Does the forward-looking Phillips Curve explain UK inflation?

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Abstract: This paper evaluates the ability of the standard Calvo model of staggered price setting to replicate inflation dynamics in the UK. The New Keynesian model specifies inflation as the present-value of future real marginal cost. We exploit forecasts of future real marginal cost generated by VAR models to assess the extent to which the model matches the behavior of actual inflation. In accordance to the literature, the model fits well at first sight. A set of bootstrapped confidence bands, however, reveals that this result is consistent with both a well fitting and a poorly fitting model. Extending the model to the open economy greatly improves the performance of the forward-looking model.

Keywords: New Keynesian Phillips Curve, present-value model, VAR, bootstrap, open-economy Phillips Curve

JEL classification: E31, E32

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1 Introduction

Under the New Keynesian paradigm of sticky-price models with monopolistic competition, inflation dynamics are forward-looking. Hence, the New Keynesian Phillips Curve (NKPC) relates current inflation to expected future inflation and a measure of current real activity. Furthermore, it can be shown that the inflation rate is given as the present-value of the entire expected path of future real marginal cost. This class of models has become the canonical framework to study inflation dynamics.

This paper analyzes the present-value relation implicit in a typical New Keynesian model as it lends itself to a well-known empirical approach. Like other present-value relations this model can be studied using the framework laid out by Campbell and Shiller (1987). Specifically, we can employ VAR-based forecasts to generate a series of model-consistent or "fundamental" (Galí, Gertler, and López-Salido, 2001) inflation that is supposed to match the behavior of actual inflation if the model is correct.

Prominent contributions that exploit the present-value structure for U.S. data are Sbordone (2002), Kurmann (2003), and Rudd and Whelan (2005).[2] For the UK case, the present-value implications are explicitly analyzed by Demery and Duck (2003) and Chadha and Nolan (2004). Both papers find that the Calvo (1983) model of staggered price setting, which serves as a workhorse to model price stickiness, generates a fundamental inflation rate that tracks actual inflation quite closely.

Other papers that provide GMM estimates of the NKPC for the UK are Banerjee and Batini (2004), Batini, Jackson, and Nickell (2005), and Jondeau and Le Bihan (2001). Moreover, a couple of papers extends the basic NKPC model to account for open-economy issues in measuring marginal cost. Major contributions are Balakrishnan and López-Salido (2002), Kara and Nelson (2002), Leith and Malley (2004), and Batini, Jackson, and Nickell (2005).

In this paper we assess the empirical fit of the present-value relation implied by the Calvo price setting scheme. We follow Kurmann (2003) and take account of estimation uncertainty.[3] Since forecasts derived from VAR estimates are mere point estimates, plotting the implied inflation rate disguises the uncertainty involved in the estimation process. Hence, we assess whether the model indeed fits or whether it fails. While bootstrapping confidence bands for major measures of the model's fit, we correct the bias due to the nonlinear nature of conventionally used measures of fit by employing

[2] Galí, Gertler, and López-Salido (2001) and Jondeau and Le Bihan (2001, 2003) are the main contributions for evidence on the New Keynesian Phillips Curve with European data.

[3] See Tillmann (2005) for a related paper that assesses the empirical performance using aggregate data for the Euro area.

Kilian's (1998) bias correction.

We find that the forward-looking NKPC fits UK data well at first sight. However, wide confidence bands impair a meaningful interpretation of conventionally employed measures of fit. Extending the model to the open economy, however, improves the model's fit.

The present paper is organized as follows. The next section derives the New Keynesian Phillips Curve and the present-value relation for inflation from a standard model of staggered price setting. Section three presents the estimation strategy, discusses estimation uncertainty, and elaborates the bootstrap approach to calculate confidence intervals around standard measures of fit. Section 4 presents the results and discusses their robustness. Finally, section 5 concludes.

2 The New Keynesian model of inflation

In this section we use a stylized log-linear model to derive the basic present-value relation for inflation that is central to most specifications of the New Keynesian Phillips Curve.[4]

Under imperfect competition, firms' price setting behavior is driven by the behavior of their marginal cost of production. Consider the case of staggered price setting following the work of Calvo (1983).[5] Each firm adjusts its price during the current period, i.e. during the current quarter, with a fixed probability $1-\mu$ where $0<\mu<1$. Firms minimize the discounted future deviations of their price from the price they would set if prices were fully flexible. It can be shown that this problem results in an optimal reset price

$$p_t^* = (1-\phi\mu)\sum_{k=0}^{\infty}(\phi\mu)^k E_t\{nmc_{t+k}\} \tag{1}$$

with a subjective discount factor ϕ. The optimal reset price is set equal to a weighted average of the prices that it would have expected to set in the future if there weren't any price rigidities. In a frictionless market this price would equal a fixed markup over marginal cost. In setting prices each firm takes the expected path of future nominal marginal cost, nmc_t, into account. The price level p_t (in logs) is given as a convex

[4] See Woodford (2003) for a systematic and profound overview.

[5] We concentrate here on Calvo-style price setting behavior. Roberts (1995) shows that fixed length contracts proposed by Taylor (1980) result in similar inflation dynamics and Sbordone (2002) shows in her appendix that both models of price setting imply a similar common trend retriction.

combination of the lagged price level and the optimal reset price p_t^*

$$p_t = \mu p_{t-1} + (1-\mu) p_t^* \tag{2}$$

Combining these two equations gives the aggregate price level as the present-value of expected future nominal marginal cost

$$p_t = \mu p_{t-1} + (1-\mu)(1-\phi\mu) \sum_{k=0}^{\infty} (\phi\mu)^k E_t \{nmc_{t+k}\} \tag{3}$$

The higher the probability μ, the more persistent is the price level. In the limiting case of perfectly flexible prices (i.e. $\mu \to 0$), the optimal reset price and, thus, the price level are determined only by the current level of marginal cost, $p_t = nmc_t$.
From this model we can derive the NKPC (see, e.g. Galí and Gertler, 1999)

$$\pi_t = \phi E_t \pi_{t+1} + \gamma rmc_t \tag{4}$$

Inflation is determined by expected future inflation and current real activity proxied by real marginal cost, where $\pi_t = p_t - p_{t-1}$ is the inflation rate, rmc_t denotes a measure of real marginal cost in deviation from its steady-state value, and E_t is the expectations operator. The composite parameter γ is given by $\frac{(1-\mu)(1-\phi\mu)}{\mu}$. Repeated substitution yields

$$\pi_t = \gamma \sum_{k=0}^{\infty} \phi^k E_t rmc_{t+k} \tag{5}$$

Equation (5) says that the inflation rate at time t is a fraction of the present-value of the expected path of future real marginal cost.
Conventionally, real marginal cost is measured by deviations of the labor share of income from its mean. Let's assume a production technology with fixed capital-input, e.g. $Y_t = A_t L_t$, where A_t is technology and L_t is the labor input. Under the assumption of frictionless labor markets, nominal marginal cost is then given by the ratio of the nominal wage to the marginal productivity of labor W_t/A_t. Dividing this expression by the price level P_t yields real marginal cost as

$$\frac{W_t L_t}{P_t Y_t} \tag{6}$$

which is the labor share of income. Linearizing this expression gives a simple representation of deviations of marginal cost from its steady-state value in terms of the deviations of the labor share from its mean.

A number of papers extends the model to account for open-economy issues. Major contributions are Balakrishnan and López-Salido (2002), Kara and Nelson (2002), Leith and Malley (2004), and Batini, Jackson, and Nickell (2005). These papers extend the measure of marginal cost to account for the role of imports. Kara and Nelson (2002), among others, derive an expression for aggregate inflation that gives a role to real exchange rate movements. Let π^D the inflation rate based on an index of goods prices that are both produced and sold domestically. The NKPC in terms of domestically produced goods is

$$\pi_t^D = \phi E_t \pi_{t+1}^D + \gamma rmc_t \tag{7}$$

Kara and Nelson (2002) show that domestic inflation can be expressed as

$$\pi_t^D = \pi_t - s^M \Delta reer_t \tag{8}$$

where s^M is the share of imported goods in the CPI and $reer_t$ is the real effective exchange rate. The resulting open-economy NKPC is

$$\begin{aligned} \pi_t &= \phi E_t \pi_{t+1} + \gamma rmc_t + \delta \left(\Delta reer_t - \phi E_t \Delta reer_{t+1} \right) \\ &= \phi E_t \pi_{t+1} + \gamma rmc_t - \delta \Delta^2 reer_{t+1} \end{aligned} \tag{9}$$

with $\Delta^2 reer_{t+1} = \phi E_t \Delta reer_{t+1} - \Delta reer_t$. Solving forward gives the open-economy present-value relation for inflation in terms of the present-value of expected future marginal cost and future real exchange rate changes

$$\pi_t = \gamma_{rmc} \sum_{k=0}^{\infty} \phi^k E_t rmc_{t+k} - \gamma_{reer} \sum_{k=0}^{\infty} \phi^k E_{t+k} \Delta^2 reer_{t+k+1} \tag{10}$$

where γ_{rmc} and γ_{reer} are reduced form coefficients.

3 The present-value relation under estimation uncertainty

Campbell and Shiller (1987) propose a well-known framework to assess the fit of forward-looking present-value models. As a clear advantage, this approach does not involve making assumptions about the structure of the whole economy in the application of maximum likelihood methods or the choice of appropriate instruments in an instrumental variables estimation. In a first step, we derive the cointegration restriction implied by the forward-looking model. In a second step, we present the estimation strategy based upon VAR projections as a proxy for market expectations.

3.1 The cointegration restriction

The Calvo model imposes a testable restriction on the long-run dynamics of the price level and the level of nominal marginal cost. To see this, subtract (3) from nmc_t and rearrange. We obtain

$$rmc_t = nmc_t - p_t = \left(\frac{\mu}{1-\mu}\right) \Delta p_t - \sum_{i=1}^{\infty} (\phi\mu)^i \, E_t \left\{\Delta nmc_{t+i}\right\} \tag{11}$$

with the difference operator given by Δ. Equation (11) specifies real marginal cost, rmc_t, as the present-value of the path of changes in nominal marginal cost. This expression imposes a restriction on the joint behavior of the price level and the level of nominal marginal cost. If nmc_t and p_t are $I(1)$, their first differences must by definition be stationary. Assume a linear combination $\boldsymbol{\beta}'\mathbf{x}_t$ with a (1×2) vector $\boldsymbol{\beta}$ and the data vector $\mathbf{x}_t' = (nmc_t, p_t)$. The testable implication is that $\boldsymbol{\beta}' = (1, -1)$. In other words, nominal marginal cost and the price level are cointegrated with that cointegrating vector.

3.2 Inflation forecasts from VAR projections

To assess the explanatory power of the Calvo model of staggered price setting, we construct an implied series for the forward-looking terms and contrast model-consistent inflation rates with actually observed inflation rates. We assume that the information contained in a small atheoretical bivariate VAR is a subset of the market's full information set.

Let the information set of agents be described by past realizations of inflation and real marginal cost. The vector $\mathbf{Z}_t = [rmc_t, ..., rmc_{t-q+1}, \pi_t, ..., \pi_{t-q+1}]'$ follows a VAR(q) in companion form

$$\mathbf{Z}_{t+1} = \mathbf{A}\mathbf{Z}_t + \mathbf{\Gamma}_{Z_{t+1}} \tag{12}$$

where $\mathbf{\Gamma}_{Z_{t+1}} = [u_{1t}, 0, ..., 0, u_{2t}, 0, ..., 0]'$ represents innovations to agents' information set and $\mathbf{A}$ is the $2q \times 2q$ companion matrix. We know that forecasts based on the econometrician's information set $\mathbf{H}_t$, which includes only current and lagged values of the variables in $\mathbf{Z}_t$, are given by the multi-period forecasting formula

$$E_t \left[\mathbf{Z}_{t+k} | \mathbf{H}_t\right] = \mathbf{A}^k \mathbf{Z}_t \tag{13}$$

The beauty of the Campbell-Shiller approach is the fact that this parsimonious VAR model the econometrician estimates is a sufficient statistic of market expectations even if agents have much more inflation available. The reason is that under the null hypothesis the inflation rate represents agents' best forecast of the present-value of future labor shares no matter what other information he has.

The vector of the discounted future paths of the variables can be calculated as

$$\sum_{k=0}^{\infty} \phi^k E_t \mathbf{Z}_{t+k} = (\mathbf{I} - \phi \mathbf{A})^{-1} \mathbf{Z}_t$$

where $\mathbf{I}$ is the 2×2 identity matrix. We map these forecasts into the present-value representation of the Calvo pricing model to obtain an expression for the model-consistent inflation rate. This "fundamental" (Galí and Gertler 1999, p. 217) inflation rate is given by

$$\pi_t^{fund} = \gamma \mathbf{h}'_{rmc} (\mathbf{I} - \phi \mathbf{A})^{-1} \mathbf{Z}_t$$

where $\mathbf{h}'_{rmc}$ denotes a selection vector that singles out the forecast of real marginal cost, i.e. the first element of $(\mathbf{I} - \phi \mathbf{A})^{-1} \mathbf{Z}_t$. The NKPC thus predicts that inflation at time t should be a scalar multiple of the first entry in the vector $(\mathbf{I} - \phi \mathbf{A})^{-1} \mathbf{Z}_t$, which is observable. Rudd and Whelan (2003) propose to infer the coefficient γ from a regression of actual inflation on the present-value of expected future real marginal cost $\mathbf{h}'_{rmc} (\mathbf{I} - \phi \mathbf{A})^{-1} \mathbf{Z}_t$. We will assess the fit of the Calvo model by comparing actual inflation with fundamental inflation. If the model provides an accurate description of inflation, these two series must coincide.

To assess the explanatory power of the open-economy NKPC, let

$$\mathbf{Z}_t = \left[rmc_t, ..., rmc_{t-q+1}, \pi_t, ..., \pi_{t-q+1}, \Delta^2 reer_t, ..., \Delta^2 reer_{t-q+1}\right]' \tag{14}$$

be the information set in the open economy case which follows a VAR(q) with a $3q \times 3q$ companion matrix A. Fundamental inflation is now given by the present-value of expected future real marginal cost and the present-value of expected future changes in the real exchange rate

$$\pi_t^{fund} = \gamma_{rmc} \mathbf{h}'_{rmc} (\mathbf{I} - \phi \mathbf{A})^{-1} \mathbf{Z}_t - \gamma_{reer} \left(\mathbf{h}'_{reer} (\mathbf{I} - \phi \mathbf{A})^{-1} \mathbf{Z}_t - \Delta^2 reer_t \right) \phi^{-1} \tag{15}$$

where $\mathbf{h}'_{reer}$ is a second selection vector that singles out the present-value of the the real exchange rate term.[6] The reduced-form coefficients γ_{rmc} and γ_{rmc} are again obtained from regressing actual inflation on the present-values of the two forcing variables.

[6] A slight modification is required to take account of the fact that the second difference of the real exchange rate is dated $t+1$. Multiplying the infinite sum of future changes by ϕ and adding $\Delta^2 reer_t$ gives $\Delta^2 reer_t + \phi \sum_{k=0}^{\infty} \phi^k \Delta^2 reer_{t+k+1} = \phi^0 \Delta^2 reer_t + \phi^1 \Delta^2 reer_{t+1} + \phi^2 \Delta^2 reer_{t+2} + ... = h'_{reer} (\mathbf{I} - \phi \mathbf{A})^{-1} \mathbf{Z}$, where h'_{reer} is an appropriate selection vector. The present value of $\Delta^2 reer_{t+k+1}$ is therefore given by $\sum_{k=0}^{\infty} \phi^k \Delta^2 reer_{t+k+1} = \left(h'_{reer} (\mathbf{I} - \phi \mathbf{A})^{-1} \mathbf{Z}_t - \Delta^2 reer_t \right) \phi^{-1}$.

We plot actual inflation against fundamental inflation and compute standard measures of fit. Following the literature on present-value models, Kurmann (2003) proposes two measures that indicate the extent to which the model is able to replicate actual inflation. The first measure is the ratio of standard deviations. A perfect fit would result in a standard deviation ratio of unity. In that case the Calvo model would explain all the variation in actual inflation. The second measure is the correlation coefficient between fundamental and actual inflation.[7]

Note that these measures of fit do not reflect the degree of uncertainty about the model's fit. Previous applications of the empirical approach sketched above to the New Keynesian model of inflation dynamics neglect this issue completely. Kurmann (2003), on the contrary, provides evidence on the uncertain fit of the NKPC for U.S. data. In this paper we follow his approach and compute confidence bands around the measures of fit.

3.3 Bootstrapping confidence bands for measures of fit

The crucial motivation of the empirical analysis in this paper is the fact that using VAR projections disguises the degree of estimation uncertainty. To assess the accuracy of the model's fit we employ a bootstrap approach that infers the distribution of our measures of fit from estimating the model with artificial data.

We obtain confidence intervals by drawing from the residuals of the estimated model and generating new observations for the data vector using the estimated companion matrix. The VAR model is estimated again and a new coefficient matrix is computed. From this we compute the series of expected real marginal cost and regress actual inflation on the present value of future real marginal cost to infer the slope coefficient. Finally, the ratio of standard deviation and the correlation coefficient is computed. Repeating this procedure 10000 times provides us with an empirical distribution for the ratio of standard deviations and the correlation coefficient from which an interval that includes 90 percent of the estimates can be calculated.

However, Kilian (1998) shows that this standard bootstrap algorithm performs poorly when it is used to compute distributions of statistics that are nonlinear functions of VAR parameters. Note that both the ratio of standard deviations and the correlation coefficient are highly nonlinear functions of the estimated VAR coefficients. Therefore, we follow Kurmann (2003) and apply Kilian's bias-corrected bootstrap algorithm. Basically, he proposes to replace the estimated VAR coefficients by bias-corrected es-

[7] Both measure are widely used in the literature on present-value relations. See, e.g., Ghosh (1995) for an application to assess the fit of the intertemporal model of the current account.

timates before running the bootstrap to compute the measures of fit. Details about this bias-correction can be found in Kilian (1998). Moreover, Kilian (1998) proposes a second bias-correction because the OLS estimates are themselves biased away from their population values. Thus, the approach amounts to a bootstrap-after-bootstrap technique.

4 Results

We use quarterly data for the UK obtained from the OECD's Economic Outlook database. The sample covers 1960:1 through 2004:1. The inflation rate is measured as the annualized quarterly change of the (log) GDP deflator (in percentage points). Real marginal cost can be shown to be proportional to labor's share of income and is approximated by the (log) ratio of compensation to employees to nominal GDP (in percentage point deviation from its mean). Standard unit-root tests cannot reject, see table (1), that both the price level and nominal marginal cost are $I(1)$ processes.
The Campbell-Shiller approach requires the price level and the level of nominal marginal cost to be cointegrated with a vector $\beta = (1, -1)$. The results of the powerful test for prespecified cointegration proposed by Horvath and Watson (1995) indeed support this cointegrating relation.[8]
We estimate the forecasting VAR model with three lags as suggested by standard information criteria and specification tests (see table 2). All estimated parameters of the auxiliary VAR are documented in table (3). Note that a test rejects the hypothesis of excluding inflation from the marginal cost equation. Hence, inflation contains information about future realizations of marginal cost. In other words, inflation is forward-looking.
We proceed by calculating fundamental inflation according to the model laid out before. The quarterly discount factor is set to $\phi = 0.99$, which is the predominant specification in the literature and yields an annual real interest rate of about 4%. To check the robustness, we alternatively impose $\phi = 0.98$ and $\phi = 0.95$. Those values roughly cover the range of specifications in the literature. Following the suggestion of Rudd and Whelan (2003), actual inflation is regressed on the present-value of expected future real marginal cost and a constant in order to infer the parameter γ. We then compare the series of fundamental inflation with actual inflation by means of the ratio of their

[8]The test statistic for the case of three lags is 11.68, which exceeds the 5% critical value of 10.18 and, thus, supports the prespecified cointegrating relation with a vector $(1, -1)$. The complete set of results from Johansen and Horvarth-Watson tests is available upon request.

standard deviations and their correlation coefficient.

Figure (1) depicts the time series of actual and model-consistent or fundamental inflation in the UK. We find that the Calvo model broadly tracks the behavior of the actual inflation rate. Apparently, however, actual inflation is more volatile than fundamental inflation. The ratio of standard deviations of fundamental and actual inflation and the correlation between both series is 0.61, see table (5). However, these results are mere point estimates. Confidence bands, whose derivation is explained above, reveal that both measures of fit are surrounded by a large degree of uncertainty. The 90% confidence interval around the ratio of standard deviations covers 0.19 as likely as 0.87. Hence, we cannot say whether the model fits or fails. It could equally likely explain 20% of the variation of the inflation rate and almost 90% of the variation in inflation. Imposing a lower discount factor improves the results. However, it turns out that the performance of the Calvo model for UK data is slightly better than for U.S. data. Kurmann (2003) finds a standard deviation ratio for the U.S. within the interval [0.01,1.57]. The confidence band around the correlation coefficient covers a range of values between 0.40 and 0.78. Hence, the model appears to be consistent with actual and fundamental inflation being mildly correlated as well as being highly correlated.

Figure (2) shows the density of the ratio of standard deviations of fundamental and actual inflation and the correlation coefficient across bootstrap replications. We find that Kilian's (1998) bias-correction of the bootstrap has only a minor impact on the distribution and the width of the confidence bands.

The estimated slope coefficient $\hat{\gamma}$ in conjunction with a fixed discount factor allows us to infer the average duration of sticky-price contracts under the Calvo price setting scheme. We obtain an average duration of fixed prices of just under 6 quarters which appears quite long in light of recent survey evidence. Recently, Hall, Walsh, and Yates (2000) survey the price setting behavior of 654 UK companies in 1995 and find that firms reset prices twice a year.

Table (6) presents additional results that are derived from slightly different empirical specifications. These results support the findings from the baseline model and corroborate their robustness. In a first modification, the short-term interest rate (the treasury bill rate) is included in the VAR as an additional variable that might contain information about future inflation rates.[9] A second specification uses the change of nominal marginal cost instead of the inflation rate in the auxiliary VAR to derive the series of fundamental inflation. Finally, we include impulse dummies to account for two outliers in actual inflation, which are observed in 1973:2 and 1979:3. All three variations leave

[9]The interest rate series is obtained from the IMF's International Financial Statistics database.

the main finding unchanged and further illustrate the modest empirical performance of the forward-looking model.

Many papers identify the absence of imported goods as a major deficiency of the basic NKPC analyzed thus far. The open-economy NKPC derived above, on the contrary, specifies inflation as the present-value of real marginal cost and change sin the real exchange rate. To test this model, we extend the empirical approach to the three-variable case and include the second difference of the real effective exchange rate into the forecasting VAR. The open-economy variant then maps the present-value of the exchange rate path into the equation for fundamental inflation, i.e. $\gamma_{reer} \neq 0$. We compare the resulting empirical fit with the case of $\gamma_{reer} \equiv 0$, i.e. with a case in which the real exchange rate does not appear in the expression for fundamental inflation. Unfortunately, the IMF's International Financial Statistics database has a real effective exchange rate series for the UK available only from 1972 onwards. Therefore, the analysis of the open-economy extension is restricted to the sample period 1972:1 to 2004:1. All estimated VAR parameters are reported in table (4).

We find that accounting for openness substantially improves the model's ability to replicate inflation. Table (7) shows that the fit improves when we allow the real exchange rate to enter agents' information set. Both measures of fit rise and their confidence bands narrow considerably. Moreover, the open-economy NKPC with $\gamma_{reer} \neq 0$ exhibits a correlation between actual and fundamental inflation of 0.87, which is significantly higher than for $\gamma_{reer} \equiv 0$, since $0.87 \notin [0.723, 0.863]$. Hence, these results corroborate the findings of the literature and point to an important role of open-economy considerations for inflation dynamics in the UK.

5 Conclusions

In this paper we assessed the ability of the standard Calvo model of staggered price setting to replicate inflation dynamics in the UK. The standard New Keynesian model specifies current inflation as the present-value of the expected future stream of real marginal cost. Previous contributions to the literature exploited VAR projections of future real marginal cost to proxy market expectations and to derive a series of model-consistent or fundamental inflation rates. It is frequently argued that this series of fundamental inflation explains actual inflation quite well. In this paper we shed light on this finding. We used bootstrapped confidence bands to quantify the degree of estimation uncertainty around these estimates. We find that the model is consistent with both a poorly fitting model and a remarkably well fitting model. Accounting for open-economy issues substantially improves the model's performance. We leave a deeper analysis of other extensions of the basic model, i.e. labor market frictions and other supply-side refinements, for further research.

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Table 1: Unit-root tests

series	specification	ADF	PP	KPSS	DF-GLS
p_t	const.	-1.29	-1.22	1.67***	0.40
	const. and trend	-1.10	-0.18	0.31***	-1.44
Δp_t	const.	-2.62***	-7.42***	0.41*	-2.63***
nmc_t	const.	-1.15	-1.30	1.66***	1.17
	const. and trend	-0.75	-0.34	0.32***	-1.05
Δnmc_t	const.	-4.14***	-8.01***	0.37*	-2.60***

Notes: ADF denotes the test statistic from the augmented Dickey-Fuller test, PP denotes the test statistic from the Phillips-Perron test, DF-GLS is the GLS detrended Dickey-Fuller test proposed by Elliott, Rothenberg, and Stock (1996), and KPSS is the Kwiatkowski-Phillips-Schmidt-Shin test statistic. While ADF, PP, and DF-GLS test the hypothesis of a unit-root, KPSS tests the Null of stationarity against the unit-root hypothesis. The lag order for the ADF test is chosen according to the Schwartz criterion; the PP and the KPSS test are specified using the Bartlett kernel with automatic Newey-West bandwidth selection. For the DF-GLS test the lag order is chosen following the modified AIC. A significance level of 1%, 5%, and 10% is indicated by ***, **, and *.

Table 2: Choosing the lag order of the auxiliary VAR

	AIC(q)	SC(q)	HQ(q)	LM(1)	LM(4)	White
$q=1$	8.83	8.94	8.988	34.69***	4.36	62.09***
$q=2$	8.68	8.86	8.76	24.72***	3.02	125.07***
$q=3$	8.58#	8.84#	8.68#	1.28	3.52	209.28***
$q=4$	8.62	8.95	8.75	12.33**	5.85	263.68***
$q=5$	8.65	9.05	8.81	7.55*	3.03	341.78***

Notes: AIC(q), SC(q), and HQ(q) denote the Akaike information criterion, the Schwartz criterion, and the Hannan-Quinn information criterion, respectively, for a VAR for $[rmc_t, \pi_t]'$ of order q. The proposed lag order is indicated by #. LM(h) is a multivariate Lagrange-Multiplier test for residual correlation up to order h. Under the null hypothesis of no serial correlation, the LM statistic is asymptotically χ^2 distributed. White denotes the χ^2 test statistic of a White test that includes cross terms. The null is the absence of heteroscedasticity. A significance level of 1%, 5%, and 10% is indicated by ***, **, and *.

Table 3: Estimated VAR parameters: closed economy

	dependent variable	
	rmc_t	π_t
rmc_{t-1}	0.835 (0.120)	1.373 (0.413)
rmc_{t-2}	0.253 (0.140)	-0.801 (0.608)
rmc_{t-3}	-0.138 (0.099)	-0.421 (0.316)
π_{t-1}	0.043 (0.029)	0.304 (0.089)
π_{t-2}	-0.055 (0.031)	0.165 (0.111)
π_{t-3}	-0.215 (0.179)	0.277 (0.072)
exclusion restriction		
(p-value)		
excl. π_t	0.093	0.00
excl. rmc_t	0.000	0.00
R^2	0.940	0.591
DW	2.033	1.995
ARCH(1)	15.274 [0.00]	0.005 [0.945]

Notes: OLS Estimates of the auxiliary VAR system. The VAR includes a constant. Standard errors in parenthesis. ARCH (1) is an LM test for ARCH effects in squared residuals based on an auxiliary regression of the squared series on a constant and own lagged values. Under the null hypothesis of no ARCH effects up to lag 1, the test statistic is approximately $\chi^2(1)$ distributed. The p-values related to the specification tests are given in brackets.

Table 4: Estimated VAR parameters: open economy

	dependent variable		
	rmc_t	π_t	$\Delta^2 reer_t$
rmc_{t-1}	0.834 (0.155)	1.671 (0.449)	-0.220 (0.214)
rmc_{t-2}	0.233 (0.178)	-0.628 (0.747)	0.568 (0.328)
rmc_{t-3}	-0.157 (0.121)	-0.596 (0.380)	-0.706 (0.240)
π_{t-1}	0.040 (0.033)	0.259 (0.110)	0.052 (0.069)
π_{t-2}	0.062 (0.039)	0.070 (0.131)	0.237 (0.068)
π_{t-3}	-0.043 (0.042)	0.176 (0.105)	0.021 (0.056)
$\Delta^2 reer_{t-1}$	-0.004 (0.034)	0.204 (0.161)	0.113 (0.100)
$\Delta^2 reer_{t-2}$	-0.007 (0.035)	0.003 (0.090)	-0.161 (0.080)
$\Delta^2 reer_{t-3}$	0.046 (0.036)	-0.056 (0.105)	-0.125 (0.077)
exclusion restriction			
(p-value)			
excl. π_t	0.154	0.000	0.002
excl. rmc_t	0.000	0.000	0.000
excl. $\Delta^2 reer_t$	0.499	0.487	0.033
R^2	0.946	0.846	0.191
DW	2.062	1.882	1.980
ARCH(1)	19.015 [0.000]	0.029 [0.864]	0.070 [0.790]

Notes: OLS Estimates of the auxiliary VAR system. The VAR includes a constant. Standard errors in parenthesis. ARCH (1) is an LM test for ARCH effects in squared residuals based on an auxiliary regression of the squared series on a constant and own lagged values. Under the null hypothesis of no ARCH effects up to lag 1, the test statistic is approximately $\chi^2(1)$ distributed. The p-values related to the specification tests are given in brackets.

Table 5: The uncertain fit of the forward-looking NKPC

discount factor		estimate	90% conf. band
$\phi = 0.99$	$\frac{std.dev.(\pi^{fund})}{std.dev.(\pi^{actual})}$	0.608	[0.189 0.867]
	$corr\left(\pi^{fund}, \pi^{actual}\right)$	0.607	[0.404 0.776]
	D	5.912	
$\phi = 0.98$	$\frac{std.dev.(\pi^{fund})}{std.dev.(\pi^{actual})}$	0.603	[0.215 0.797]
	$corr\left(\pi^{fund}, \pi^{actual}\right)$	0.601	[0.413 0.761]
	D	5.567	
$\phi = 0.95$	$\frac{std.dev.(\pi^{fund})}{std.dev.(\pi^{actual})}$	0.589	[0.277 0.698]
	$corr\left(\pi^{fund}, \pi^{actual}\right)$	0.588	[0.432 0.725]
	D	4.881	

Notes: D denotes the average duration (in quarters) of fixed-price Calvo contracts. The parameter γ is estimated by regressing actual inflation on the present-value of the future path of expected real marginal cost. The confidence bands denote the 5% and the 95% fractiles of the distribution of the respective measure of fit across 10000 bias-corrected bootstrap replications.

Table 6: The uncertain fit of the forward-looking NKPC: robustness

VAR model		estimate	90% conf. band
$[rmc_t, \pi_t, i_t]'$	$\frac{std.dev.(\pi^{fund})}{std.dev.(\pi^{actual})}$	0.664	[0.207 0.970]
	$corr(\pi^{fund}, \pi^{actual})$	0.664	[0.368 0.824]
	D	5.449	
$[rmc_t, \Delta nmc_t]'$	$\frac{std.dev.(\pi^{fund})}{std.dev.(\pi^{actual})}$	0.652	[0.197 0.940]
	$corr(\pi^{fund}, \pi^{actual})$	0.651	[0.524 0.781]
	D	5.716	
$[rmc_t, \pi_t]'$ with $d_{1973:2}$ and $d_{1979:3}$	$\frac{std.dev.(\pi^{fund})}{std.dev.(\pi^{actual})}$	0.608	[0.190 0.867]
	$corr(\pi^{fund}, \pi^{actual})$	0.607	[0.404 0.776]
	D	5.912	

Notes: The discount factor is $\phi = 0.99$. D denotes the average duration (in quarters) of fixed-price Calvo contracts. The parameter γ is estimated by regressing actual inflation on the present-value of the future path of expected real marginal cost. The confidence bands denote the 5% and the 95% fractiles of the distribution of the respective measure of fit across 10000 bias-corrected bootstrap replications.

Table 7: The uncertain fit of the NKPC and the role of openness

model		estimate	90% conf. band
$\gamma_{reer} \neq 0$	$\frac{std.dev.(\pi^{fund})}{std.dev.(\pi^{actual})}$	0.871	$\left[\ 0.798 \quad 0.902\ \right]$
	$corr\left(\pi^{fund}, \pi^{actual}\right)$	0.864	$\left[\ 0.791 \quad 0.895\ \right]$
$\gamma_{reer} \equiv 0$	$\frac{std.dev.(\pi^{fund})}{std.dev.(\pi^{actual})}$	0.824	$\left[\ 0.723 \quad 0.863\ \right]$
	$corr\left(\pi^{fund}, \pi^{actual}\right)$	0.818	$\left[\ 0.717 \quad 0.857\ \right]$

Notes: The forecasting VAR with $q = 3$ lag contains $\left[rmc_t, \pi_t, \Delta^2 reer_t\right]'$ for the sample 1972:1 to 2004:1, where $\Delta^2 reer_t$ is the second difference of the real effective exchange rate. The discount factor is $\phi = 0.99$. The confidence bands denote the 5% and the 95% fractiles of the distribution of the measures of fit across 10000 bias-corrected bootstrap replications.

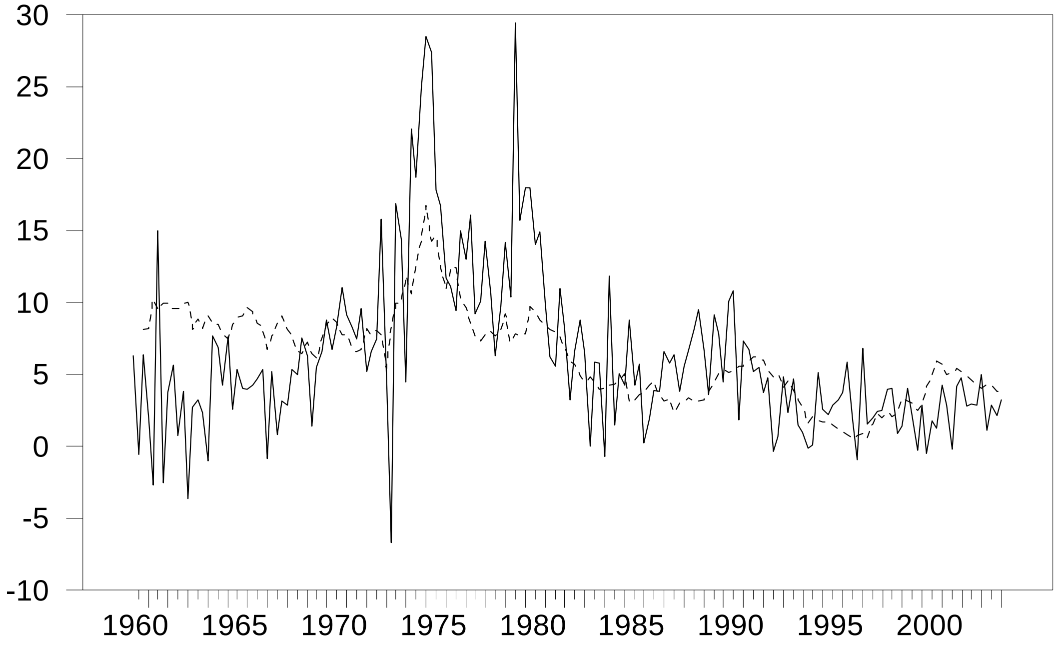

Figure 1: Actual inflation (solid line) and fundamental inflation (dotted line) in the UK (in % p.a.)

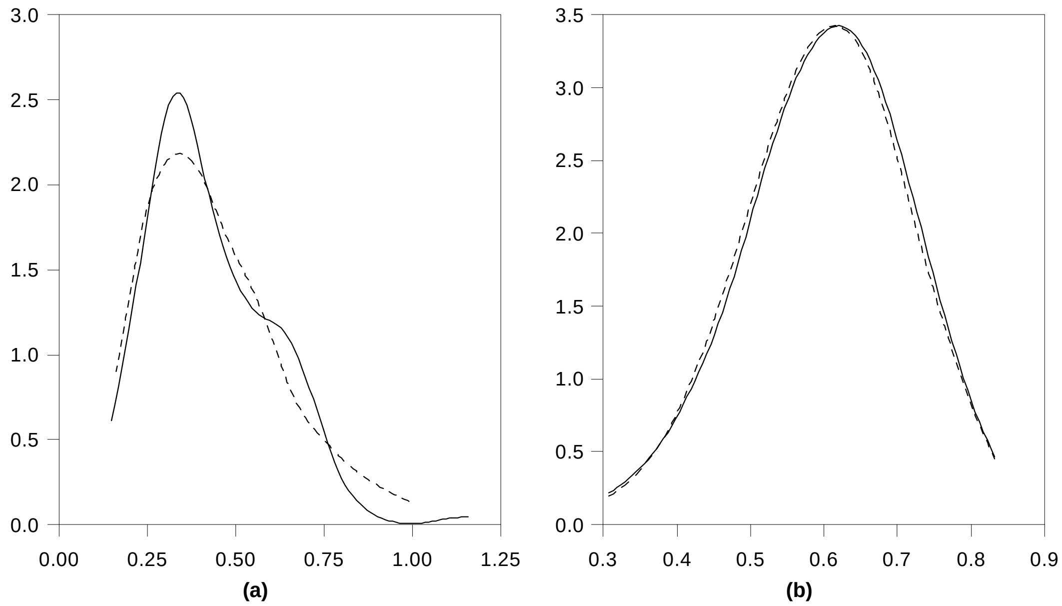

Figure 2: Distribution of (a) ratio of standard deviations and (b) correlation coefficient across bias-corrected (solid line) and standard (dotted line) bootstrap replications for baseline specification with $\phi = 0.99$.