Inflation and relative-price changes in the Swedish economy

BY BENGT ASSARSSON

Bengt Assarsson works in the Monetary Policy Department, Sveriges Riksbank, and in the Department of Economics, Uppsala University.

Shocks to diverse markets generate changes in relative prices – some nominal prices rise, others fall. If all prices were perfectly flexible, such price movements would largely cancel out and leave inflation unaffected. In practice, however, certain prices tend to be sticky because price adjustments are costly. In such cases, prices are adjusted quickly only in the event of large shocks, not when the shocks are small. The positively skewed distribution of relative-price changes then results in a temporary increase in inflation. This has been the case in Sweden and explains a large part of the short-run fluctuations in CPI inflation over the past quarter-century. The variance and skewness of relative-price changes also explain shortcomings in existing models of inflation.

I am grateful for comments on an earlier version from Per Jansson, Magnus Jonsson and Staffan Viotti, as well as for data provided by Micke Andersson, Mårten Löf and Josef Svensson.

Rigidities in connection with major and minor shocks

A familiar phenomenon in the analysis of price-setting and inflation is the sizeable rigidities that occur in price adjustments and the marked differences in this respect between firms. Due to these rigidities, various market conditions may change without leading to the price adjustment that should normally occur. A basic explanation for these rigidities is that the costs associated with altering prices may make it more profitable to abstain from or postpone an adjustment. The cost of price adjustment makes a price change more probable if the market shock is large than if it is small. If a few large shocks that motivate relative-price increases are countered by numerous small shocks that call for relative-price reductions, it may be mainly the increases that actually occur as nominal-price adjustments. Such a positively skewed distribution of relative-price changes implies increased inflation, while a distribution that is negatively skewed lowers inflation. When this theory was put forward and tested in the mid

1990s, it provided a better explanation of inflation's historical path in the United States[1].

I test whether the variance and skewness in the distribution of relative-price changes can improve traditional models of inflation.

In this article I describe the theory and apply it to data for the Swedish economy for the period 1980–2003. The aim is to study whether the variance and skewness in the distribution of relative-price changes can improve traditional models of inflation. For this purpose I extend traditional price equations or Phillips curves to include these new measures and examine the effects. I also use the data on variance and skewness in an attempt to explain residuals or forecasting errors, that is, unexplained inflation, in other models of inflation.

The empirical results show that variance and skewness in relative-price changes make an important contribution to the explanation of the development of inflation in Sweden during the period analysed here. The new measures improve conventional price equations and indicate that several models which have been used in the past are probably misspecified.

Relative-price changes and inflation

The larger the shock, the greater the probability of a nominal-price change.

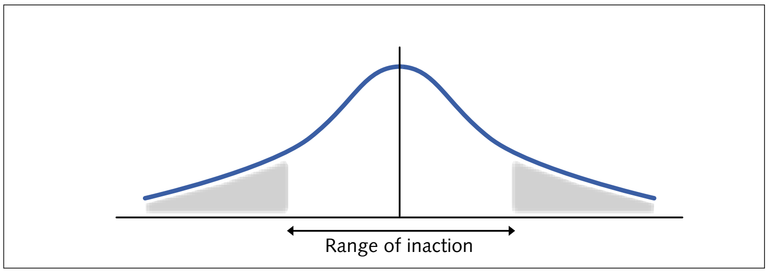
If a shock (for example, a supply shock) occurs in a market and generates an increase in supply relative to demand, the relative price will tend to fall and an equilibrium with a lower price will be established. If no shocks occur in other markets and there are no price rigidities, the nominal price will then fall as well. But if the price is nominally rigid because an adjustment entails a cost for the firm, the shock will not necessarily lead to a nominal price fall; that will depend on whether or not the benefit of a lower price – of moving towards the optimal price – exceeds the cost of adjusting the price. The larger the shock, the greater the probability of a price adjustment. The full range of relative shocks includes a number of large positive and large negative shocks that result in a lower and a higher price, respectively, as well as numerous small shocks that do not generate price adjustments because in these cases the benefit of a price adjustment does not outweigh its cost.

Figure 1 presents a symmetric distribution of relative shocks that is matched by the distribution of firms' *desired* relative-price changes. The shaded segments of the distribution represent the shocks which are so large that they lead to price adjustments. These segments can be called *action ranges*. The unshaded segment contains the shocks in the distribution that do *not* generate any price changes; this can be called the *range*

[1] See Ball & Mankiw (1994, 1995).

of inaction. Note that the mean value of the relative shocks is (by definition) zero.[2]

Figure 1. A symmetric distribution of relative shocks



If the distribution is symmetric, as in Figure 1, there are equal numbers of large positive and large negative shocks. That is not the case in Figure 2, where the distribution is positively skewed. This means that the unusually large positive shocks outnumber the unusually large negative shocks in the action ranges. The positive skewness therefore leads to an increased rate of inflation. A negative skewness, as in Figure 3, has the opposite effect.

A positively skewed distribution means that the unusually large positive shocks outnumber the unusually large negative shocks, which can lead to an increased rate of inflation.

Figure 2. A positively skewed distribution of relative shocks

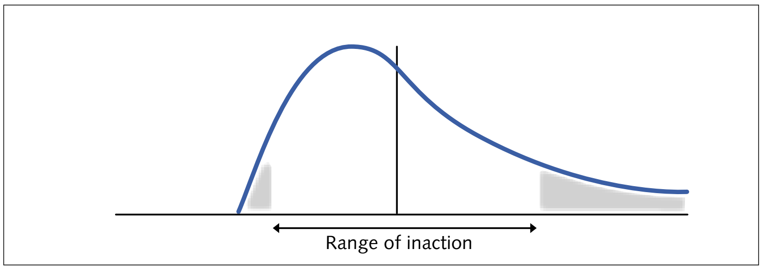
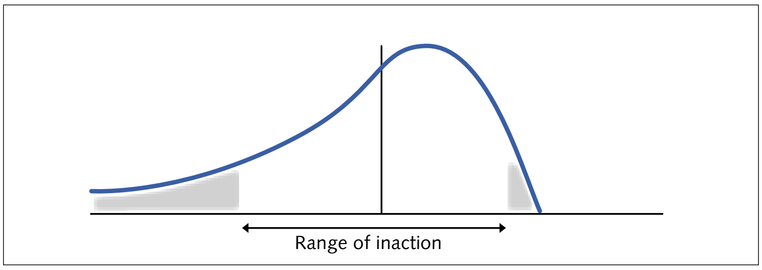


Figure 3. A negatively skewed distribution of relative shocks



2 See the appendix, where inflation as well as the variance and skewness in relative-price changes are defined.

The distribution of relative shocks also represents firms' desired relative-price changes, which are not observable. Due to the cost of adjusting prices, the corresponding nominal-price changes will not all occur immediately. Using data simulations, Ball & Mankiw found a clear correlation between desired and actual relative-price changes, which means that the skewness of observed, actual relative-price changes can be used in the empirical analysis.[3]

The positive relationship between the skewness of relative-price changes and inflation is due to price rigidities.

The positive relationship between the skewness of relative-price changes and inflation is due to price rigidities whereby price adjustment to shocks is not complete in the short run. In time, however, the price adjustments will be made even if the shocks are small, making it reasonable to suppose that in the next period the skewness will affect inflation negatively instead of positively. So in a dynamic econometric model there should be a negative correlation between inflation and the lagged skewness.

Over a longer period, skewness has been found to be positive in a number of countries.

Over a longer period, skewness has been found to be positive in a number of countries. Trend inflation can account for this, that is, inflation being positive in the long run. Relative-price reductions can then be achieved by keeping the nominal-price constant. This can be seen as a range of action to the left in the distribution (the negative tail) that is smaller than the range of action to the right (the positive tail).

It can be mentioned that the observed relationship between skewness and inflation also has some alternative explanations that are not necessarily based on price rigidities.[4]

If the distribution is skewed to the right, an increased variance will magnify the positive skewness and lead to a further increase in inflation.

Variance is a measure of the dispersion in a distribution. Variance and skewness can co-vary and affect inflation.[5] Figure 4 illustrates this: with the symmetric distribution in the upper figure, an increased variance extends the two tails equally; if the distribution is skewed to the right – as in the lower figure – on the other hand, an increased variance magnifies the positive skewness and thereby leads to a further increase in inflation.

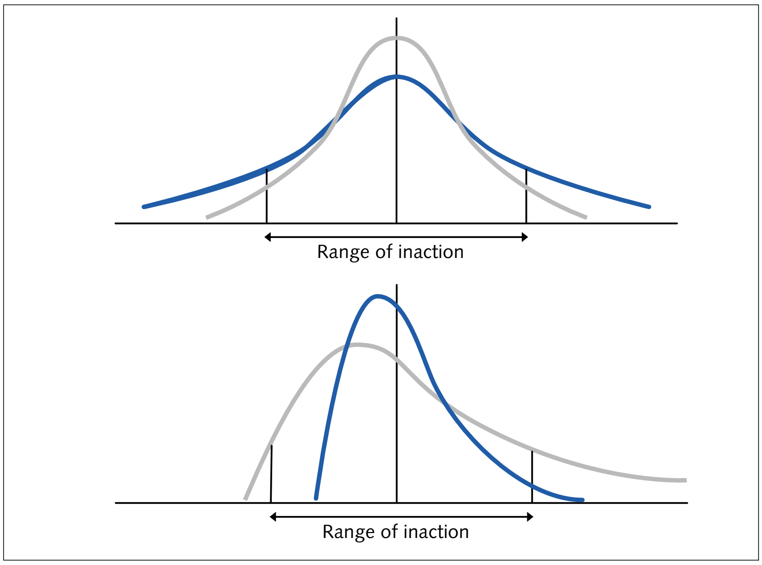
---

[3] See Ball & Mankiw (1995), where the distribution of price-adjustment costs was assumed to follow the exponential distribution and the distribution of relative shocks/desired price changes follows a normal distribution with skewness/symmetry. The assumptions were chosen so that the maximum deviation between desired and actual prices was 15 per cent. An inaction range of 15 per cent is consistent with empirical studies on the frequency of price adjustments: Apel, Friberg & Hallsten (2001), Assarsson (1989) and Blinder (1991). Ball & Mankiw's simulations demonstrated a monotonic positive relationship between the desired and the actual price changes.

[4] Productivity shocks can generate a positive relationship between skewness and inflation in some models: Aukrust (1970) and Balke & Wynne (1996). The business cycle can influence inflation and skewness in the same direction, see Assarsson (2003). The relationship may also have a purely statistical explanation, see Ball & Mankiw (1999), Bryan & Cecchetti (1999a) and Bryan & Cecchetti (1999b).

[5] See Ball & Mankiw (1995).

Figure 4. Relationship between variance and skewness in the distribution of relative shocks



The positive relationship between inflation and the variance in relative-price changes has been thoroughly explored in the literature. The causal relationship goes from variance to inflation according to some theories and in the opposite direction or through a third variable according to other theories.[6]

Phillips-curves with measures of variance and skewness

Let us now see how the insights acquired so far can be incorporated in what is otherwise a traditional econometric analysis of price-setting and inflation. In a market with perfect competition, a firm is not in a position to set the price, which cannot deviate from the established market price. In a market with limited competition, a firm can chose a certain price and observe how it influences demand and thereby the firm's profit. The less competition there is, the higher will be the price that is set in the market. In this way, a price that is optimal for the firm in relation to demand and the competition is established and applies for the long run provided market conditions do not change.

A price that is optimal for the firm in relation to demand and the competition is established for the long run.

[6] Inflation affects the variance in relative-price changes in Assarsson (1986), Cukierman (1979), Cukierman (1982), Cukierman (1983), Cukierman & Wachtel (1982), Lucas (1973), Parks (1978) and Sheshinski & Weiss (1977). The variance in relative-price changes affects inflation due to asymmetric price adjustment in Tobin (1972).

The optimal price depends on the firm's marginal cost. Costs are determined by input prices on for instance raw materials, energy, wages and capital costs or rents. Costs are also related, of course, to the volume of output. The marginal cost (the cost of producing an additional unit) normally depends on the same factors.[7]

The cost of changing the price may cause the firm to refrain from an adjustment despite a change in the marginal cost.

The cost of changing the price may cause the firm to refrain from a price adjustment despite a change in the marginal cost. But how can this be taken into account when explaining the path of inflation in price equations or Phillips curves? Doing so has proved difficult in practice. When a price adjustment is being considered on account of increased costs, the firm looks ahead and tries to assess what the marginal cost is likely to be in the future. If the cost increase is expected to persist, the price eventually will be raised more or less immediately. However, such forward-looking price equations (Keynesian Phillips curves) have proved difficult to handle empirically,[8] partly because the expected future marginal costs are not observable. Instead I shall test Ball & Mankiw's theory about the effect of variance and skewness in relative-price changes to explain the path of inflation in Sweden.

To this end, a number of alternative Phillips curves that include measures of variance and skewness are specified. In order to avoid unduly narrow specifications, I have chosen to present the results with a model that is so general that several alternative specifications can be derived as special cases. The calculations show that the effects of the measures of variance and skewness are robust for alternative specifications. The general model is:

$$\pi_t = \beta_0 + \beta_1 \Delta w_t + \beta_2 \Delta \rho_t + \beta_3 \pi_{t-1} + \beta_4 \left(U_t - \bar{U}_t\right) + \beta_5 \Delta p_t^{oil} +$$
$$\beta_6 \Delta p_t^{metals} + \beta_7 \Delta p_t^{food(a)} + \beta_8 \Delta p_t^{food(b)} + \beta_9 g_t$$

where inflation is dependent on wage changes w_t, capital costs ρ_t, lagged inflation[9] π_{t-1}, the output or unemployment gap $U_t - \bar{U}_t$ (where $\bar{U}_t$ is equilibrium unemployment) and supply or price shocks, which are price changes for oil (π^{oil}), metals (π^{metals}), food products from industrialised countries, ($\pi^{food(a)}$) and food products from developing countries ($\pi^{food(b)}$). g_t is a productivity shock measured as a Solow residual.[10] β_i are parameters to be estimated.

[7] A mathematical description is given in the appendix to this article.
[8] See Bårdsen, Jansen & Nymoen (2002).
[9] Price inflation is dependent on wage inflation, which depends in turn on expected inflation. It follows that inflation in period t-1 can mirror wage inflation in period t.
[10] Inflation and the skewness in relative-price changes can both be driven by productivity shocks; Balke & Wynne (2000). By including productivity changes, one can obtain some indication of how they affect the equation compared with the skewness measure.

This equation is then augmented with measures of variance and skewness (VS in the following):

$$\beta_{10}\sigma_t^3 + \beta_{11}\sigma_{t-1}^3 + \beta_{12}\sigma_t^2 + \beta_{13}\sigma_t^3\sigma_t^2$$

which are thus intended to catch the effects of skewness, lagged skewness, variance and the interaction of variance and skewness. In accordance with the theory above, the coefficients are expected to have the following signs: $\beta_{10} > 0$, $\beta_{11} < 0$, $\sigma_t^2 > 0, \beta_{13} > 0$. Various special cases of Phillips curves can be derived as restrictions on the parameters and the effects of the VS measures can be studied on each of the curves. For example, the restrictions $(\beta_0, \beta_1, \beta_2, \beta_9, \beta_{10}, \beta_{11}, \beta_{12}, \beta_{13}) = 0$ and $\beta_3 = 1$ lead to the Phillips curve $\pi_t = \pi_{t-1} + \beta_4\left(U_t - \bar{U}_t\right) + \text{price shocks}$ which can be given a microeconomic foundation in terms of unsynchronised labour market contracts.[11]

One way of assessing the VS measures' ability to explain inflation's historical path is to analyse whether these measures can explain forecasting errors (residuals) generated by inflation models that are used in practice. I have therefore generated or obtained residuals from some models:

One way of assessing the VS measures' ability to explain inflation's historical path is to analyse whether these measures can explain forecasting errors generated by inflation models.

– an unrestricted vector autoregression (VAR) for short-run inflation with the variables CPI, wage costs, capital costs, productivity, import prices, GDP and the interest rate
– A Bayesian VAR model that is one of the models used in the Riksbank[12] and is a Bayesian variant of the so-called FOA-VAR model[13]
– actual residuals from predictions by the National Institute of Economic Research[14]

If the models are specified correctly, there should be no patterns in the residuals obtained with them. Thus, in a regression with the residuals as dependent variable, no independent variables should be significant and R^2 should be low. I attempt to explain the residuals with the VS variables. Significance and high R^2 suggest that it is just these variables which are lacking in the models from which the residuals come.

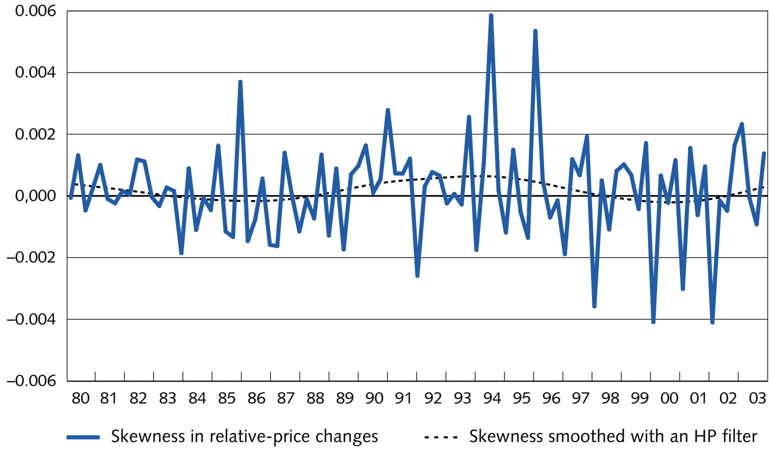
11 See Taylor (1980).
12 See Andersson (2004); these residuals were provided by Michael K. Andersson.
13 See Jacobson et al. (1999, 2001).
14 Forecasting errors provided by Mårten Löf.

Inflation 1980–2003

Skewness contributed to the high rate of inflation 1993–94; after that the contribution from skewness decreased and lowered the rate of inflation in the late 1990s.

Ball & Mankiw (1995) studied the effects on price equations for American producer prices in the period 1949–89 on an annual basis, that is, for a total of 41 observations. As the analysis concerns price stickiness in the short run, it is perhaps more appropriate to use more frequent data. I therefore chose quarterly data based on a decomposition of the CPI into 71 items for the period 1980–2003.[15] Figure 5 illustrates the skewness in the relative-price changes. Price changes are measured as the logarithmic difference between quarters.[16] A smoothed measure (using an HP filter) is also shown in the figure.[17] An upward tendency can be noted in the second half of the 1980s. In the period 1994–2000, when Sweden had adopted the policy of inflation targeting, skewness decreased. So according to the theory, skewness contributed to the high rate of inflation 1993–94; after that the contribution from skewness decreased and lowered the rate of inflation in the late 1990s.

Figure 5. Skewness in relative-price changes 1980-2003
Per cent



Note. Skewness is defined in the Appendix to this article.

Source: Statistics Sweden, consumer price index.

[15] Analyses at Uppsala University show that a further decomposition into up to about 350 representative goods gives similar results; Pettersson & Wikström (2004).

[16] The logarithmic difference multiplied by 100 approximates the percentage change.

[17] The HP filter is a method for calculating the trend in a time series, see Hodrick & Prescott (1997). The smoothing was done simply to give a better illustration of developments in the period studied here. The smoothed series was not used in the regressions.

Can the VS variables explain inflation?

The econometric calculations were done to analyse the extent to which the skewness and variance in relative-price changes can explain the path of inflation. They can also be used to study whether the effects are those the theory predicts. Sweden abandoned the fixed exchange rate in November 1992 and then moved successively to an inflation-targeting monetary policy. Nominal prices are probably stickier when inflation is low than when it is high, since with low inflation, price adjustments are less beneficial (shocks bring the prices closer to the optimal levels). I therefore tested whether the equations changed between these two periods.

The VS variables are the most important factors for explaining the variation in the rate of inflation.

Column (i) in Table 1 presents results of estimations based on the general equation, which includes input prices, unemployment, some dummy variables for extreme values and the VS variables in accordance with the theory.[18] The other columns contain the results with different specifications, that is, excluding in turn input prices (ii), unemployment (iii), price shocks and productivity changes (iv) and the VS measures (v). The first thing to note is the positive correlation between inflation and skewness and the negative sign of the lagged effect, which agrees with the theoretical predictions.[19] The positive effect of variance on inflation is also in line with the theory, whereas the negative effect of the interaction of variance and skewness is not. However, this effect is only statistically significant in specification (ii) in Table 1. In specifications (ii) – (v) the exclusion of different variables reduces the general model and one can see how this affects the correlation coefficient R^2 or the standard error[20] in the equation. That provides an indication of each variable's importance in explaining the variation in the rate of inflation. The results show that the distributional measures are most important. The difference between the observed rate of inflation and the rate predicted by the model averages ±0.50 per cent (the standard error in the regression) but grows to ±0.76 per cent when the VS variables are excluded. When input prices, unemployment and price shocks together with productivity shocks, respectively, are excluded, the standard error grows considerably less, to around 0.56 per cent in each case. Thus, the VS variables are the most important factors for explaining the variation in the rate of inflation.

[18] Since variables are in difference form, the long-term price level may not be determined in a reasonable manner in the equation. However, the results are qualitatively the same when the equation is estimated instead in error-correction form. The level term in such an equation comes out in accordance with the theory but is not statistically significant.

[19] This coefficient was falsely negative for American data, see Ball & Mankiw (1995).

[20] R^2 and the standard error in the regression are explained in the appendix to this article.

The errors in the regression without the VS variables for the period with low inflation are almost as large as for the high-inflation period with the VS variables included.

I have also estimated the equation with the best econometric fit – the general equation (i) including the VS variables – separately for two periods: 1980–93 when inflation was not targeted and 1994–2003 with inflation-targeting. The results are presented in Table 2. A Chow test (which compares the sum of the residuals in the total sample with the sum in each sub-sample) shows that the model is significantly different in the two periods; it will also be seen that certain parameters differ markedly between the two periods. The lower and less variable rate of inflation in the more recent period is evident in a standard error in the equation of only 0.34 per cent compared with 0.54 per cent for the period when inflation was not targeted. In the model without the VS variables the standard error for the more recent period is 0.48 per cent. This warrants the conclusion that on average, the error in the regression without the VS variables for the period with low inflation will be almost as large as for the high-inflation period with the VS variables included.

The changeover to targeting inflation has altered inflation's characteristics.

A comparison of the equations during the two sub-periods in Table 2 reveals some interesting differences. The effect of the VS variables is marked in both periods but relatively larger in the earlier one. The effects of the cost variables also differ and seem to be larger in the later period. All in all, the comparison suggests that it is prudent not to calculate parameters based on the entire period and that the characteristics of inflation have been altered by the changeover to targeting inflation. The higher coefficient for lagged inflation in the later period may be a sign that inflation expectations and the focus on the inflation target have strengthened the role of price expectations at the expense of other variables.

The VS measures make a major contribution to the explanation of inflation's historical path and there is a considerable risk that inflation equations which do not include these variables are incorrectly specified.

Table 3 shows whether the VS measures can explain the residual series for inflation that were obtained from calculations with alternative inflation models. In regression analyses a battery of tests is commonly used to determine whether or not the residual series are entirely random. In the analyses with the VAR model I used tests for autocorrelation and heteroscedasticity. Both tests indicated that the residual series for inflation was random. Even so, in Table 3 all the VS measures are statistically significant and explain 37 per cent of the variation in the residuals. That is a strong indication of errors in the specification of the VAR model. As Table 3 shows, an analysis of the residuals from the Bayesian VAR model gives much the same result: the VS variables explain 35 per cent of the variation in the residuals. The VAR models are estimated with quarterly data and evaluated with quarterly changes. I have also studied the characteristics of residuals from inflation predictions by the National Institute of Economic Research using monthly data for the period 1998–2004; the predictions, which are those with the most recent information (often the month before the forecast month), are for annual changes and the VS

TABLE 1. RESULTS OF ECONOMETRIC ESTIMATIONS WITH VARIANTS OF PHILLIPS CURVES

Dependent variable: CPI inflation (π)

Period: Q3 1980 – Q4 2003

No. of observations: 94

No. of price indexes: 71

Columns: *(i)* general equation, *(ii)* equation without cost variables, *(iii)* equation without unemployment gap, *(iv)* equation without price shocks and productivity variable, *(v)* equation without variance and skewness variables

Variable	Coefficient *(p)*				
	(i)	*(ii)*	*(iii)*	*(iv)*	*(v)*
Constant	−0.070146 (0.0002)	−0.093795 (0.0000)	−0.060754 (0.0024)	0.000551 (0.7318)	−0.067085 (0.0145)
ULC_t	0.181111 (0.0022)		0.274820 (0.0000)	0.212979 (0.0012)	0.035508 (0.6363)
ρ_t	0.039494 (0.0621)		0.052226 (0.0246)	0.052080 (0.0201)	0.063145 (0.0390)
π_{t-1}	0.21873 (0.0032)		0.380702 (0.0000)	0.293896 (0.0002)	0.136198 (0.1649)
$U-\bar{U}$	−0.001179 (0.0001)	−0.002099 (0.0000)		−0.000967 (0.0017)	−0.001791 (0.0000)
π_t^{oil}	0.008519 (0.0557)	0.005050 (0.2943)	0.010913 (0.0258)		0.003510 (0.5806)
π_t^{metals}	−0.002567 (0.7849)	−0.005405 (0.6033)	0.002001 (0.8462)		−0.013572 (0.3291)
$\pi_t^{food(a)}$	0.010434 (0.4755)	0.012673 (0.4271)	0.011767 (0.4661)		0.012282 (0.5778)
$\pi_t^{food(b)}$	0.015739 (0.0156)	0.017467 (0.0160)	0.012089 (0.0866)		0.022719 (0.0196)
σ_t^3	2.728386 (0.0002)	3.345240 (0.0000)	2.142734 (0.0058)	3.136132 (0.0001)	
σ_{t-1}^3	−0.886493 (0.0230)	−0.419452 (0.2989)	−1.363048 (0.0011)	−1.041088 (0.0150)	
σ_t^2	5.716703 (0.0000)	5.333165 (0.0000)	6.020147 (0.0000)	5.777538 (0.0000)	
$\sigma_t^3\ \sigma_t^2$	−452.7294 (0.2188)	−838.0001 (0.0316)	−137.9741 (0.7276)	−641.0698 (0.1145)	
g_t	−0.040923 (0.0001)	−0.057668 (0.0000)	−0.033187 (0.0036)		−0.043719 (0.0060)
DUMMY Q4 1980	0.017610 (0.0022)	0.022609 (0.0003)	0.016045 (0.0107)	0.018744 (0.0022)	0.021058 (0.0123)
DUMMY Q1 1996	−0.031116 (0.0000)	−0.022732 (0.0019)	−0.039896 (0.0000)	−0.028605 (0.0003)	−0.004628 (0.5611)
DUMMY Q3 1994	−0.020026 (0.0024)	−0.021749 (0.0028)	−0.019921 (0.0059)	−0.013486 (0.0447)	−0.008683 (0.3248)
DUMMY Q1 1986	−0.018733 (0.0018)	−0.016970 (0.0102)	−0.017939 (0.0064)	−0.018332 (0.0034)	−0.007755 (0.3676)
R^2	0.831227	0.778230	0.791509	0.772721	0.584179
Standard error in regression	0.005007	0.005617	0.005528	0.005628	0.007632
Mean: dependent variable	0.011111	0.011008	0.011111	0.011111	0.011193
Standard deviation: dependent variable	0.011017	0.011004	0.011017	0.011017	0.010987

R^2 is a multiple correlation coefficient that indicates the proportion of the variance in inflation that is explained in the equation. The standard error in the regression is the square root of the sum of the squared residuals divided by the number of observations. The table also shows inflation's mean value and standard deviation for the period covered by the data. The dummy variables = 1 during the indicated period, otherwise 0.

TABLE 2. GENERAL EQUATION ESTIMATED FOR PERIODS BEFORE AND WITH THE INFLATION TARGET.

Dependent variable: CPI inflation: π		
Period: Q3 1980 to Q4 2003 subdivided into 1980–93 and 1994–2003		
No. of observations: 94, of which 54 and 40, respectively, in the sub-periods		
No. of price indexes: 71		
Variable	Coefficient (p)	
	1980:3–1993:3	1994:1–2003:4
Constant	–0.190133 (0.0550)	–0.002072 (0.9638)
ULC_t	0.136332 (0.0799)	0.494732 (0.0031)
ρ_t	0.048085 (0.1201)	0.029355 (0.4997)
π_{t-1}	0.208021 (0.0313)	0.290887 (0.0432)
$U-\bar{U}$	–0.002228 (0.0022)	0.000300 (0.7499)
π_t^{oil}	0.009077 (0.1726)	0.007637 (0.1875)
π_t^{metals}	–0.005505 (0.6817)	0.031363 (0.0349)
$\pi_t^{food(a)}$	–0.010053 (0.7085)	0.024934 (0.1214)
$\pi_t^{food(b)}$	0.031689 (0.0046)	–0.001621 (0.8248)
σ_t^3	3.448516 (0.0019)	3.169680 (0.0163)
σ_{t-1}^3	–1.081000 (0.1741)	–1.422743 (0.0010)
σ_t^2	6.661226 (0.0000)	3.508158 (0.0131)
$\sigma_t^3\ \sigma_t^2$	–941.1715 (0.0572)	–1050.226 (0.1873)
g_t	–0.106758 (0.0527)	0.001502 (0.9582)
DUMMY Q4 1980	0.021330 (0.0025)	
DUMMY Q1 1996		–0.019821 (0.521)
DUMMY Q3 1994		–0.013409 (0.0424)
DUMMY Q1 1986	–0.021749 (0.0028)	
R^2	0.808037	0.770941
Standard error in regression	0.005405	0.003380
Mean: dependent variable	0.016938	0.003245
Standard deviation: dependent variable	0.010445	0.005540

measures have been calculated correspondingly. The results are somewhat weaker but here, too, the VS variables explain an appreciable part of the variance in the forecast errors. From this I conclude that the VS measures make a major contribution to explaining inflation's historical path and that without these variables there is probably a large risk of inflation equations being incorrectly specified.

TABLE 3. REGRESSIONS WITH MODEL RESIDUALS – ε_t – AS DEPENDENT VARIABLE

	Model		
	VAR	Bayesian VAR	N. I. Economic Research
Variable	Coefficient (p)		
	Quarterly 1980–2003	Quarterly 1981–2003	Monthly 1998–2004
Constant	–0.005012 (0.000)	–0.403792 (0.000)	0.269104 (0.001)
ε_{t-1}	–0.010574 (0.908)	0.096325 (0.292)	0.130121 (0.281)
σ_t^3	2.812243 (0.000)	197.8204 (0.000)	70.25972 (0.062)
σ_{t-1}^3	–1.260631 (0.009)	–80.26362 (0.017)	–16.73187 (0.188)
σ_t^2	5.153802 (0.000)	331.5355 (0.000)	–100.0026 (0.002)
$\sigma_t^3 \sigma_t^2$	–1205.869 (0.003)	–74240.61 (0.007)	–7991.953 (0.474)
R^2	0.372	0.357	0,292

Note: Quarterly changes have been used for the VAR models, 12-month changes for the forecasts from the National Institute.

Monetary policy is forward-looking

Monetary policy in Sweden is based on a 2 per cent inflation target with a tolerance interval of ±1 percentage point. The monetary transmission mechanism – the time lag before the policy is effective – calls for a forward-looking perspective in which policy reacts to predictions of inflation about two years ahead. As nominal price rigidities play a decisive part in the transmission mechanism, it is important to capture them in specifications of price equations and Phillips curves.

Nominal price rigidities seem important and it is urgent to capture them in specifications of price equations and Phillips curves.

Producer as well as consumer prices are evidently sticky in a number of sectors but the part played by these rigidities in economic policy is less clear. Interview studies show that there may be rigidities in a number of sectors whereby full price adjustment to shocks can take several years. Econometric studies with time-series data have yielded similar findings. In the absence of reliable methods for incorporating these varying rigidities in macroeconomic models, the inclusion of VS measures in price equations seems to be a promising approach, partly because the historical path is then explained more satisfactorily.

Full price adjustment to shocks can take several years.

Against the VS variables it might be argued that it is difficult or even impossible to predict variance and skewness but such an argument is faulty for several reasons.

Monetary policy's perspective is forward-looking, however, and calls for reliable predictions of inflation about two years ahead. A model that explains history successfully will not necessarily provide good forecasts, just as models that are bad at explaining history may yield good forecasts. Against including the VS variables in price equations it might be argued that it is difficult or even impossible to predict the future development of variance and skewness but such an argument is faulty for several reasons. For one thing, excluding the VS variables means accepting a faulty specification of the price equations. That leads to erroneous estimates of the effects of other variables in the price equations, which can result in turn in poorer inflation forecasts.[21] For another thing, the VS variables are presumably not very much more difficult to predict than many other variables in macroeconomic models. Are the VS variables harder to predict than, for instance, asset prices, which are needed to forecast household consumption expenditure or corporate investment? Moreover, the *long-term* equilibrium level of skewness is unusually simple to predict in that in theory as well as empirically it is virtually zero.[22]

Inflation in Sweden was overestimated by most forecasters in the period 1993–2001.[23] Might the reason be that the variance and skewness in the distribution of relative-price changes were not taken into account, so that the forecasts failed to catch short-run rigidities in price-setting? Unusually high skewness in the period 1991–96 had an upward effect on the rate of inflation (see Figure 5) but in the period 1994–2001 skewness decreased successively and may thus have helped to explain the fall in inflation in those years.

[21] Compare the coefficients in equations (i) and (v) in Table 1. A wage change has a short-run elasticity of 0.2 in the model with the higher moments as against about 0 in the incorrectly specified model without VS variables.

[22] Experiments with the basic macroeconomic model BASMOD (one of the models that are used for forecasting at the Riksbank) have shown that including the higher moments tends to improve forecasts of inflation and GDP growth. Those forecasts were made with a simple ARMA(1,1) time-series model. When the above equation is estimated up to the end of 2001 in order to predict the past three years and the actual variance and skewness measures are used for these three years, the forecasting errors are only a third of those that occur without variance and skewness measures. Work is in progress on improving and evaluating inflation forecasts that use the variance and skewness variables.

[23] See Blix, Friberg & Åkerlind (2002).

Conclusions

To sum up, it seems that including the variance and skewness in the distribution of relative-price changes can appreciably improve the estimation of Phillips curves for the Swedish economy. This can be seen as a way of catching price-setting differences between firms in a few aggregated index numbers. These indexes appear to mirror the fact that for certain firms, unusually large shocks are needed to induce a quick price adjustment. It also looks as though inflation forecasts can be improved with the aid of these variables, though further evaluations are needed. Time series with skewness are highly volatile (see Figure 1). Further improvements to analyses of this type could presumably be achieved by using robust measures (excluding extreme observations) of variance and skewness.[24]

Improving inflation forecasts with the aid of VS variables seems to be possible, though further evaluations are needed.

[24] Such measures have been used by Aucremanne et al. (2003).

Appendix

DEFINITIONS

Measures used in the calculations are defined below; they apply to a decomposition of the CPI into 71 indexed items.

Inflation: $\pi_t = \sum_{i=1}^{71} w_{it} \Delta \log p_{it}$

$$w_{it} = \frac{p_{it} q_{it}}{\Sigma_j p_{jt} q_{jt}}$$

is the budget share for good i in period t, p_{it} is the price, q_{it} is the volume and Δ is the difference operator.

Variance in relative-price changes: $\sigma_t^2 = \sum_{i=1}^{71} w_{it} (\Delta \log p_{it} - \pi_t)^2$

Skewness in relative-price changes: $\sigma_t^3 = \dfrac{\sum_{i=1}^{71} w_{it} (\Delta \log p_{it} - \pi_t)^3}{\sqrt{\sigma_t^2}}$

$0 \leq R^2 \leq 1$ is the multiple correlation coefficient, which measures how much of the variance in the dependent variable (in this case: inflation) that is explained in the model (by the independent variables).

The standard error in the regression is measured as $\frac{1}{n-1} \sqrt{\sum_{i=1}^{n} \varepsilon_{it}^2}$ where $\varepsilon_t = \pi_t - \hat{\pi}_t$ is the residual (unexpected inflation) in the inflation equation. It is a measure of the average error, taking into account that residuals are both positive and negative.

THE FIRM'S OPTIMAL PRICE

The firm's equilibrium condition is that mr = mc, that is, that the marginal revenue equals the marginal cost. This condition can be rewritten as:

$$p = \left[1 - \frac{H}{\varepsilon} \right]^{-1} mc$$

where p is the firm's price, $\varepsilon = \frac{\delta q}{\delta p} \frac{p}{q}$ is the price elasticity of demand and H is an index for the degree of competition (0=perfect competition, 1=monopoly).The marginal cost is derived from a cost function with input prices and the volume of production as arguments. Note that it is only in a special case of the cost function that the specification will include the output gap, that is, the difference between actual and potential output.[25] The optimal price would always apply if price-setting did not entail a cost for the firm.

[25] See Sbordone (2002).

References

Andersson, M. K., (2004), "The forecasting performance of the Riksbank Bayesian VAR models", unpublished manuscript.

Apel, M., Friberg, R. & Hallsten, K., (2001), "Micro foundations of macroeconomic price adjustment: survey evidence from Swedish firms", Sveriges Riksbank Working Paper Series, 128.

Assarsson, B., (1986), "Inflation and relative-price variability—a model for an open economy applied to Sweden", *Journal of Macroeconomics,* Autumn, vol. 8:4, 455–69.

Assarsson, B., (1989), *Prisbildning på Industriella Marknader. En empirisk undersökning av prisbildningen i den svenska tillverkningsindustrin* (Price formation in industrial markets. An empirical study of price formation in Swedish manufacturing), Bjärnum, SNS Förlag.

Assarsson, B., (2003), "Inflation and higher moments of relative-price changes", BIS Papers 19.

Aucremanne, L., Brus, G., Hubert, M., Rousseeuw, P. J. & Struyf, A., (2003), "Inflation, relative prices, and nominal rigidities", BIS Papers 19.

Aukrust, O., (1970), "PRIM I: A Model of the Price and Income Distribution Mechanism of an Open Economy", *Review of Income and Wealth,* March, vol. 16:1, 51–78.

Balke, N. S. & Wynne, M. A., (1996), "Supply shocks and the distribution of price changes", *Federal Reserve Bank of Dallas Economic Review,* Q1, vol. 8, 10–18.

Balke, N. S. & Wynne, M. A., (2000). "An equilibrium analysis of relative price changes and aggregate inflation", *Journal of Monetary Economics,* April, vol. 45:2, 269–92.

Ball, L. & Mankiw, N. G., (1994), "Asymmetric price adjustment and economic fluctuations", *Economic Journal,* March, vol. 104:423, 247–61.

Ball, L. & Mankiw, N. G., (1995), "Relative-price changes as aggregate supply shocks", *Quarterly Journal of Economics,* February, vol. 110:1, 161–93.

Ball, L. & Mankiw, N. G., (1999), "Interpreting the correlation between inflation and the skewness of relative prices: a comment", *Review of Economics and Statistics,* May, vol. 81:2, 197–98.

Bårdsen, G., Jansen, E. S. & Nymoen, R., (2002), "Model specification and inflation forecast uncertainty", *Annales d'Economie et de Statistique,* July–December, no. 67–68, 495–517.

Blinder, A. S., (1991), "Why are prices sticky? Preliminary results from an interview study", *American Economic Review,* May, vol. 81:2, 89–96.

Blix, M., Friberg, K. & Åkerlind, F., (2002), "An evaluation of forecasts for the Swedish economy", Sveriges Riksbank Economic Review, 3, 39–74.

Bryan, M. F. & Cecchetti, S. G., (1999a), "Inflation and the distribution of price changes", *Review of Economics and Statistics,* May, vol. 81:2, 188–96.

Bryan, M. F. & Cecchetti, S. G., (1999b), "Inflation and the distribution of price changes: rejoinder", *Review of Economics and Statistics,* May, vol. 81:2, 203–04.

Cukierman, A., (1979), "The relationship between relative prices and the general price level: a suggested interpretation", *American Economic Review,* June, vol. 69:3, 444–47.

Cukierman, A., (1982), "Relative price variability, inflation and the allocative efficiency of the price system", *Journal of Monetary Economics,* March, vol. 9:2, 131–62.

Cukierman, A., (1983), "Relative price variability and inflation: a survey and further results", *Carnegie Rochester Conference Series on Public Policy,* Autumn, vol. 19, 103–57.

Cukierman, A. & Wachtel, P., (1982), "Relative price variability and nonuniform inflationary expectations", *Journal of Political Economy,* February, vol. 90:1, 146–57.

Hodrick, R. J. & Prescott, E.C. (1997). "Postwar U.S. business cycles: an empirical investigation", *Journal of Money, Credit, and Banking*, vol. 29, 1–16.

Jacobson, T., (2001), "Monetary policy analysis and inflation targeting in a small open economy: a VAR approach", *Journal of Applied Econometrics*, July–August, vol. 16, 487–520.

Jacobson, T., Jansson, P., Vredin, A., & Warne, A., (1999), *A VAR Model for Monetary Policy Analysis in a Small Open Economy*, Sveriges Riksbank Working Paper Series, 77.

Lucas, R. E. J., (1973), "Some international evidence on output-inflation tradeoffs", *American Economic Review,* June, vol. 63:3, 326–34.

Parks, R. W., (1978), "Inflation and relative price variability", *Journal of Political Economy,* February, vol. 86:1, 79–95.

Pettersson, L. & Wikström, J., (2004), "Inflation och högre moment av fördelningen av relativprisförändringar, En studie med finfördelat svenskt konsumentprisindex" (Inflation and higher moments of the distribution of relative-price changes: a study with a decomposed Swedish CPI), research paper, Uppsala University.

Sbordone, A. M., (2002), "Prices and unit labor costs: a new test of price stickiness", *Journal of Monetary Economics,* March, vol. 49:2, 265–92.

Sheshinski, E. & Weiss, Y., (1977), "Inflation and costs of price adjustment", *Review of Economic Studies*, June, vol. 44:2, 287–303.

Taylor, J. B., (1980), "Aggregate dynamics and staggered contracts", *Journal of Political Economy,* February, vol. 88:1, 1–23.

Tobin, J., (1972), "Inflation and unemployment", *American Economic Review*, March, vol. 62:1, 1–18.