation method with instrumental variables should be used. Consequently, we use the generalized method of moments (GMM) approach, which is frequently used in the literature for this type of model (Galí et al., 2005). The model is estimated in three different specifications – SP1 for closed economies, SP2 for open economies without domestic intermediate inputs and SP3 for the general form – to allow conclusions about the estimated degree of price rigidity and inflation persistence to be drawn for the different model assumptions of marginal costs. Using various measures of fit, we then determine which of the three specifications can explain inflation dynamics in Austria best in the period under review.

Following the procedure used by others in the literature, the rate of change of the GDP deflator at the quarterly frequency is used as the dependent variable of the inflation rate in the regressions, real unit labor cost, s_n, is defined as the nominal total compensation to employees divided by nominal GDP, and s_{m^d} as well as s_{m^f} are the ratios of domestically produced and imported intermediate inputs to nominal GDP.[6] y denotes real GDP, domestic nominal wages per employee are used for w, and the domestic GDP deflator and the import deflator are used as proxies for p^d and p^f, respectively. The data stem from the Austrian System of National Accounts (ESA 79 until 1988, ESA 95 from 1988); input/output tables available for the review period were used to separate intermediate inputs into domestic and imported shares.

3 Results

3.1 Estimation for Austria

Table 1 summarizes the estimation results of the structural parameters of equations (5) and (6) for model specifications SP1, SP2 and SP3. The columns contain the estimated coefficients for the share of firms that keep prices fixed in a given period (the Calvo probability of not changing a price), $\hat{\theta}$, for the firms' discount factor, $\hat{\beta}$, for the share of firms that follow a backward-looking rule of thumb, $\hat{\omega}$, and for the elasticity of substitution between input factors, $\hat{\rho}$. The standard errors of the coefficient estimators are given in parentheses. The adjustment frequency of prices, $1-\hat{\theta}$, may be used to derive the implicit average duration of prices using the formula $1/(1-\hat{\theta})$ This duration, measured in months,[7] is stated in the last column.

The Calvo probability of changing a price, θ, is frequently referred to as the NKPC's price rigidity parameter in the literature. Under specification SP1 (closed economy; standard NKPC), 68% of all Austrian firms leave their prices unchanged during a given quarter. This implies an average price duration of 9.5 months. For specification SP2 (open economy without domestic intermediate inputs), the degree of macroeconomic price rigidity is estimated at 0.45, which corresponds to an average 5.5 month price duration. The difference between the estimated degree of macroeconomic price rigidity in each specification is thus likely to be attributable to the modeling of marginal cost: The SP2 specification includes import prices as a key deter-

Table 1

Estimation of the Structural Parameters of Model Specifications SP1, SP2 and SP3 for the Extended New Keynesian Phillips Curve Model for Austria

Dependent variable: Inflation rate of the GDP deflator quarter on quarter changes

	$\hat{\theta}$	$\hat{\beta}$	$\hat{\omega}$	$\hat{\rho}$	Implied price duration in months
SP1	0.68 (0.16)	1.02 (0.12)	0.52 (0.20)	×	9.5
SP2	0.45 (0.09)	0.95 (0.08)	0.52 (0.09)	3.83 (2.07)	5.5
SP3	0.69 (0.14)	0.97 (0.06)	0.32 (0.18)	–4.07 (3.79)	9.7

Instrument variables: Rate of inflation lags 2 to 4, wage inflation lags 1 to 4, real unit labor cost lags 1 to 6, ratio of wages to import prices lags 1 to 4.

Source: Author's calculations.

Note: The estimation method is GMM. Newey-West standard errors are given in parentheses.

[6] *Unlike the parameters θ, β, ω and ρ, firms' demand elasticity, ε, cannot be estimated empirically, as it is not explicitly included in the estimation equation. The common practice in the literature is followed to obtain an empirical value for ϕ by calibrating demand elasticity with a value of 11, which implies a steady-state markup of 10% (Galí et al., 2001).*

[7] *To give the duration in months, $1/(1-\hat{\theta})$ has to be multiplied by 3, as θ is estimated with quarterly data.*

minant of marginal costs in addition to real unit labor cost. As a rule, import prices exhibit a more volatile development than the cost of domestic labor, possibly prompting firms that use a large share of imported intermediate inputs in production to adjust prices more often. Consequently, the estimation results confirm the hypothesis that the extension of the model to include open-economy aspects has a significant[8] influence on the estimated degree of price rigidity.

Interestingly, for the general specification of the extended model SP3 (which includes both domestic and imported intermediate inputs), the price rigidity estimate of 0.69 is again slightly higher than that for SP2, but roughly of the same order as that for the SP1 closed-economy specification. The SP3 value may be higher than that for SP2 because domestic firms may have substituted domestic intermediate inputs for imported intermediate inputs (provided the production process allows for such a substitution) owing to fluctuations of the relative prices of the two input factors. Such a substitution would neutralize the impact of price fluctuations of imported intermediate inputs on marginal cost and would reduce the need of a firm to adjust its prices. Thus, the estimated degree of price rigidity of the Austrian economy differs depending on the specification of the NKPC. Now, to answer the question which of these values is most appropriate, one has to evaluate the different specifications by means of econometric measures of fit.[9]

Compared with other euro area countries, Austria exhibits an estimated degree of price rigidity that is neither especially high nor especially low: Rumler (2006) estimated the structural parameters of the extended NKPC for a total of nine euro area countries (euro area except Ireland, Luxembourg and Portugal). According to this study, Austria's values of θ place it fifth out of the nine countries. Germany displayed the highest degree of price rigidity among these countries, followed by Belgium, whereas price rigidity was estimated to be lowest in Greece and the Netherlands.

An additional comparison may be made using the results of a study on price-setting behavior in Austria in which the degree of price rigidity was estimated on the basis of micro CPI data (Baumgartner et al., 2005). The study finds that the average duration of a price spell for all products represented in the CPI is about 11 months. This value is roughly comparable to the estimated price duration of just under 10 months for SP1 and SP3, but is markedly higher than the price duration estimated for SP2. However,

[8] *A test of whether this difference in the parameter estimates of SP1 (0.68) and SP2 (0.45) is also statistically significant shows only a marginally significant difference (significance level: 15%); see Rumler (2006). However, as the two parameter values imply a difference in the average price duration of four months, the difference is at least economically significant.*

[9] *The results refer to the estimation period Q1 1980 to Q2 2003. To verify the robustness of the results, the model was also estimated for the period Q1 1980 to Q2 2006. However, the fundamental revision of Austrian national accounts data in 2004, when all series were also adjusted retroactively, makes the comparison of the results problematic. Despite this revision, the results remain qualitatively unchanged for the longer estimation period. The results for θ may serve as an example: For the longer estimation period, SP3 exhibits the highest θ at 0.66, followed by SP1 at 0.64 and SP2 at 0.53. Hence, the magnitude of the coefficients and the ranks of the specifications for θ are hardly different. Overall, the additional estimation confirms that the results of table 1 are also robust for a longer estimation period and revised data.*

three important differences between the two studies impair the comparison: the period reviewed (1996 to 2003 in the micro CPI survey versus 1980 to 2003 in this study), the data base (micro CPI data versus macro time series of the GDP deflator) and the method (price duration measured directly from price data versus GMM estimates from a structural model).

According to the NKCP theory, the discount factor, β, which corresponds to the reciprocal value of the steady-state real interest rate, should exhibit a value of close to but below 1.[10] The estimates for SP2 and SP3 are in line with this theory. However, as the coefficients were estimated with uncertainty, values marginally higher than 1 – like for SP1 – do not represent a problem either, as long as they are not significantly higher than 1.

The parameter ω, which gives the fraction of firms that follow the backward-looking rule of thumb in setting prices, is directly linked to inflation persistence: The higher ω is, the higher is inflation persistence as measured by the GDP deflator. The estimation results show that the share of backward-looking firms in Austria comes to 30% to 50%, implying that the degree of inflation persistence in Austria is fairly high. This result is broadly confirmed in a cross-country comparison, as well as in other studies that examine inflation persistence in Austria empirically (Rumler, 2006; Cecchetti and Debelle, 2005; Gadzinski and Orlandi, 2004). Moreover, we found that the specification of a closed versus an open economy of the NKPC has no impact on ω, as the estimation values of SP1 and SP2 are nearly the same. Only for SP3 did the estimates result in a somewhat lower ω, which nevertheless remains high in an international comparison.

The elasticity of substitution between the input factors of the production function, ρ, cannot be estimated for SP1, as this specification contains only one variable production factor (labor). In the case of SP2, ρ denotes the elasticity of substitution between labor and imported intermediate inputs. This elasticity is fairly high, posting an estimated value of 3.8, and is also statistically significant.[11] A negative elasticity of substitution between the production factors – albeit not statistically significant – is estimated for SP3. This result could reflect the fact that a constant elasticity of substitution between the three production factors is hard to estimate with the available data, because the actual substitution is possibly not the same between all production factors.

3.2 Identifying the Specification with the Highest Explanatory Power

An evaluation of the inflation rates implied by SP1, SP2 or SP3 may help determine which of the three specifications is best suited to characterize the Austrian inflation dynamics during the period observed. The idea of using this implied inflation rate – also called fundamental rate of inflation – to evaluate the explanatory power of the NKPC goes back to Galí and Gertler (1999). The fundamental rate of inflation is derived from the pres-

[10] *An estimated value of 0.99 for β would, for instance, correspond to an average real interest rate of around 1% per quarter during the estimation period.*

[11] *A value of 1 would imply a Cobb-Douglas production function.*

Chart 1

Comparison between Fundamental Rates of Inflation of SP1, SP2 and SP3 and the Actual Inflation Rate

Source: Author's calculations.

Table 2

Measures of Fit of the Implied Fundamental Rate of Inflation Derived from SP1, SP2 and SP3 and the Actual Development of Inflation

	$\frac{StDev(\pi^*_t)}{StDev(\pi_t)}$	$Corr\ (\pi^*_t, \pi_t)$	$RMsD\ (\pi^*_t, \pi_t)$	Rank
SP1	1.03	0.49	0.69	1
SP2	0.78	0.23	0.77	3
SP3	0.93	0.32	0.76	2

Source: Author's calculations.

ent value formulation of the NKPC, which presents the inflation rate as the sum of present and all expected future marginal costs.[12]

For the evaluation, the following three common measures of fit are used to compare the fundamental rate of inflation, π^*_t, for each specification with the actual development of inflation, π_t (1) the ratio of the standard deviation of the fundamental and the actual rate of inflation, $StDev(\pi^*_t)/StDev(\pi_t)$, (2) the correlation coefficient between the fundamental and the actual rate of inflation, $Corr(\pi^*_t, \pi_t)$, and (3) the root mean squared deviation of the fundamental rate of inflation from the actual inflation rate, $RMSD(\pi^*_t, \pi_t)$.

Chart 1 compares fundamental inflation as derived from SP1, SP2 and SP3 and actual inflation developments (quarter on quarter) from 1980 to 2003. Overall, chart 1 shows that all three specifications of the NKPC explain inflation developments in Austria during the observation period fairly well. The deviations from the actual developments were somewhat more pronounced only in the first third of the observation period (until about 1987), when inflationary developments were generally slightly more volatile. Moreover, specification SP1 is found to trace actual developments best. A simple eyeball inspection of the middle (SP2) and lower (SP3) panels in chart 1 does not induce a clear preference for one or the other specification. Hence, the comparison should be based on the measures of fit defined above.

Table 2 shows the three measures of fit of the fundamental inflation rate with actual inflation and ranks the specifications' performance resulting from the total of all three measures. The data confirm the graphic analysis that specification SP1 displays the highest explanatory power for Austrian inflation developments during the observation period: The ratio of standard deviations in the first two rows is close to the optimum value of 1, the correlation is highest with a value of just under 0.5, and the root mean squared deviation of the fundamental from the actual inflation rate is lowest among the three specifications. According to the measures of fit, specification SP3 has the second-highest explanatory power, as both the deviation from the optimum value of the ratio of standard deviations and the root mean squared deviation are smaller than in the case of SP2, and the correlation coefficient for SP3 is larger than that for SP2.

Thus, the closed-economy specification of the NKPC, SP1, exhibits the highest explanatory power for Austrian inflation developments in the period from 1980 to 2003, followed by the general open-economy specification, SP3, and the specification with only imported intermediate inputs as an additional production factor, SP2. For the estimated degree of price rigidity (table 1), this means that the value for θ estimated at just under 0.7 for both SP1 and SP3 is likely to be more accurate than the lower price rigidity estimate of 0.45 for SP2.

Moreover, the average price duration of just under 10 months derived from the higher value also corresponds better to the price duration of 11 months derived from the micro CPI data. However, this result – SP1

[12] *For more detailed information on the derivation and calculation of the fundamental inflation rate, see Rumler (2006).*

exhibiting the highest explanatory power – does not mean that the extension of the NKPC for Austria is irrelevant. On the one hand, the performance of SP1 proves to be only marginally better than that of SP3, and on the other hand, there is another important criterion for the performance of the NKPC, and this criterion has not yet been taken into account: the plausibility of the estimates of the reduced form model. In particular, it is relevant whether the respective marginal cost term is significant, as a problem with the identification of the structural parameters arises if it is not (Guay and Pelgrin, 2004). According to this criterion, SP3 should be preferred over SP1 and SP2, as SP3 is the only specification in which marginal cost provides a significant contribution to explaining inflation developments (Rumler, 2006).

Hence, based on these considerations, one may infer that only SP2 was misspecified for Austria, and thus the relatively low price rigidity estimate of this specification is likely to be inappropriate.

4 Inflation Forecasting Using the New Keynesian Phillips Curve

The NKPC is used as a structural model above all to explain past inflation developments, but is not generally used to forecast inflation.[13] In this section, an attempt is made to employ the NKPC model for forecasting purposes. The starting point is the concept of the fundamental inflation rate, which is adapted to produce an inflation forecast, reporting current inflation as the sum of current and expected discounted future marginal costs. To construct a measure of fundamental inflation, a forecast of future marginal cost must be made on the basis of an econometric model. Galí and Gertler (1999) propose a bivariate vector autoregressive (VAR) model with the variables inflation and marginal cost for this purpose. If the forecast of future marginal cost is lagged by one period, so that a forecast of current and expected future marginal cost is provided from the perspective of the last period, this forecast may be used to construct the current fundamental inflation rate. This fundamental rate of inflation expected from the perspective of the past period is interpreted as the inflation forecast, i.e. based on information from period t a forecast of the inflation rate implied by the model is calculated for $t+1$, and iteratively for $t+2$, $t+3$ etc.

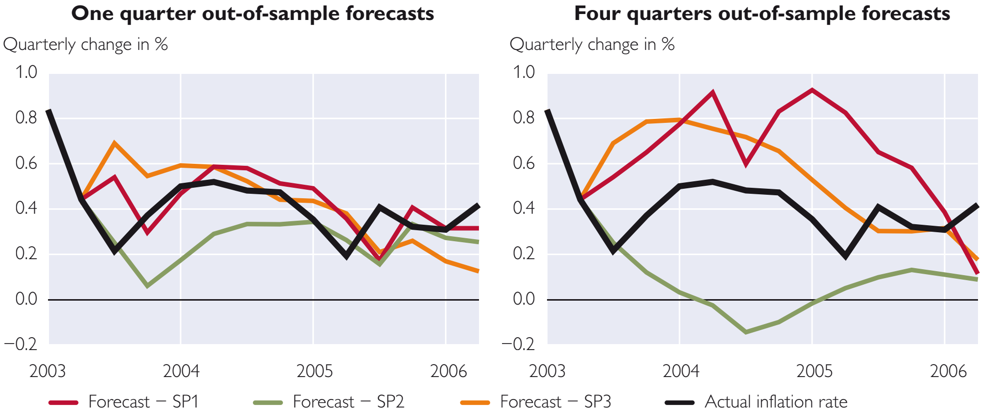
To evaluate the predictive power of the NKPC, out-of-sample forecasts were made for each of the three specifications for the period ranging from the third quarter of 2003 (end of the estimation period) up to the second quarter of 2006 (end of the sample period). Chart 2 shows these inflation forecasts and the actual inflation developments for this period, with a forecasting horizon of one quarter (left panel) and four quarters (right panel). Thus, the colored lines in the chart represent the stacked forecast values over the respective forecasting horizons.

Chart 2 shows that pronounced forecasting errors are concentrated in the first half of the evaluation period for both forecasting horizons; forecasts converge – and hence display smaller forecasting errors – in the second half of the period. Forecasting errors are naturally smaller for the

[13] *In the literature no contribution was found that uses the NKPC for inflation forecasting.*

Chart 2

Inflation Forecasts Based on SP1, SP2 and SP3 and Actual Inflation Developments



Source: Author's calculations.

Table 3

Root Mean Square Forecasting Error (RMSE) for Inflation Forecasts based on SP1, SP2 and SP3 and the Naive Forecast by Forecasting Horizon

	RMSE	RMSE
	One quarter out-of-sample forecasts	Four quarters out-of-sample forecasts
SP1	0.14	0.35
SP2	0.18	0.38
SP3	0.20	0.25
Naive	0.13	0.21

Source: Author's calculations.

shorter horizon (left panel) than for the four-quarter horizon (right panel). Interestingly, the three specifications perform quite differently for the different forecasting horizons. According to the chart, specification SP1 appears to perform best for the short forecasting horizon, whereas specification SP3 seems to deliver the best forecast for the longer forecasting horizon.

Table 3 confirms the impression gained by the visual inspection of chart 2 that the specifications display differences in the relative forecasting performance for both forecasting horizons. We use a common measure to evaluate forecasting performance, namely the root mean square forecasting error (RMSE) for each forecasting horizon. The last line of the table provides naive forecast (random walk forecast) figures as a benchmark to gauge the forecasting accuracy. The naive forecast assumes a flat forecasting profile of the inflation rate over the respective forecasting horizon (with the forecast equaling the last period's actual value). The naive forecast is frequently used as a benchmark in the empirical literature, as it has proved to be hard to outperform in the medium to long term for many macroeconomic variables, among them also inflation.

For the forecasting horizon of one quarter, specification SP1 has the lowest RMSE at 0.14, followed by SP2 and SP3. However, the naive forecast still performs best, with an RMSE of 0.13 for the one-quarter horizon, and it performs best for the four-quarter forecasting horizon at 0.21, compared with 0.25 for SP3 and much higher results for SP1 and SP2.

Thus, the evaluation of the forecasting quality of the NKPC demonstrates a fairly poor performance for the Phillips curve model – it cannot beat a naive forecast, neither over a short- nor over a longer-term forecasting horizon. One reason could be the relatively complex construction of the inflation forecast, which is based on a forecast of future marginal cost using a bivariate VAR model. Thus, the quality of the inflation forecast depends directly on the quality of the forecast of future marginal cost. The marginal cost forecast, in turn, is based on a very simple method whose quality cannot be verified, as the discounted sum of all future marginal costs is not observable.

Given these results, NKPC models are not suited as an alternative to econometric time-series models for inflation forecasts, especially because in the short term (up to one year), time-series models usually clearly outperform the naive forecast (Benalal et al., 2004). Hence, it may be noted that the NKPC is better suited to explain inflation developments ex post and to estimate the structural parameters of the price-setting process than to inflation forecasting.

5 Conclusions

The NKPC is a structural model to explain inflation dynamics. The model is helpful in estimating the structural parameters of the price-setting process in an economy. The resulting parameter values in the estimation largely depend on the model specification used. As the NKPC was originally conceived for a closed-economy setting, it should be adapted accordingly if it is estimated for an open economy such as Austria. The NKPC model presented in this study is extended to account for open-economy effects and is additionally extended by intermediate inputs; it thus nests the standard closed-economy model as a special case.

The estimates for the parameter representing structural price rigidity differ depending on the model specification: they are higher for the closed-economy specification and for the general formulation of the extended NKPC (with both domestic and imported intermediate inputs) than for the specification that contains only imported intermediate inputs. One reason could be more frequent price adjustments by firms that do not have the option of substituting domestic intermediate inputs (with less volatile prices) for imported intermediate inputs (that are subject to stronger price fluctuations resulting e.g. from exchange rate fluctuations or volatile commodity prices).

However, on evaluating the different specifications using econometric measures of fit, we determined that SP2, which results in a lower degree of price rigidity, is likely to be misspecified. According to the measures of fit, the general formulation of the extended NKPC model and the standard closed-economy model are about equally well suited to explaining inflation developments in Austria since 1980. The estimated degree of price rigidity is also roughly equal in both specifications: They both show that somewhat more than 30% of all firms adjust their prices in a given quarter, which means that a single firm's prices remain unchanged for an average of just under ten months. This value is neither very high nor very low by comparison to other euro area countries, and it roughly matches the average price duration derived from Austrian micro CPI data.

The estimation of the structural parameters shows that depending on the specification, 30% to 50% of all Austrian firms follow a backward-looking rule of thumb in updating their prices. This implies a fairly high degree of inflation persistence, also by international standards, which is generally confirmed by other multi-country studies on this topic. A high degree of inflation persistence has implications for economic policymaking, as pertinent studies show that it dampens the transmission of specific types of macroeconomic shocks on the inflation rate. For instance, the impact of an oil price shock on inflation is more subdued but lasts longer if inflation persistence is high. At the same time, though, a high degree of inflation persistence triggers a stronger output reaction to an oil price shock, which means that in the case of a supply shock, the inflation-output variability trade-off shifts in favor of inflation and to the disadvantage of output (Altissimo et al., 2006).

The result of an examination of the NKPC's suitability as an inflation forecasting tool for Austria was rather disappointing. The results obtained using the NKPC fell short of those obtained with the naive forecast (the forecast equals the last period's actual value) both over the one-quarter and the four-quarter forecasting horizons. Thus, the NKPC does not appear to be useful as a forecasting alternative to the established time-series models, which perform far better over a short-term forecasting horizon of up to one year. However, it may by all means complement time-series models as a structural model in which firms' pricing is determined by their expectations of the development of their future marginal costs. Inflation forecasting using the NKPC is an indirect approach, as it is based on a forecast of future marginal cost developments. Depending on the specification, this approach indirectly accounts for labor cost developments and the price developments of domestic and imported intermediate inputs. However, this method has the disadvantage that a forecast based on such a two-stage construction does not lend itself very well to economic interpretation.

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