Does the Cost Channel of Monetary Transmission Explain Inflation Dynamics?

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Abstract: This paper proposes a novel approach to empirically assess the impact of the cost channel of monetary transmission on the dynamics of inflation within a New Keynesian Phillips curve framework. According to the cost channel, higher interest rates translate into higher marginal costs of production and, eventually, into higher inflation. We exploit the present-value implications of the model to derive a series of fundamental inflation that is contrasted with actual inflation. We show that the cost channel adds significantly to the explanation of inflation dynamics in forward-looking sticky-price models for the US, the UK, and the Euro area. Moreover, the cost channel can explain inflation episodes that cannot be accounted for by the standard New Keynesian model.

Keywords: cost channel, monetary transmission, inflation dynamics, New Keynesian Phillips Curve, present-value model

JEL classification: E31, E32

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1 Introduction

The transmission of monetary impulses to the real economy and the inflation rate is one of the key questions of macroeconomics. Both researchers and policymakers are interested in the precise nature of the transmission channels. The dominant view is that, by affecting saving and investment decisions of households and firms through changing interest rates, monetary policy primarily affects the demand side of the economy.

Recent empirical research by Barth and Ramey (2001), however, draws attention to the supply side of the economy. These authors identify a supply-side effect of monetary policy that augments the conventional demand-side channel. They refer to a cost channel of monetary policy transmission.

One way to motivate a cost channel is the assumptions that firms hold working capital. To the extend that firms must pay the factors of production before they receive revenues from selling their products, they rely on borrowing from financial intermediaries. Monetary policy therefore impacts on the cost side of the economy. Since this transmission channel rests on the assumption of firms holding working capital, it is sometimes referred to as the working-capital channel of monetary transmission. Consider the case of a monetary thightening that leads to a rise in the short-term interest rate. Higher interest rates translate into higher costs of working capital and induce a rise in inflation. This adverse supply-side effect counteracts the more conventional demand-side effects of monetary policy operating through the IS equation.

Recently, Ravenna and Walsh (2006) and Chowdhury, Hoffmann, and Schabert (2006) integrate a cost channel in an otherwise standard New-Keynesian models of the business cycle and show that the presence of a cost channel is tantamount to a direct effect of interest rates on the inflation rate within a forward-looking Phillips curve. Interest rates affect firms' marginal costs of production, which in turn drive inflation dynamics. Hence, the existence of a cost channel implies a simple extension of the measure of marginal costs. Both paper estimate these augmented Phillips curve equations and find evidence in support of the cost channel.

This paper estimates the impact of a cost channel on inflation dynamics for the US, the UK, and the aggregate Euro area within a forward-looking Phillips curve framework. We test the direct effect of interest rates on inflation, which is the decisive characteristic that constitutes the cost channel. Hence, we refrain from testing the overall effect of interest rate shocks which also propagate through the demand side. While previous contributions to the literature use the GMM estimator, we rely on an alternative approach to assess the empirical fit of forward-looking models for inflation. Campbell and Shiller (1987) originally propose this well-known framework to assess the fit of forward-looking present-value models. This VAR (Vector Autoregression)-based approach is an interesting alternative to estimate inflation Euler equations, since it does not suffer from various problems that notoriously trouble GMM estimates.[2] Most notably, the virtue of this approach is its robustness to omitted information. To assess the explanatory power of the augmented 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 can then investigate whether accounting for a cost channel significantly improves the model's explanatory power. Moreover, we can assess the role of the cost channel in explaining particular episodes of inflation dynamics. The results suggest that the cost channel plays a non-negligible role in explaining inflation and is able to explain certain inflation episodes that cannot be explained by the conventional New Keynesian Phillips curve.

The present paper is organized as follows. Section 2 portrays supply side effects of monetary transmission and incorporates the cost channel into an otherwise standard empirical model of the New Keynesian Phillips curve. Sections 3 introduces the estimation strategy which derives a series of fundamental inflation based on VAR projections. The results are presented and discussed in section 4 while section 5 concludes.

2 The cost channel, sticky prices, and inflation dynamics

In this section we investigate how the presence of supply-side effects of monetary policy shocks affect inflation dynamics. For that purpose, we will proceed in two steps. In a first step, we will review existing empirical evidence of the cost channel of monetary policy transmission. In a second step, we will build the cost channel into a standard reduced-form model of the New Keynesian Phillips curve.

2.1 The cost channel of monetary transmission

Monetary policy shocks are usually thought of as affecting the economy through their effect on aggregate demand. In a widely cited study, Barth and Ramey (2001) provide

[2] See Kurmann (2006) for a detailed treatment of these two approaches.

aggregate and industry-level evidence for the hypothesis that monetary policy impulses also have important supply-side effects that accompany the impact on the demand-side of the economy. They refer to the cost channel of monetary transmission and find that for some industries the cost channel is the primary channel of monetary transmission. The mechanism behind the cost channel is the following. Monetary policy shocks have an impact on firms' costs of production if firms held working capital. Firm that must pay their factors of production before they receive revenues from selling their products need to borrow from financial intermediaries. Thus, a rise in the short-term interest rate directly translates into higher costs of working capital. Even if firms do not hold working capital borrowed from banks, their opportunity costs of internal funds rise with market interest rates. A monetary contraction affects the cost side of the economy and leads to a decline in output through an adverse supply-side effect. Barth and Ramey collect data and show that, on average over the period 1959 through 2000, US firms hold gross (value of inventories plus trade receivables) working capital equivalent to 17 months of sale revenues and net (nets trade payables) working capital equivalent to 11 months of sale revenues.

Barth and Ramey's results found their way into various branches of the literature on monetary policy transmission. Let us briefly survey the most important contributions: Dedola and Lippi (2005) scrutinize industry-specific effects of monetary policy for five OECD countries and 21 manufacturing sectors. They find that output effects of monetary policy reflect both supply and demand side channels of transmission and corroborate the hypothesis of Barth and Ramey (2001) that systematic differences in working capital needs are behind sectoral differences in the responses to monetary policy impulses. Gaiotti and Secchi (2004) use micro data of Italian manufacturing firms to show the existence of a cost channel, whose relevance is proportional to the amount of working capital held by each firm. Two recent contributions use fully-specified Dynamic General Equilibrium Models estimated with Bayesian methods and find conflicting results for the Euro area. While Rabanal (2003) finds that the cost channel is absent in both the US and the Euro area, Adolfson et al. (2005) find supportive evidence for the existence of a cost channel in Europe.

The present paper is closest to the work of Ravenna and Walsh (2006) and Chowdhury, Hoffmann, and Schabert (2006).[3] Both papers assess the impact of the cost channel

[3] Early evidence of a direct effect of changing interest rates on inflation is provided by Seeliger

on inflation dynamics and estimate reduced-form New Keynesian Phillips curves in which the measure of real marginal costs is supplemented by the nominal interest rate. Ravenna and Walsh (2006) provide supportive evidence for the US while Chowdhury, Hoffmann, and Schabert (2004) lend support to the hypothesis of a cost channel in most of the G7 countries. Besides providing empirical evidence, Ravenna and Walsh (2006) work out the implications of the existence of a cost channel for optimal monetary policy. They find that supply-side effects of monetary policy alter optimal policy responses to shock in important ways. Chowdhury, Hoffmann, and Schabert (2006) use the estimated coefficients from the Phillips curve equation to simulate the dynamic adjustment of key macroeconomic variables in the presence of a cost channel.
This paper also investigates the role of the cost channel of interest rate transmission for inflation dynamics. While Ravenna and Walsh (2006) and Chowdhury, Hoffmann, and Schabert (2006) employ the GMM estimator to obtain parameter estimates of the inflation Euler equation, we put forward a VAR-based approach that circumvents some of the fallacies plaguing GMM estimates. In particular, we construct an implied series for the forward-looking terms and contrast model-consistent inflation rates with actually observed inflation rates.

2.2 Inflation dynamics under sticky-prices and the cost channel

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 (NKPC). Consider the case of staggered price setting put forward by Calvo (1983). Each firm adjusts its price during the current period with a fixed probability $1 - \mu$ where $0 < \mu < 1$. It is fairly standard to derive the NKPC (see, e.g. Galí and Gertler, 1999)

$$\pi_t = \phi E_t \pi_{t+1} + \gamma \hat{\varphi}_t \tag{1}$$

with a subjective discount factor ϕ. Inflation (in deviation from the zero inflation steady state) is determined by expected future inflation and current real activity proxied by real marginal costs, where $\pi_t = p_t - p_{t-1}$ is the inflation rate, $\hat{\varphi}_t$ denotes a measure of the deviation of real marginal costs from the steady-state value, and E_t is the expectations operator. The composite parameter γ is a function of the structural

(1974).

model parameters. In particular, the slope coefficient γ is decreasing in the degree of price-stickiness μ. Solving the model forward yields

$$\pi_t = \gamma \sum_{k=0}^{\infty} \phi^k E_t \hat{\varphi}_{t+k} \tag{2}$$

Equation (2) states that the inflation rate at time t is a fraction of the present-value of the expected path of future real marginal costs. Conventionally, real marginal costs are measured by deviations of the labor share of income from its mean.[4] Here we extend the model to a richer supply side.

We now extend the conventional representation of the New Keynesian Phillips curve to allow for interest rates to have an impact of the supply-side of the economy by rasing firms' marginal costs and, thus, the inflation rate. We draw on recent work of Christiano, Eichenbaum, and Evans (1997, 2005), Ravenna and Walsh (2006), Brückner and Schabert (2003), and Surico (2005) who introduce costs of working capital into a general equilibrium model, assuming that factors of production have to be paid before the proceeds from the sale of output are received. Here, labor is the only factor of production. Let L_t denote employment and W_t the nominal wage rate. Firms must borrow an amount $W_t L_t$ from financial intermediaries, such that firms' total costs are given by

$$R_t^{\chi} W_t L_t \tag{3}$$

where R_t is the gross nominal interest rate. The parameter $\chi > 0$ measures the strength of the cost channel. If $\chi = 0$, the cost channel is absent and total costs equal the wage bill.

Let's assume a production technology with fixed capital-input, e.g. $Y_t = A_t L_t$. Nominal marginal costs are then given by

$$\left(\frac{\partial (R_t^{\chi} W_t L_t)}{\partial L_t}\right)\left(\frac{\partial Y_t}{\partial L_t}\right)^{-1} = \frac{R_t^{\chi} W_t}{A_t} \tag{4}$$

Dividing this expression by the price level P_t yields real marginal costs φ_t as the ratio of the real wage rate to the marginal product of labor

$$\varphi_t = \frac{R_t^{\chi} W_t}{P_t A_t} = \frac{R_t^{\chi} W_t L_t}{P_t Y_t} = R_t^{\chi} S_t \tag{5}$$

[4]For empirical evidence of the present-value implications of this model with marginal costs approximated by the labor share see Galí, Gertler, and López-Salido (2001), Kurmann (2003), and Tillmann (2005).

where $S_t = \frac{W_t L_t}{P_t Y_t}$ is the labor share of income. The marginal costs of hiring labor are the labor share multiplied by the gross nominal interest rate. Linearizing this expression gives a simple representation of deviations of marginal costs from their mean in terms of the deviations of the labor share and deviations of the gross interest rate from their respective steady-state values

$$\hat{\varphi}_t = \hat{s}_t + \chi \hat{R}_t \tag{6}$$

Thus, in the presence of a cost channel of monetary transmission, changes in interest rates propagate into the cyclical dynamics of marginal costs and, via (1) or (2), into inflation dynamics.[5]

3 The empirical approach

The empirical approach exploits the forward-looking nature of inflation dynamics to derive a series of fundamental inflation, i.e. an inflation rate that is observable if the model is correct, that can be compared with actually observed inflation. Essentially, the approach follows Campbell and Shiller's (1987) seminal contribution. While their present-value analysis is restricted to one variable being driven by one single forcing variable, the analysis presented in this section formulates the inflation rate as the present-value of two driving variables. We follow Ravenna and Walsh (2006) and restrict the analysis to a forward-looking formulation of the inflation adjustment equation, i.e. the New Keynesian Phillips curve.

3.1 Forecasts from VAR projections

Remember that inflation is the present-value of expected real marginal costs. Taking account of the cost channel by combining equations (2) and (6) thus leads to the following present-value relation for the inflation rate

$$\pi_t = \phi E_t \pi_{t+1} + \gamma \left(\hat{s}_t + \chi \hat{R}_t \right) \tag{7}$$

$$= \gamma \sum_{k=0}^{\infty} \phi^k E_t \left(\hat{s}_{t+k} + \chi \hat{R}_{t+k} \right) \tag{8}$$

[5] The parameter χ can alternatively be interpreted as measuring the pass-through from policy rates to actual lending rates, see Chowdhury et al. (2006).

or, alternatively,

$$\pi_t = \gamma_s \sum_{k=0}^{\infty} \phi^k E_t \hat{s}_{t+k} + \gamma_R \sum_{k=0}^{\infty} \phi^k E_t \hat{R}_{t+k} \tag{9}$$

The coefficients γ_s and γ_R are reduced-form parameters to be estimated. Hence, we do not restrict the slope coefficient of the labor share and the interest rate terms to be identical. Previous contributions, e.g. Sbordone (2002 and 2005), Kurmann (2005), and Tillmann (2005), study only the present-value of the labor share as a driving variable of inflation, i.e. they assume $\gamma_R = 0$. Hence, in this paper the inflation rate is, in addition to the annuity value of the labor share, driven by the present-value of interest rates.

We assume that the information contained in a small atheoretical three-dimensional VAR is a subset of the market's full information set. Let us consider a simple VAR(q) representation with $q = 1$ for expositional purposes.

$$\begin{bmatrix} \hat{s}_{t+1} \\ \pi_{t+1} \\ \hat{R}_{t+1} \end{bmatrix} = \begin{bmatrix} \psi_{11} & \psi_{12} & \psi_{13} \\ \psi_{21} & \psi_{22} & \psi_{23} \\ \psi_{31} & \psi_{32} & \psi_{33} \end{bmatrix} \begin{bmatrix} \hat{s}_t \\ \pi_t \\ \hat{R}_t \end{bmatrix} + \begin{bmatrix} u_{1t+1} \\ u_{2t+1} \\ u_{3t+1} \end{bmatrix} \tag{10}$$

where the vector containing the labor share, the inflation rate, and the interest rate is regressed on own lags. We can then use the 3×3 coefficient matrix to generate forecasts of each endogenous variable. Since the restriction to a first-order VAR is certainly too restrictive, the ultimate choice of the lag order is determined by appropriate statistical information criteria to be discussed below. The model can, for the general case of a VAR(q) in companion form, more compactly be written as

$$\mathbf{Z}_{t+1} = \mathbf{A}\mathbf{Z}_t + \mathbf{\Gamma}_{Z_{t+1}} \tag{11}$$

with

$$\mathbf{Z}_t = \left[\hat{s}_t, ..., \hat{s}_{t-q+1}, \pi_t, ..., \pi_{t-q+1}, \hat{R}_t, ..., \hat{R}_{t-q+1} \right]' \tag{12}$$

where $\mathbf{\Gamma}_{Z_{t+1}} = [u_{1t,}0, ..., 0, u_{2t}, 0, ..., 0, u'_{3t}, 0..., 0]$ represents innovations to agents' information set and $\mathbf{A}$ is the $3q \times 3q$ companion matrix. Hence, $\mathbf{Z}_t$ is an approximation to agents' information set, which can be described by current and past realizations of the labor share, the inflation rate, and the interest rate.

As mentioned before, 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 information available. The reason is that under the null hypothesis the inflation rate represents agents' best forecast of the present-value of future interest rates and labor shares no matter what other information they have.

Forecasts of the endogenous variables based on the econometrician's information set $\mathcal{I}_t$ are given by the multi-period forecasting formula

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

Using the matrix version of the summation formula for geometric series, the vector of the discounted future paths of the variables can be calculated as

$$\sum_{k=0}^{\infty}\phi^k E_t\mathbf{Z}_{t+k} = \left(\mathbf{I}-\phi\mathbf{A}\right)^{-1}\mathbf{Z}_t \tag{14}$$

where $\mathbf{I}$ is the 3×3 identity matrix. Let $\mathbf{e}'_s$ and $\mathbf{e}'_R$ be selection vectors that single out the present-value of future labor shares and of future interest rates, respectively. 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

$$\pi_t^{fund} = \gamma_s\mathbf{e}'_s\left(\mathbf{I}-\phi\mathbf{A}\right)^{-1}\mathbf{Z}_t + \gamma_R\mathbf{e}'_R\left(\mathbf{I}-\phi\mathbf{A}\right)^{-1}\mathbf{Z}_t \tag{15}$$

Under the restriction $\gamma_s = \gamma_R = \gamma$, i.e. $\chi = 1$, fundamental inflation simplifies to

$$\pi_t^{fund} = \gamma\left(\mathbf{e}'_s + \mathbf{e}'_R\right)\left(\mathbf{I}-\phi\mathbf{A}\right)^{-1}\mathbf{Z}_t \tag{16}$$

To calculate this series of fundamental inflation from the VAR coefficients and the data, we need to fix the discount factor ϕ. In accordance to the vast literature we choose to calibrate $\phi = 0.99$. However, all results are robust to other choices of the discount factor as long as the discount factor is close to but below unity. Note that the approach pursued here is similar to Bergin and Sheffrin's (2000) analysis of the present-value model of the current account. These authors include the present-value of future interest rates as an additional driving variable for the current account in an equation similar to (9).

Rudd and Whelan (2006) propose to infer the coefficients γ_s and γ_R from a regression of actual inflation on the present-values of the driving variables.[6] We follow their suggestion and will assess the fit of the Calvo model by comparing actual inflation with fundamental inflation that results from this estimation exercise. If the model provides an accurate description of inflation, these two series must coincide.[7]

We plot actual inflation against fundamental inflation and compute standard measures of fit. Following the literature on present-value models, Kurmann (2005) 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 deviations 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.

If the cost channel contributes to the explanation of inflation dynamics, we should observe that the empirical fit increase once we allow $\gamma_R \neq 0$. In this case the present-value of future interest rates enters the equation for fundamental inflation for a given information set $\mathbf{Z}_t$. Note that the forecasting relation between interest rates and inflation does not stem from the conventional Fisher equation. Rather, the New Keynesian model posits that to the extent that inflation is forward looking, future interest rates determine current inflation, while the Fisher relation specifies expected inflation as a determinant of current interest rates.

3.2 The role of estimation uncertainty

Note that using VAR projections disguises the degree of estimation uncertainty. The VAR companion matrix $\mathbf{A}$ that is needed to derive fundamental inflation according to (15) contains only point estimates. 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

[6] The slope coefficients γ_s and γ_R are allowed to vary acrosss bootstrap replications, in contrast to e.g. Kurmann (2005) and Tillmann (2005), to allow for changing weights of the two forcing variables across bootstrap replications.

[7] Due to that fact that the $\hat{\gamma}$ coefficients are OLS regressors, the ratio of standard deviations is positive and (in the absence of small sample problems) equal to the correlation coefficient $corr(\pi_t^{fund}, \pi_t)$ and therefore bounded by unity.

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 future labor shares and interest rates and regress actual inflation on the present-value of these two forcing variables to infer the slope coefficients. Finally, the ratio of standard deviations and the correlation coefficient are 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.[8] 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 (2005) and apply Kilian's bias-corrected bootstrap algorithm. Basically, he proposes to replace the estimated VAR coefficients by bias-corrected estimates before running the bootstrap to compute the measures of fit. Details about this bias-correction can be found in Kilian (1998). The algorithm also includes a procedure for shrinking the bias estimates in case the bias-corrected VAR estimates imply that the resulting VAR becomes nonstationary. 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 assess the role of the cost channel of monetary transmission for the US, the UK, and the aggregate Euro area. Details about the data set and the definition of the variables are given in the appendix. Figure (1) depicts the two variables that drive inflation dynamics in a forward-looking model augmented with the cost channel, i.e. the labor share of income and the short term interest rate.

[8] By definition, this bootstrap approach respects the boundedness of the correlation coefficient. Furthermore, this approach allows for skewness and does not impose symmetry.

4.1 The role of the cost channel

To estimate the auxiliary VAR system, we have to specify a lag order q. Based on standard selection criteria and specification tests, whose results are documented in table (1), we decide to include 4 lags for the US, 3 lags for the UK, and 5 lags for the Euro area. Given the specified lag order, the VAR system containing $\left[\hat{s}_t, \pi_t, \hat{R}_t\right]'$ and a constant is estimated and the series of fundamental inflation is derived as explained above. This series is contrasted with actually observed inflation by means of the correlation coefficient and the ratio of standard deviations. Under the null hypothesis, $\pi_t^{actual} = \pi_t^{fund}$; hence $\rho(\pi_t^{actual}, \pi_t^{fund}) = 1$ and $\sigma(\pi_t^{fund})/\sigma\left(\pi_t^{actual}\right) = 1$, where $\rho(\cdot)$ is the correlation coefficient and $\sigma(\cdot)$ is the standard deviation.

We compare both series under two different scenarios. Under the first scenario, the cost channel is present, hence inflation is driven not only by the discounted present-value of marginal costs, but also by the discounted present-value of future interest rates. Under the second scenario, the cost channel is absent and inflation is solely driven by the present-value of the labor share. This scenario corresponds to a model with $\gamma_R = 0$. A significantly better empirical fit under the first scenario would lend support to the empirical relevance of the cost channel. Note that the two specifications, i.e. with and without the cost channel, differ with respect to the number of degrees of freedom. Since our measure of fit, i.e. the correlation coefficient, corresponds to the square root of the coefficient of determination from the regression of inflation on the present values of the driving variables, we will also cross-check the results and compare a degrees of freedom-adjusted R^2 across specifications.

Figures (2), (3), and (4) compare the series of fundamental inflation with actually observed inflation rates for each country under either scenario. We find that fundamental inflation tracks the behavior of actual inflation quite well for all economies considered here. Below we will interpret the difference across the two scenarios. Table (2) presents baseline estimation results for the three economies.

In the US, the model with a cost channel replicates actual inflation surprisingly well. The correlation and the standard deviations ratio between fundamental and actual inflation are around 0.96. Without the cost channel of interest rate transmission, however, both measures of fit drop to 0.85. Note that the inclusion of the cost channel means a significant improvement in the model's empirical performance, since the value of 0.96 lies outside the 90% confidence bands around measures of fit for the case without the cost channel, i.e. $0.96 \notin [0.375, 0.930]$. The confidence bands denote the 5% and the 95% fractiles of the distribution of the measures of fit across 10000 bias-corrected bootstrap replications. Furthermore, the model's reliability gains support because confidence bands substantially narrow once we allow for the presence of the cost channel.

In the UK, the empirical fit also improves once the cost channel is present. The correlation between actual and fundamental inflation increases from 0.58 without the cost channel to 0.78 in a scenario with a cost channel. However, the confidence bands around the measures of fit under the no-cost channel scenario also cover the value of 0.78. Thus, the rise in the model's explanatory power is economically significant, but not statistically.

Allowing for the presence of the cost channel also increases the model's performance with respect to explaining inflation in the Euro area. The measures of fit significantly increase from 0.85 without a cost channel to 0.95 with a cost channel. Note that the confidence bands narrow drastically in the presence of a cost channel. Figures (5), (6), and (7) graph the distribution of the measures of fit for each economy under both scenarios considered. In all economies, the estimated correlation coefficient and the ratio of standard deviations are much more reliable once we take account of the cost channel.

Table (4) reports results obtained under the restriction $\chi = 1$. For the US, the cost channel remains a significant determinant of inflation dynamics. For the UK and the Euro area, the empirical performance increases if we allow for the cost channel. However, the effect is smaller than in the unrestricted case.

The correlation coefficient between actual and fundamental inflation corresponds to the square root of the R^2 of the auxiliary regression that relates inflation to the two present values of the driving variables. Therefore, we can check whether the loss of one degree of freedom in the cost channel specification affects the results. For that purpose, we compare the square roots of the degrees of freedom-adjusted R^2 across specifications in table (3). This measure corresponds to the correlation between actual and fundamental inflation with a penalty for loosing one degree of freedom if the cost channel is present. It turns out that the cost channel remains a significant transmission channel in all three samples.

4.2 Explaining inflation episodes

Given that the cost channel significantly contributes to the explanation of inflation dynamics, we can now take a closer look at the series of actual and fundamental inflation presented in figures (2), (3), and (4). Interestingly, the figures allow us to assess the role of the cost channel over time as it explains phases of divergence of fundamental inflation from actual inflation.

Let us consider the case of the US. The no-cost channel scenario provides a reasonable description of inflation, see the lower panel of figure (2). However, fundamental inflation falls short of actual inflation during the Volcker disinflation in 1979-82 and severely exceeds actual inflation in the last years of the sample. Once we take account of the cost channel, see panel (a), these episodes of divergence disappear. Hence, high interest rates during the Volcker experiment add to fundamental inflation via the supply-side and reconcile actual and fundamental inflation in this period. In the last years of the sample, when interest rates were at an unprecedentedly low level and the deviation of the labor share from its mean was high, the negligence of the cost channel leads fundamental inflation to exceed actual inflation. Thus, lower interest rates in the last years of the sample period translate into lower inflation rates by easing cost pressure. Note that these considerations only pertain to the direct effect of interest rates on inflation, not to the overall effect that includes important demand-side channels. Taking account of the effect of low interest rates on the supply side of the US economy brings fundamental inflation back to actually observed inflation.

In the UK, the presence of the cost channel also bridges sustained divergences of fundamental inflation from actual inflation. However, these episodes are not as striking as in the US or in the Euro area. In the Euro area, low interest rates in the period 1999-2003 also give rise to a series of fundamental inflation that persistently exceeds actual inflation in the no-cost channel scenario, see panel (b) of figure (4). Once we take account of supply-side effects of low interest rates and allow for the cost channel, fundamental inflation closely corresponds to actual inflation, see panel (a). Again, fundamental inflation falls short of actual inflation during the period of high interest rates around 1980 if we neglect the cost channel. With the cost channel, fundamental inflation tracks actual inflation throughout the entire sample period.

4.3 Lending rates versus policy-controlled rates

All estimates presented thus far are based on a VAR system that includes the policy-controlled short-term interest rate. The theory sketched above, however, is based on firms' financing costs. A primary determinant of these costs is the interest rate banks charge for loans to firms. To the extend that the pass-through from the central bank's policy rate to actual lending rates is incomplete, the lending rate serves as a more reliable indicator of the cost channel effect on firms' costs.[9] In a set of additional estimates we therefore replace the short-term interest by an indicator of the economy-wide bank lending rate in an otherwise identical model. Due to the lack of time series data on lending rates for the aggregate Euro area, these additional estimates are restricted to the cases of the US and the UK. Figure (8) depicts both interest rate series and visualizes remarkable differences in interest rate behavior.
The results from the lending rate-based specification are reported in table (5). The cost channel significantly adds to the explanation of inflation dynamics in the US and, in contrast to the previous specification based on the policy rate, also in the UK. With the cost channel, the variance of fundamental inflation explains 86 percent of actual inflation volatility. Without the cost channel, the model can only explain 65 percent. Note that the standard deviations ratio lies outside the confidence band $[0.371, 0.844]$ and, therefore, confirms the significant role of the cost channel in the UK. Compared to the policy rate-based specification reported above, the confidence bands around both measures of fit substantially narrow when the lending rate is used in the VAR system. Figures (9) and (10) document the time series of actual and fundamental inflation with and without the cost channel obtained from the VAR model based on the lending rate. Evidently, allowing for the cost channel leads to a very accurate replication of actual inflation dynamics.

To sum up, all results support the notion that the cost channel of interest rate transmission matters for inflation dynamics. Interest rate movements appear to impact directly on firms' marginal costs of production and, eventually, on inflation dynamics. We can corroborate the findings of Ravenna and Walsh (2006) and Chowdhury, Hoffmann, and Schabert (2006) within a different and arguably more robust empirical

[9] Note that ample empirical evidence points to an incomplete and sluggish response of market interest rates to policy rates. See Hofmann and Mizen (2004) for a recent empirical investigation using UK data.

framework. Moreover, we can identify specific time periods in which the cost channel appears to be of particular relevance for the model's explanatory power. Finally, we find that the cost channel matters in Europe as well as in the US, which stands in stark contrast to Rabanal (2003), who finds the cost channel to be absent in both economies. Hence, the fact the US is best described as a market-based financial system whereas continental Europe is closer to a bank-based financial system does not seem to affect the relevance of the cost channel.[10]

5 Conclusions

The cost channel of monetary transmission describes the supply-side effect of interest rates on firms' cost structure. If firms have to lend from financial intermediaries to pay the factors of production in advance, interest rates impact on their costs of production and, hence, on inflation. This paper provided supportive empirical evidence for a direct effect of interest rates on firms' marginal costs and, thus, on inflation within a forward-looking Phillips curve framework. The model generates a series of fundamental inflation that tracks actual inflation well. Once we allow for the presence of a cost channel, this explanatory power further improves. Moreover, the cost channel helps to bridge the divergence between actual and model-consistent inflation rates throughout various episodes.

Certainly, this analysis provides evidence only for a very basic form of the cost channel. Given that financial intermediaries play a crucial role in propagating interest rate shocks to the cost side of the economy and, finally, to inflation, a more detailed analysis of the transmission from policy-controlled interest rates to market interest rates might be fruitful. In particular, financial frictions as proposed by the financial-accelerator or credit channel literature, see e.g. Oliner and Rudebusch (1996) or Bernanke, Gertler, and Gilchrist (1999), affect inflation dynamics in the presence of a cost channel and multiply monetary policy impulses. We leave these aspects for further research.

[10] Kaufmann and Scharler (2005) show theoretically that the characteristics of the financial system play only a minor role for the mechanism of the cost channel.

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6 Appendix: The data set

We use quarterly data for the US, the UK, and the Euro area. For all countries, the inflation rate is measured as the annualized quarterly change of the (log) GDP deflator (in percentage points). The labor share of income $\hat{s}_t$ (in percentage point deviation from its mean) is

$$\hat{s}_t = \log\left(\frac{WL}{PY}\right)_t - mean$$

Where WL is compensation to employees, Y is real GDP and P is the price level. The data sources are the following:

US: The sample covers 1960:1-2004:1. All series apart from the short-term interest rate are taken from the OECD's Main Economic Indicators database. The short-term interest rate is the three-months Treasury-bill rate obtained from the FRED database of the St. Louis Federal Reserve Bank. The lending rate (Prime Rate) is also taken from the IMF's International Financial Statistics database.

UK: The sample covers 1960:1-2004:1. All series apart from the short-term interest rate are taken from the OECD's Main Economic Indicators database. The short-term interest rate is the Treasury-bill rate obtained from the IMF's International Financial Statistics database. The lending rate (available only from 1966:3 onwards) is also taken from the IMF's International Financial Statistics database.

Euro area: The sample covers 1970:1-2003:4. All series are taken from the ECB's Area Wide Model database. The short-term interest rate is the weighted short-term interest rate of the member countries ("STN" in the database).

Table 1: Choosing the lag order of the auxiliary VAR

		AIC(q)	SC(q)	HQ(q)	LM(1)	LM(4)
US	$q=1$	7.69	7.86	7.76	31.64***	31.76***
	$q=2$	7.63	7.96	7.77	43.53***	23.33***
	$q=3$	7.45	7.95	7.65	30.48***	17.77**
	$q=4^{\#}$	7.39	8.05	7.66	13.08	13.54
	$q=5$	7.42	8.25	7.76	15.53*	10.37
UK	$q=1$	11.45	11.67	11.54	51.57***	16.06*
	$q=2$	11.32	11.71	11.48	25.74***	10.01
	$q=3^{\#}$	11.30	11.87	11.53	6.60	10.35
	$q=4$	11.36	12.10	11.66	13.18	13.37
	$q=5$	11.36	12.27	11.73	26.12***	39.97***
EMU	$q=1$	7.59	7.85	7.70	67.78***	46.02***
	$q=2$	7.23	7.69	7.41	22.29***	25.02***
	$q=3$	7.20	7.86	7.47	43.34***	20.62**
	$q=4$	7.07	7.93	7.42	24.20***	11.02
	$q=5^{\#}$	7.05	8.11	7.49	6.24	12.54

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 trivariate VAR of order q. These criteria compare the goodness of the fit of maximum likelihood estimations and correct for the loss of degrees of freedom when additional lags are added. LM(h) is a multivariate Lagrange-Multiplier test for residual correlation up to order h. Under the null hypothesis of no serial correlation of order h, the LM statistic is asymptotically χ^2 distributed with 4 degrees of freedom. A significance level of 1%, 5%, and 10% is indicated by ***, **, and *. The chosen lag order is indicated by #.

Table 2: The fit of the NKPC and the role of the cost channel I

	model	measure of fit	estimate	90% conf. band
US	with cost channel (γ_s and γ_R unrestricted)	$\sigma(\pi_t^{fund})/\sigma\left(\pi_t^{actual}\right)$	0.960	$\left[\begin{array}{cc} 0.687 & 0.969 \end{array}\right]$
		$\rho\left(\pi_t^{actual}, \pi_t^{fund}\right)$	0.959	$\left[\begin{array}{cc} 0.686 & 0.968 \end{array}\right]$
	without cost channel ($\gamma_R \equiv 0$)	$\sigma(\pi_t^{fund})/\sigma\left(\pi_t^{actual}\right)$	0.847	$\left[\begin{array}{cc} 0.375 & 0.930 \end{array}\right]$
		$\rho\left(\pi_t^{actual}, \pi_t^{fund}\right)$	0.846	$\left[\begin{array}{cc} 0.375 & 0.930 \end{array}\right]$
UK	with cost channel (γ_s and γ_R unrestricted)	$\sigma(\pi_t^{fund})/\sigma\left(\pi_t^{actual}\right)$	0.785	$\left[\begin{array}{cc} 0.667 & 0.848 \end{array}\right]$
		$\rho\left(\pi_t^{actual}, \pi_t^{fund}\right)$	0.784	$\left[\begin{array}{cc} 0.666 & 0.847 \end{array}\right]$
	without cost channel ($\gamma_R \equiv 0$)	$\sigma(\pi_t^{fund})/\sigma\left(\pi_t^{actual}\right)$	0.581	$\left[\begin{array}{cc} 0.276 & 0.790 \end{array}\right]$
		$\rho\left(\pi_t^{actual}, \pi_t^{fund}\right)$	0.581	$\left[\begin{array}{cc} 0.275 & 0.789 \end{array}\right]$
EMU	with cost channel (γ_s and γ_R unrestricted)	$\sigma(\pi_t^{fund})/\sigma\left(\pi_t^{actual}\right)$	0.950	$\left[\begin{array}{cc} 0.923 & 0.961 \end{array}\right]$
		$\rho\left(\pi_t^{actual}, \pi_t^{fund}\right)$	0.944	$\left[\begin{array}{cc} 0.917 & 0.955 \end{array}\right]$
	without cost channel ($\gamma_R \equiv 0$)	$\sigma(\pi_t^{fund})/\sigma\left(\pi_t^{actual}\right)$	0.852	$\left[\begin{array}{cc} 0.660 & 0.943 \end{array}\right]$
		$\rho\left(\pi_t^{actual}, \pi_t^{fund}\right)$	0.846	$\left[\begin{array}{cc} 0.656 & 0.937 \end{array}\right]$

Table 3: The fit of the NKPC and the role of the cost channel II

	model	measure of fit	estimate	90% conf. band
US	with cost channel (γ_s and γ_R unrestricted)	$\sqrt{R^2_{dof-adj.}}$	0.956	$\left[\begin{array}{cc} 0.683 & 0.968 \end{array}\right]$
	without cost channel ($\gamma_R \equiv 0$)	$\sqrt{R^2_{dof-adj.}}$	0.845	$\left[\begin{array}{cc} 0.388 & 0.929 \end{array}\right]$
UK	with cost channel (γ_s and γ_R unrestricted)	$\sqrt{R^2_{dof-adj.}}$	0.802	$\left[\begin{array}{cc} 0.701 & 0.863 \end{array}\right]$
	without cost channel ($\gamma_R \equiv 0$)	$\sqrt{R^2_{dof-adj.}}$	0.525	$\left[\begin{array}{cc} 0.125 & 0.796 \end{array}\right]$
EMU	with cost channel (γ_s and γ_R unrestricted)	$\sqrt{R^2_{dof-adj.}}$	0.943	$\left[\begin{array}{cc} 0.915 & 0.954 \end{array}\right]$
	without cost channel ($\gamma_R \equiv 0$)	$\sqrt{R^2_{dof-adj.}}$	0.845	$\left[\begin{array}{cc} 0.653 & 0.937 \end{array}\right]$

Table 4: The fit of the NKPC and the role of the cost channel III

	model	measure of fit	estimate	90% conf. band
US	with cost channel ($\gamma_R \equiv 1$)	$\sigma(\pi_t^{fund})/\sigma\left(\pi_t^{actual}\right)$	0.933	[0.463 0.957]
		$\rho\left(\pi_t^{actual}, \pi_t^{fund}\right)$	0.932	[0.462 0.957]
	without cost channel ($\gamma_R \equiv 0$)	$\sigma(\pi_t^{fund})/\sigma\left(\pi_t^{actual}\right)$	0.847	[0.375 0.930]
		$\rho\left(\pi_t^{actual}, \pi_t^{fund}\right)$	0.846	[0.375 0.930]
UK	with cost channel ($\gamma_R \equiv 1$)	$\sigma(\pi_t^{fund})/\sigma\left(\pi_t^{actual}\right)$	0.743	[0.454 0.820]
		$\rho\left(\pi_t^{actual}, \pi_t^{fund}\right)$	0.742	[0.453 0.818]
	without cost channel ($\gamma_R \equiv 0$)	$\sigma(\pi_t^{fund})/\sigma\left(\pi_t^{actual}\right)$	0.581	[0.276 0.790]
		$\rho\left(\pi_t^{actual}, \pi_t^{fund}\right)$	0.581	[0.275 0.789]
EMU	with cost channel ($\gamma_R \equiv 1$)	$\sigma(\pi_t^{fund})/\sigma\left(\pi_t^{actual}\right)$	0.886	[0.752 0.948]
		$\rho\left(\pi_t^{actual}, \pi_t^{fund}\right)$	0.881	[0.747 0.942]
	without cost channel ($\gamma_R \equiv 0$)	$\sigma(\pi_t^{fund})/\sigma\left(\pi_t^{actual}\right)$	0.852	[0.660 0.943]
		$\rho\left(\pi_t^{actual}, \pi_t^{fund}\right)$	0.846	[0.656 0.937]

Table 5: The fit of the NKPC and the role of the cost channel (based on lending rate)

	model	measure of fit	estimate	90% conf. band
US	with cost channel	$\sigma(\pi_t^{fund})/\sigma\left(\pi_t^{actual}\right)$	0.961	$\left[\begin{array}{cc} 0.733 & 0.970 \end{array}\right]$
	(γ_s and γ_R unrestricted)			
		$\rho\left(\pi_t^{actual}, \pi_t^{fund}\right)$	0.960	$\left[\begin{array}{cc} 0.733 & 0.969 \end{array}\right]$
	without cost channel	$\sigma(\pi_t^{fund})/\sigma\left(\pi_t^{actual}\right)$	0.770	$\left[\begin{array}{cc} 0.332 & 0.902 \end{array}\right]$
	($\gamma_R \equiv 0$)			
		$\rho\left(\pi_t^{actual}, \pi_t^{fund}\right)$	0.769	$\left[\begin{array}{cc} 0.332 & 0.901 \end{array}\right]$
UK	with cost channel	$\sigma(\pi_t^{fund})/\sigma\left(\pi_t^{actual}\right)$	0.858	$\left[\begin{array}{cc} 0.772 & 0.907 \end{array}\right]$
	(γ_s and γ_R unrestricted)			
		$\rho\left(\pi_t^{actual}, \pi_t^{fund}\right)$	0.833	$\left[\begin{array}{cc} 0.749 & 0.880 \end{array}\right]$
	without cost channel	$\sigma(\pi_t^{fund})/\sigma\left(\pi_t^{actual}\right)$	0.647	$\left[\begin{array}{cc} 0.371 & 0.844 \end{array}\right]$
	($\gamma_R \equiv 0$)			
		$\rho\left(\pi_t^{actual}, \pi_t^{fund}\right)$	0.647	$\left[\begin{array}{cc} 0.360 & 0.820 \end{array}\right]$

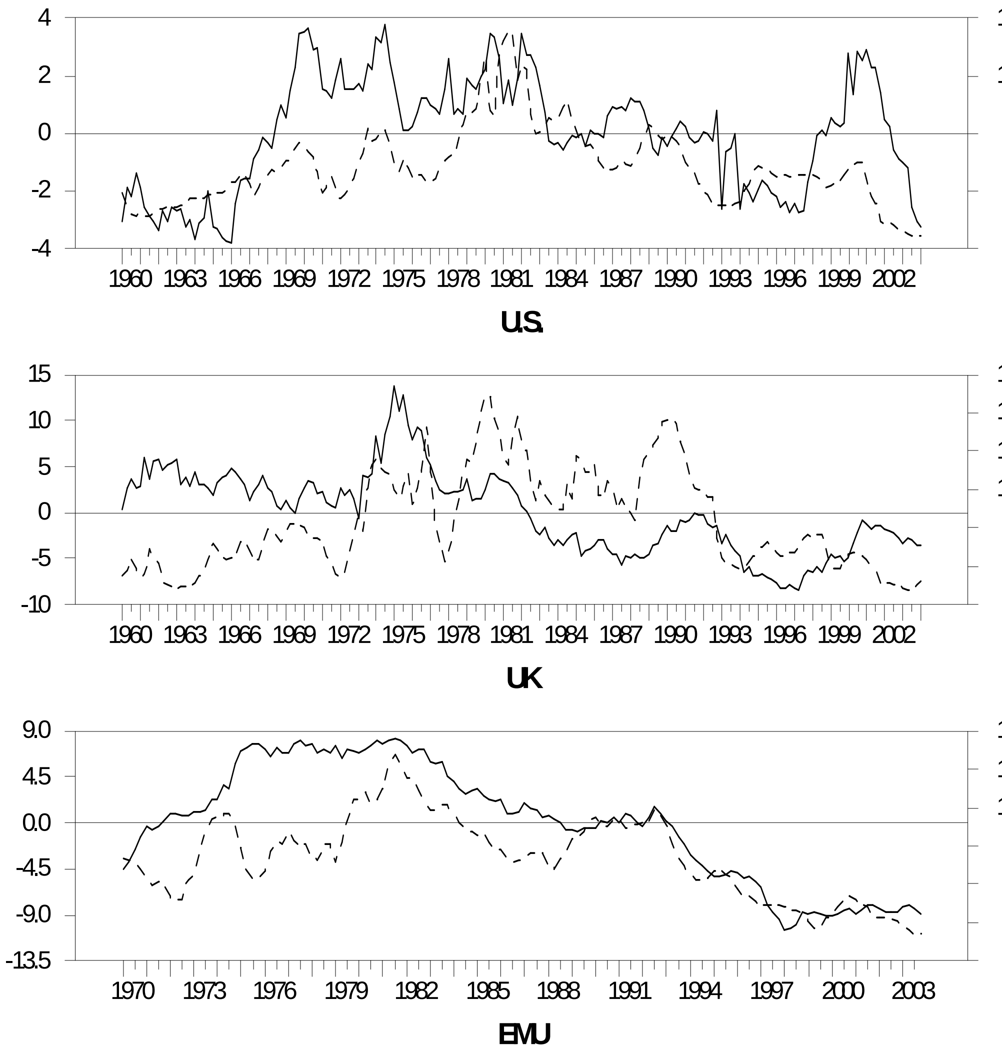


Figure 1: Labor shares (solid line, left scale) and short-term interest rates (dotted line, right scale)

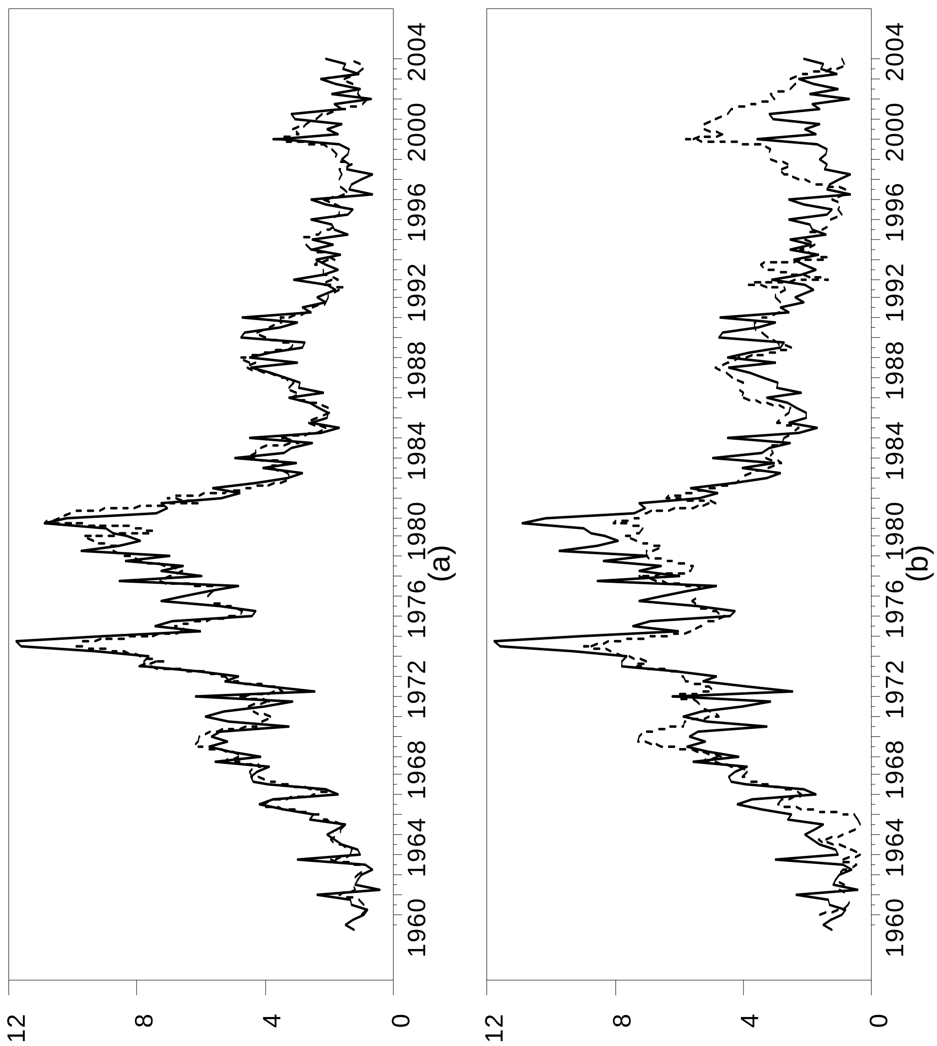


Figure 2: US - Actual (solid line) and fundamental inflation (dotted line) with (a) the cost channel and without (b) the cost channel in % p.a.

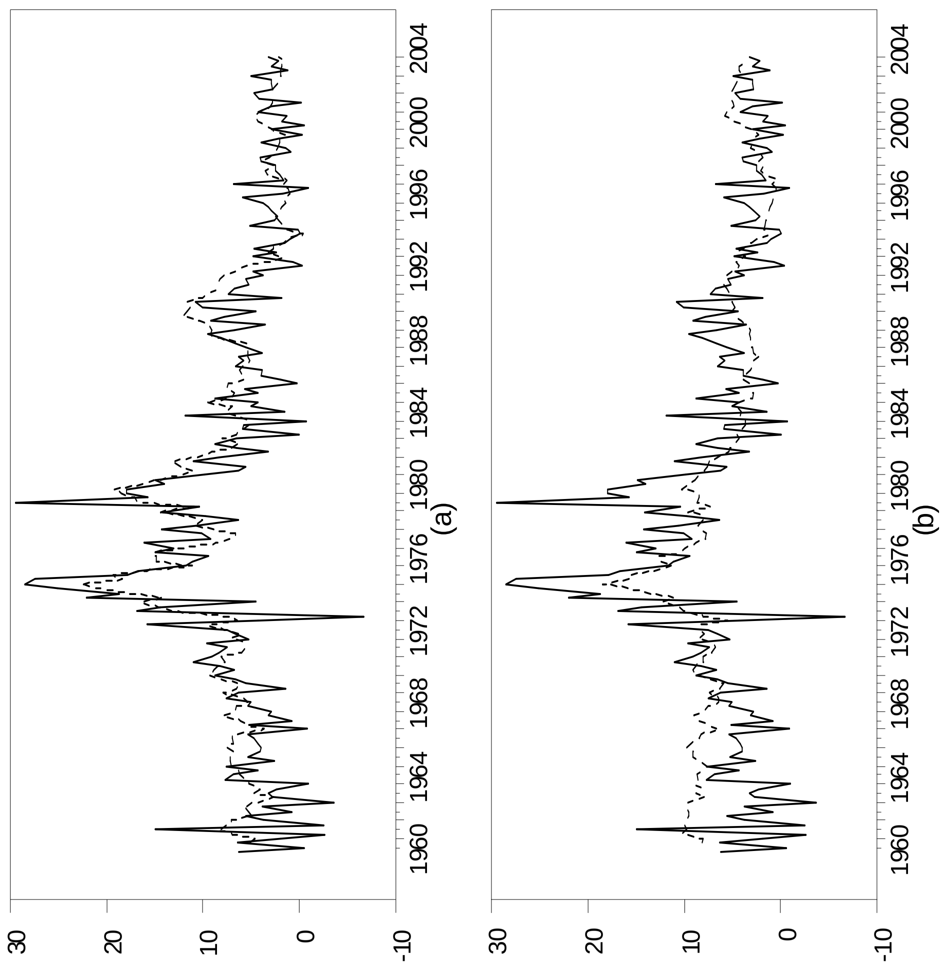


Figure 3: UK - Actual (solid line) and fundamental inflation (dotted line) with (a) the cost channel and without (b) the cost channel in % p.a.

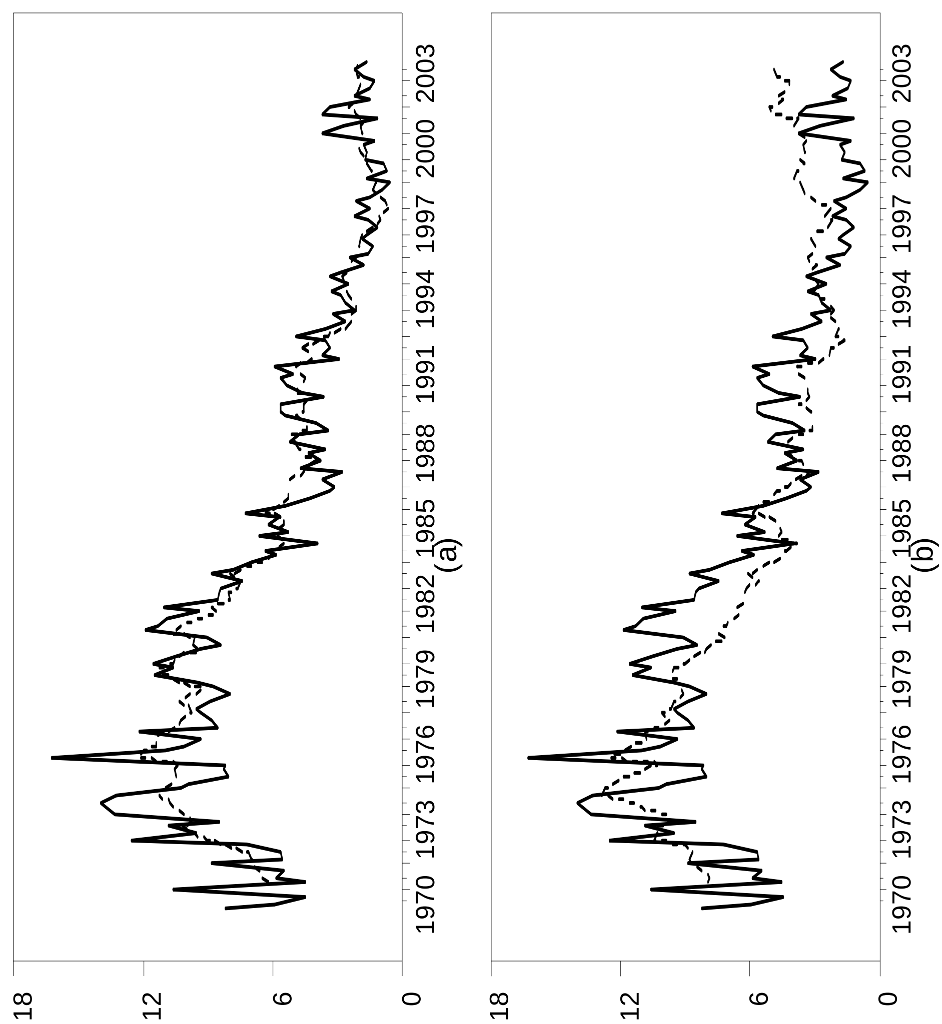


Figure 4: EMU - Actual (solid line) and fundamental inflation (dotted line) with (a) the cost channel and without (b) the cost channel in % p.a.

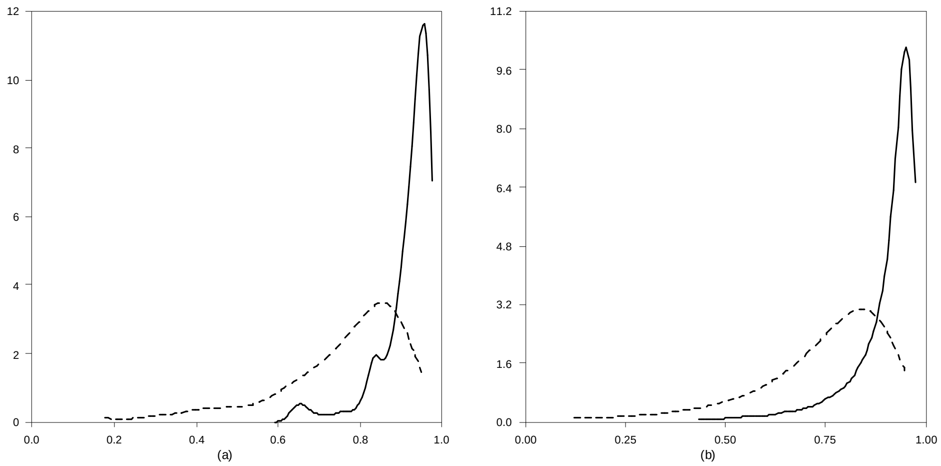


Figure 5: US- Distribution of (a) ratio of standard deviations and (b) correlation coefficient across bias-corrected bootstrap replications for model with (solid line) and without (dotted line) cost channel

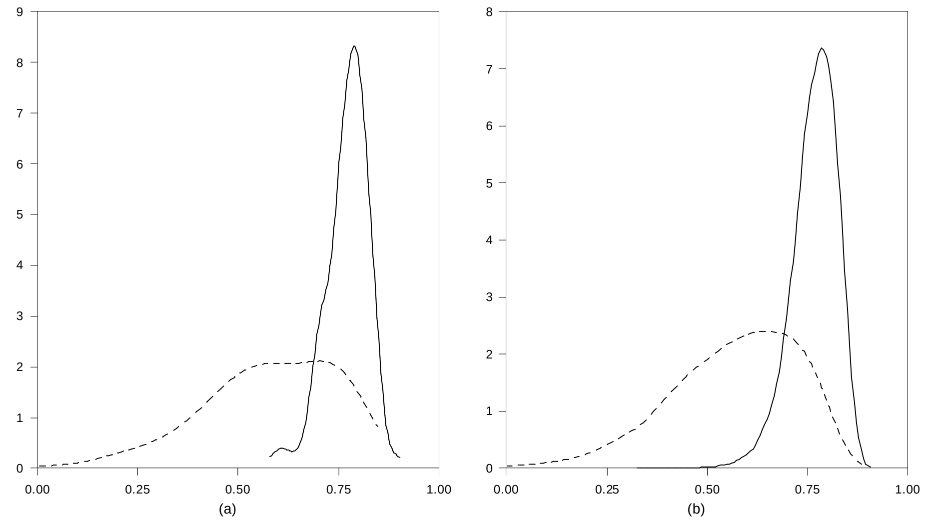


Figure 6: UK- Distribution of (a) ratio of standard deviations and (b) correlation coefficient across bias-corrected bootstrap replications for model with (solid line) and without (dotted line) cost channel

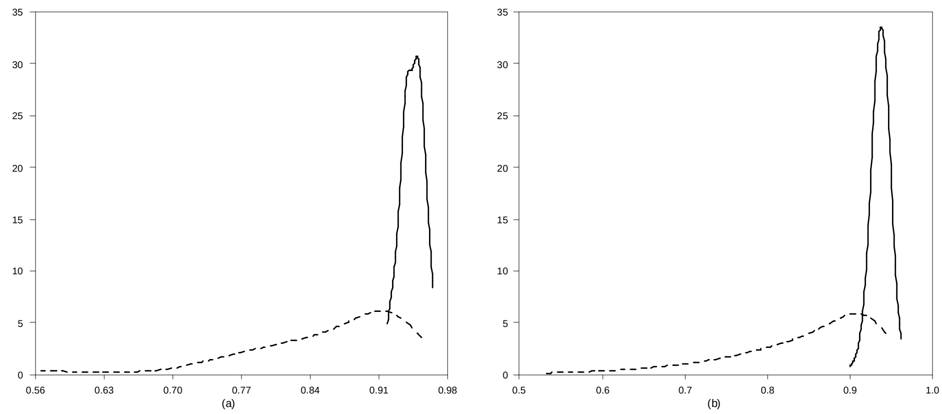
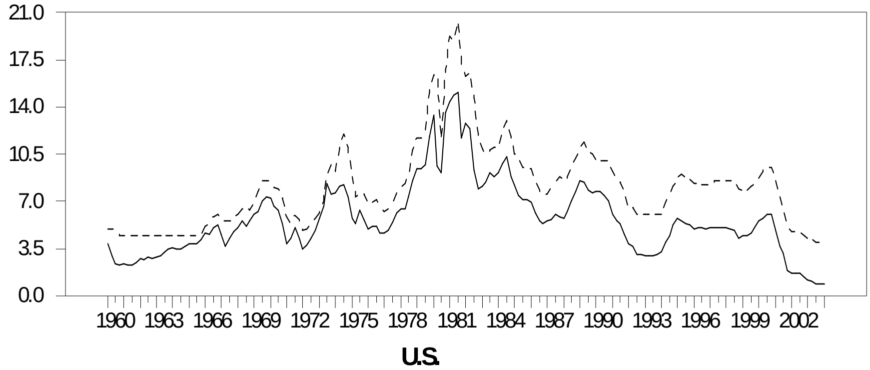


Figure 7: EMU- Distribution of (a) ratio of standard deviations and (b) correlation coefficient across bias-corrected bootstrap replications for model with (solid line) and without (dotted line) cost channel



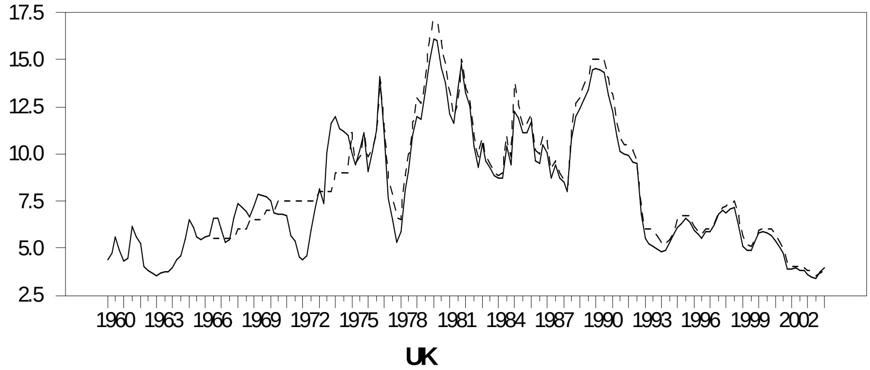


Figure 8: Policy-controlled short-term interest rates (solid line) and lending rates (dotted line)

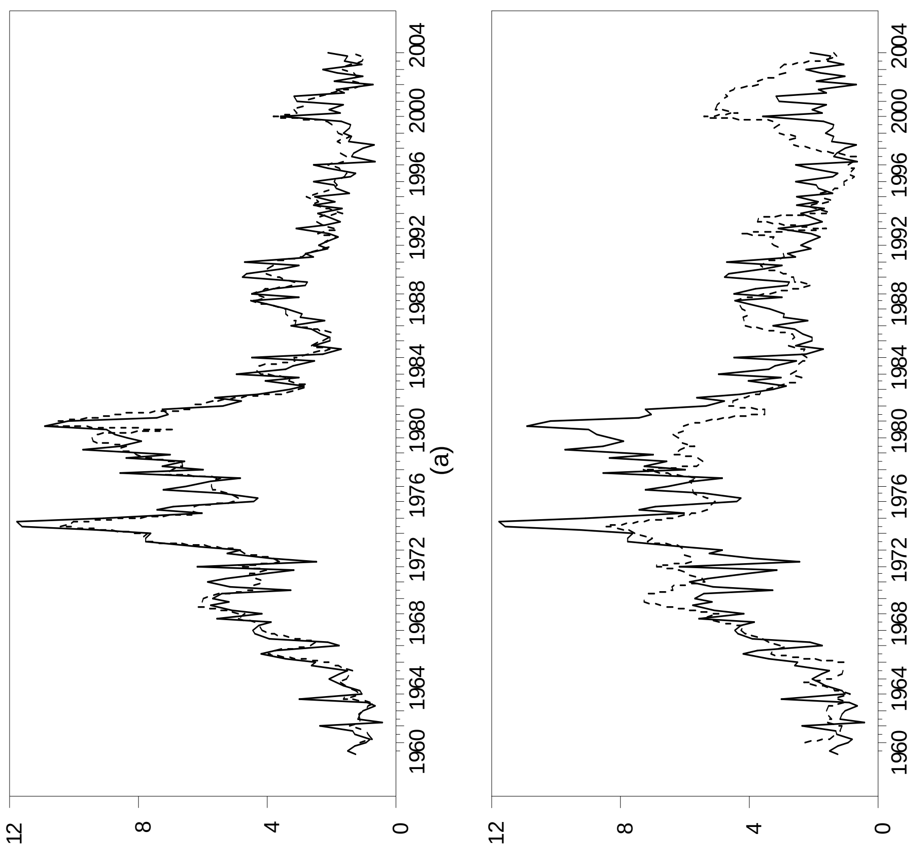


Figure 9: US - Actual (solid line) and fundamental inflation (dotted line) with (a) the cost channel and without (b) the cost channel in % p.a (based on lending rate)

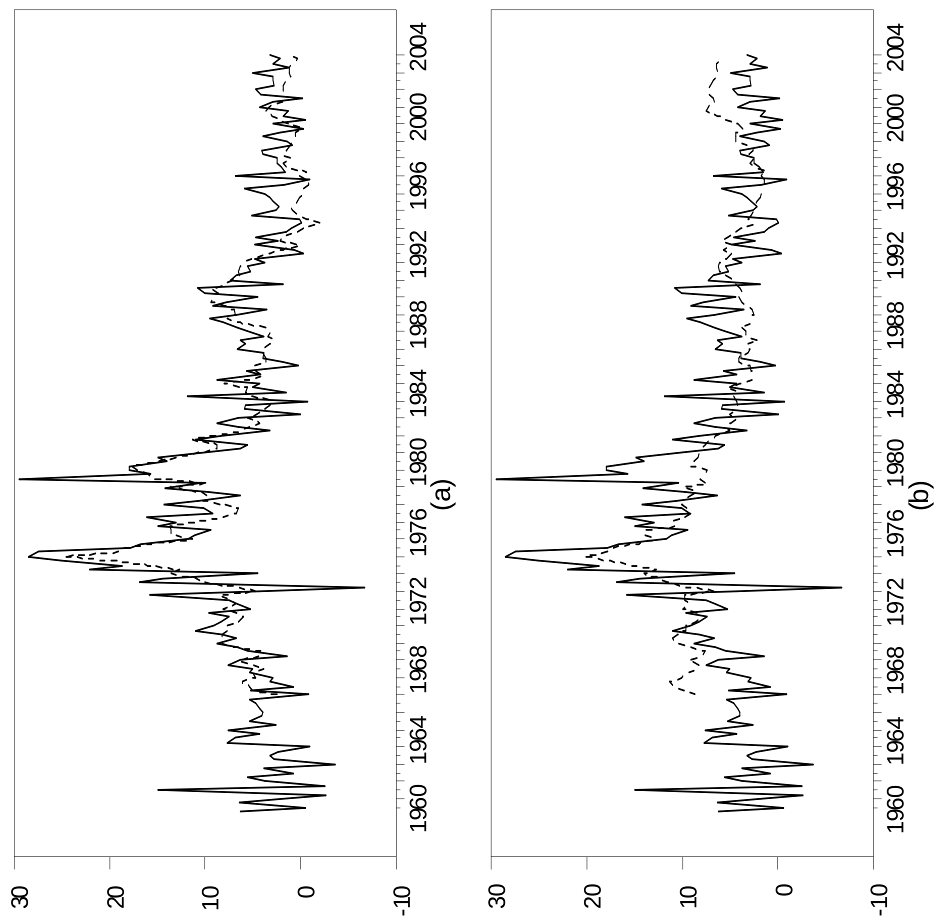


Figure 10: UK - Actual (solid line) and fundamental inflation (dotted line) with (a) the cost channel and without (b) the cost channel in % p.a (based on lending rate)