Inflation and higher moments of relative price changes in Sweden

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1. Introduction and summary

This paper analyses the relationship between inflation and relative prices in the Swedish economy. In particular, the relationship between inflation and the skewness of relative price changes is studied and Phillips or price curves are estimated for Swedish data in which skewness is incorporated as a proxy measure of nominal rigidity. This is an alternative to new Keynesian Phillips curves in which forward-looking firms base price decisions on future expected marginal cost. The empirical results show that there is a significant positive relationship between inflation and the second and third moments of relative price changes. It is also shown that the skewness variable improves the Phillips curve significantly.

2. Inflation and relative prices in theory

There is a statistically significant positive relationship between the mean of price changes, ie the rate of inflation, and the second and third moments[2] of relative price changes in many countries. According to a standard classical dichotomised macroeconomic model, inflation and relative prices are independent. However, several arguments have been raised to explain why there may be a relationship between inflation and the dispersion of relative prices, and there is no one-way causality between the variables: inflation may affect the variance of relative price changes and the variance of relative price changes may affect inflation. It is likely that the relationship is positive. Several empirical studies have been done in which the causality between inflation and the second moment of the distribution of relative price changes has been examined. Some studies have been done in which other variables has been included as well and been allowed to affect both inflation and the distribution of relative price changes. One result in some studies is that some third variable (such as oil price shocks) is the driving force behind both inflation and the variance of relative price changes.

The main reason for causality running from inflation to relative prices is the existence of short-run nominal rigidity, ie costs associated with changing prices (menu costs). This was shown by Sheshinski and Weiss (1977), who analysed the behaviour of a price setting monopolist with costs associated with changing prices, facing inflation but no other shocks. The profit-maximising behaviour implies that prices are fixed in time intervals that depend on the rate of inflation and the cost of changing prices. The frequency of price changes depends positively on the rate of inflation and negatively on the cost of changing prices. If costs associated with changing prices vary across firms then an increase in the rate of inflation will increase the variability of relative price changes. This occurs even if inflation is fully *expected*. Another explanation of the relationship can be found in Assarsson (1986) and Parks (1978), where there is a positive relationship between the variance of relative price changes and the rate of

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[1] I am grateful for comments on an earlier version of this paper from Michael J Andersson and Pernilla Meyersson.

[2] See Aarstol (1999a,b), Assarsson (1986), Blejer and Leiderman (1980, 1982), Bomberger and Makinen (1993), Bossone (1992), Buck (1990), Debelle and Lamont (1996), Glezakos and Nugent (1986a,b), Goel and Ram (1993), Haubrich (1993), Jaramillo (1999), Jinushi (1990), Jurkovic (1989), Kandel et al (1991), Karasulu (1998), Lach and Tsiddon (1993), Mizon (1991), Mizon et al (1989, 1990), Murty (1984), Parks (1978), Parsley (1996), Ram (1988a,b), Sellekaerts and Sellekaerts (1984, 1986), Smith and MacKinnon (1987), Stockton (1988), Tommasi (1992), Vining and Elwertowski (1976), Balk (1978) for the Netherlands, Blejer and Leiderman (1980) for Argentina, Assarsson (1986) for Sweden for the variance and Balke and Wynne (2000), Ball and Mankiw (1993) and Bryan and Cecchetti (1999) for the United States and the skewness.

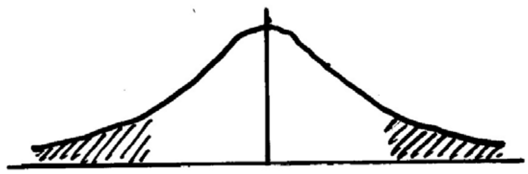
unexpected inflation. This is established in non-stochastic models in which the variance of relative prices is endogenous and depends on supply and demand variables. In the stochastic Lucas island parable model (Lucas (1972, 1973)), a positive relationship between the variance of relative price changes and the variance of inflation can be found.[3] This relationship depends on agents having imperfect information about absolute/relative prices. Lucas's model is an example of where causality goes from a third variable, monetary shocks or relative demand shocks, to inflation and relative price changes. Another example can be found in the Scandinavian model of inflation, in which productivity shocks cause both inflation and the variance of relative price changes to move in the same direction.[4]

There are also examples where the causality runs from the variance of relative price changes to inflation, eg in models[5] with asymmetric price changes and downward rigidity in prices.

Several studies also find a positive relationship between the rate of inflation and the third moment of the distribution of relative price changes, the skewness. At least three explanations for this correlation are available in the literature, causally going from skewness to the rate of inflation. The first explanation is based on menu costs.[6]

Graph 1

A uniform distribution of relative shocks



Graph 1 illustrates a uniform distribution of relative shocks, which may be thought of as supply shocks. The mean of these is by definition zero. In the presence of menu costs, prices will only be changed due to shocks that are big enough to yield benefits, ie coming closer to the desired optimal price, that outweigh the cost of changing the price. These shocks are the shaded areas of the distribution in Graph 1, whereas the blank area depicts a *range of inaction*. If the distribution is uniform, there is no effect on inflation, since the relative price *increases* are offset by the relative price *decreases*. Consider instead the distribution with positive skewness in Graph 2.

Graph 2

Distribution of relative shocks with positive skewness

A positively skewed distribution has relatively more large relative price increases (negative supply shocks) and many small relative price decreases (positive supply shocks). Due to the cost of price changes, the large negative shocks add to inflation while the small positive shocks do not fully balance

3 On the relationship in Lucas's model, see also Cukierman and Wachtel (1979) and Cukierman (1979, 1983).

4 See Aukrust (1970).

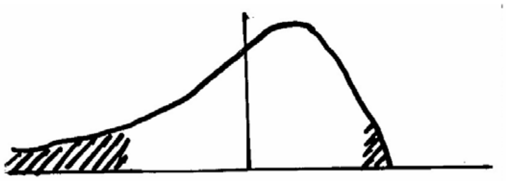
5 See Schultz (1959), Ball and Doyle (1959) and Tobin (1972).

6 This theory is based on Ball and Mankiw (1993).

the negative ones, though the mean of the relative shocks is still zero. Hence, inflation rises with positive skewness and falls with negative skewness, as in Graph 3 below.

Graph 3

Distribution of relative shocks with negative skewness



The second explanation is not based on nominal rigidities[7] but shown in a dynamic general equilibrium model in which the positive correlation depends on a particular process for productivity shocks. The third explanation is a statistical explanation put forward by Bryan and Cecchetti (1999), where the positive correlation is a small sample bias problem in a situation where the distribution of relative price changes has high kurtosis (fat tails). This problem is explained in economic terms by Balke and Wynne (2000), where a certain process for productivity shocks produces both fat tails and a positive correlation between inflation and the skewness of relative price changes. Finally, a fourth explanation of the relationship between inflation and skewness is offered by combining the business cycle model in Bils and Klenow (1998) with the nominal rigidity/skewness model in Ball and Mankiw (1993). In a peak, the demand for durables and luxuries increases more than the demand for other goods. Therefore, aggregate shocks have implications not only for inflation but for relative prices as well. If the production structure of firms is characterised by cyclical utilisation (rather than increasing returns), then marginal costs and relative prices on durables and luxuries as well as the skewness of relative prices are likely to be procyclical.

Ball and Mankiw (1993, p 165) also show that if the distribution of relative price changes is skewed, an increased variance will magnify the effect of skewness on inflation: a larger variance is inflationary when the distribution of relative price changes is skewed to the right and deflationary when it is skewed to the left.

3. Price setting and the Phillips curve

In a standard price equation the price level is determined as a markup on marginal cost. The equation, derived from profit maximisation, is:

$$p_t = \left[1 - \frac{H_t}{\varepsilon_t}\right]^{-1} mc_t \qquad (1)$$

where p_t is the price level, $0 \le H_t \le 1$ is an index of the degree of competition where $H_t = 0$ for free competition and $H_t = 1$ for monopoly, ε_t is the price elasticity of demand and mc_t is marginal cost. All variables are assumed to vary over time and are therefore indexed by *t*. mc_t is the derivative of a cost function $C(p_t^I, y_t)$ where y_t is output and p_t^I is a vector of input prices. $mc_t \equiv C'(p_t^I, y_t)$ and the price equation can be written:

$$p_t = \left[1 - \frac{H_t}{\varepsilon_t}\right]^{-1} C'(p_t^I, y_t) \qquad (2)$$

7 See Balke and Wynne (2000).

This equation is probably a reasonable description of long-run price behaviour. In the short run, however, prices presumably are affected by nominal rigidities, especially at high data frequencies as in monthly or quarterly data. It is important to try to capture the short-run dynamics of prices, for instance with respect to the monetary transmission mechanism.

In the empirical literature several restrictions are usually put on equation (2) at the outset. H_t and ε_t are often arbitrarily treated as constants despite the fact that other relevant literature finds them varying quite substantially, maybe even more than marginal cost.[8]

Several attempts have been made to incorporate the effects of nominal rigidities in the Phillips curve. One attempt is the staggered wage contracts model in Taylor (1980). This leads to the Phillips curve equation:

$$\pi_t = \pi_{t-1} + \gamma\left[y_t - y_t^*\right] + z_t \tag{3}$$

where $\pi_t \equiv \Delta \log p_t$, y_t^* is the log of potential output and z_t is a vector of supply shocks.

Another possibility was proposed by Calvo (1983). In his model, for a number of identical firms there is a fixed probability $1 - \theta$ for each firm to change its price, a probability which is assumed to be independent of the time elapsed since the last price revision. The average time over which a price is fixed is then given by $(1-\theta)\sum_{k=0}^{\infty} k\,\theta^{k-1} = \frac{1}{1-\theta}$. The aggregate price level then evolves as a convex combination of the lagged price level p_{t-1} and the optimal price p_t^*:

$$p_t = \theta p_{t-1} + (1-\theta)p_t^* \tag{4}$$

where the optimal price depends on future expected marginal costs. The Phillips curve can be written:

$$\pi_t = \lambda\sum_{k=0}^{\infty}\beta^k E_t\left[mc_{t+k}\right] \tag{5}$$

where β is the discount factor, $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}$ and E_t is the expectations operator. According to Bårdsen et al (2002) and Roberts (1995), equation (5) may be represented by:

$$\pi_t = \gamma_1 E_t \pi_{t+1} + \gamma_2 x_t \tag{6}$$

where x_t is some approximation to (the change in) marginal costs, such as the output gap. Both $E_t\pi_{t+1}$ and mc_t are unobservables. Various approximations have been used but there is no consensus among researchers about which measures or approximations to adopt. Note also that the models in the recent literature assume that firms are identical and that H_t and ε_t are constants.

Several attempts have been made to estimate and test new Keynesian Phillips curves, but it seems to be difficult to settle for a particular specification or estimation method,[9] which in view of equation (6) is not very surprising. Some authors, like Bårdsen et al (2002) or Lindé (2001), stress the need to incorporate the forcing variables as well as the rate of inflation in a system of equations. Bårdsen et al (2002) also argue that it is difficult to evaluate models with respect to goodness of fit since the fit of new Keynesian Phillips curve models is well approximated by simple statistical models. Instead Bårdsen et al (2002) suggest testing the parameter on the forward term in equation (6) and report rather disappointing but somewhat mixed results for the new Keynesian model.

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8 For instance, in estimations of price elasticities, flexible functional form cost functions are preferred that imply varying price elasticities, see Edgerton (1996).

9 See Bårdsen et al (2002).

In equation (6) the term $\gamma_1 E_t\pi_{t+1}$ represents the effect of nominal rigidity (menu costs). This effect may also be represented by the skewness, σ^3_{rp} of relative price changes, which is proposed here. An alternative Phillips curve then is:

$$\pi_t = \gamma_1\sigma^3_{rp} + \lambda_2 x_t \tag{7}$$

Ball and Mankiw (1993) perform a similar exercise and specify a Phillips curve:

$$\pi_t = \alpha_0 + \alpha_1\pi_{t-1} + \alpha_2\left[u_t - u_t^*\right] + \alpha_3 z_t + \alpha_4\sigma^2_{rp} + \alpha_5\sigma^3_{rp} + \alpha_6\left[\sigma^2_{rp}\sigma^3_{rp}\right] \tag{8}$$

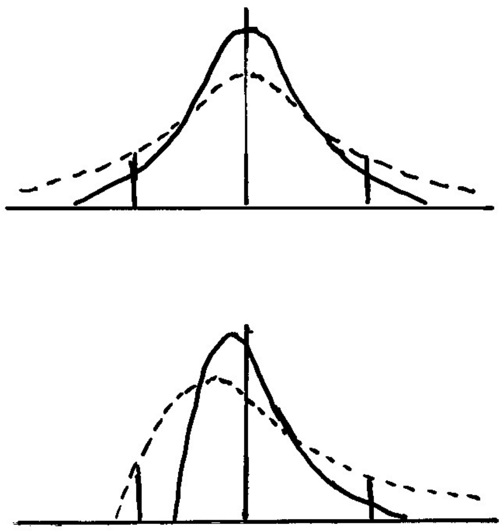
where the last four terms are supposed to capture the effect of supply shocks. They find the effects of the terms with higher moments important and raise the goodness of fit from 0.360 to 0.898 on US annual producer price data for the period 1949-89.[10] Ball and Mankiw include both supply shock variables like food, energy and raw materials prices (the z variable in equation (8)) alongside the σ variables. Another interpretation is then that the last three terms in equation (8) capture nominal rigidity rather than the effect of supply shocks.

4. Empirical results I: the relationship between inflation and higher moments of the distribution of relative price changes

Ball and Mankiw (1993) show that the effect of the skewness of relative price changes on the rate of inflation depends on the variance. A large variance magnifies the effect of skewness.

Graph 4

The interaction of variance and skewness



This can be seen in Graph 4. In the upper part, an increase in the variance of shocks affects the tails symmetrically and consequently has no effect on inflation. In the lower part, where the distribution is asymmetric, an increase in the variance has a larger effect on the right-hand than on the left-hand tail

10 Ball and Mankiw (1993) used a Hodrick-Prescott filter to compute the trend in unemployment, u_t^*.

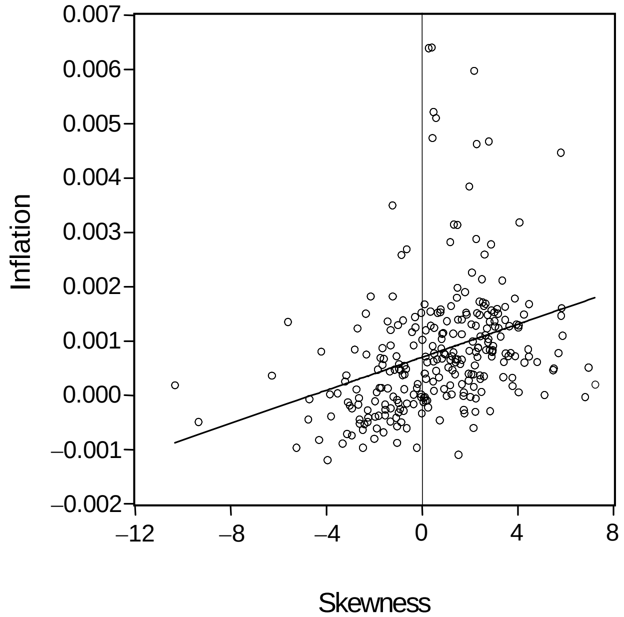
and hence strengthens the effect of skewness on the rate of inflation. I therefore include a variance/skewness interaction term in the regressions below.

The data consist of 71 consumer goods items in the Swedish consumer price index (CPI). The individual price is denoted p_{it} and the general price level $\log p_t = \sum_{i=1}^{71} w_{it} \log p_{it}$ where $w_{it} = \frac{p_{it} q_{it}}{\sum_{j=1}^{71} p_{jt} q_{jt}}$ is the budget share, q_{it} is the volume of item *j* at time *t* while $p_{it} q_{it}$ is the expenditure. The relative price is then defined as $\frac{p_{it}}{p_t}$ and the mean of relative price changes as $\sum_{i=1}^{71} w_{it} \left[\Delta \log p_{it} - \Delta \log p_t\right] = 0$. The variance of relative price changes is defined as $\sigma_{rp}^2 = \sum_{i=1}^{71} w_{it} (\Delta \log p_{it} - \Delta \log p_t)^2$ and the skewness as $\sigma_{rp}^3 = \frac{\sum_{i=1}^{71} w_{it} (\Delta \log p_{it} - \Delta \log p_t)^3}{\sqrt{\sigma_{rp}^2}}$. In theory, there is a positive correlation between inflation and σ_{rp}^2 and σ_{rp}^3 respectively. If relative prices are normally distributed, we also expect $\sigma_{rp}^3 = 0$ in the long run and the positive correlation between inflation and skewness to be a short-run phenomenon, presumably associated with nominal rigidities.

The variance and skewness measures are calculated for both monthly and quarterly data. Since skewness is assumed to capture effects of nominal rigidity, the time interval of the data is likely to be important and may affect the results. The econometric models below are dynamic and include lagged dependent variables. Therefore, the equations may be affected by temporal aggregation.[11] Another possible econometric problem is simultaneity since both the variance and the skewness possibly depend on inflation, whether expected or unexpected.[12]

Graph 5

Inflation and skewness



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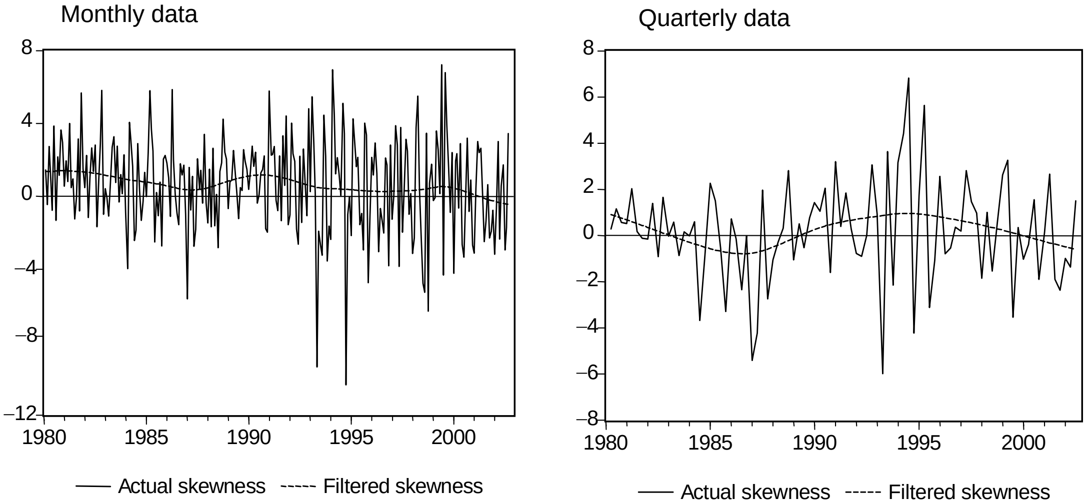
11 I try to remedy this possible negative effect on the specification by including a moving average term. However, this term was never significant, not even with quarterly data. On this, see Ermini (1991,1993), Wei (1978) and Weiss (1984).

12 This can clearly be seen in models where variance or skewness is endogenous, as in Assarsson (1986) and Parks (1978), where variance and skewness depend on inflation and various demand and supply factors like domestic and foreign input prices and income.

Graph 5 shows the data and draws a positively sloped regression line. In Graph 6 the time series of monthly and quarterly data for the data period 1980-2002 are shown. A filtered[13] series is also drawn in order to show the long-run development. One would expect the distribution to be symmetric in the long run with zero skewness, but for the monthly data in the left panel of Graph 6 skewness seems to be positive even in the long-run. This has also been found for other countries.[14] In Graph 7 we also show the recursive mean of the monthly and quarterly skewness series, and it can be seen that the monthly but not the quarterly series has a long-run positive skewness. This long-run positive skewness is attributed to trend inflation. With a positive rate of inflation, the range of inaction with respect to price change moves to the left, since a price decrease can be effected through inaction. Therefore, a price increase is more likely than a price decrease and the distribution of actual price changes has a tendency to be positively skewed.

Graph 6

Actual and filtered skewness of relative price changes



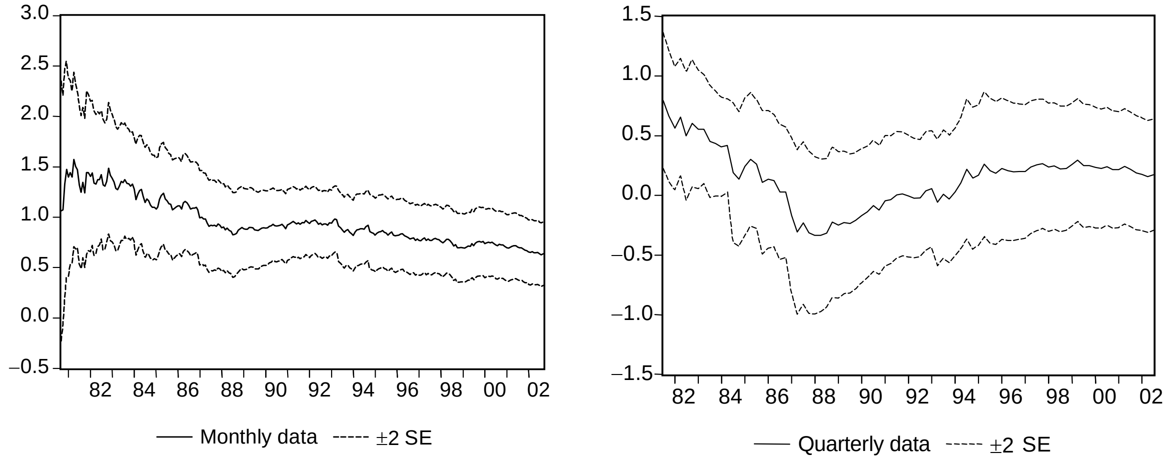
This is, however, not the case here for quarterly data. One explanation for this finding is that the longer the time intervals of the data, the less important are the nominal rigidities. More likely, however, is that at reasonably low inflation rates, most prices will be changed on a quarterly rather than on a monthly basis and the rate of inflation in the sample at hand is relatively low. This result may depend on the level of aggregation in the data. It is more likely that a chronic positive skewness will be found if the data are more disaggregated.

[13] A Hodrick-Prescott filter was used.

[14] See Aucremanne et al (2002).

Graph 7

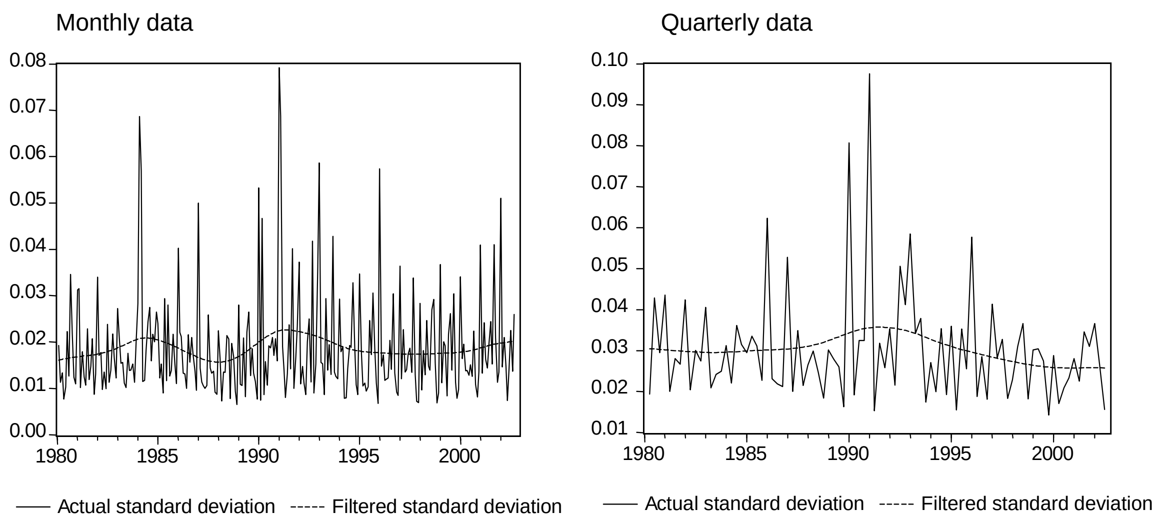
Recursive mean of skewness of relative price changes



In Graph 8 the development of the second moment of relative price changes is shown for monthly and quarterly data. There is no clear tendency over time in the monthly data, while for quarterly data there is a tendency towards decreasing variance during the last decade. With decreasing variance, the effect of skewness on the rate of inflation would be reduced. Decreasing variance and a tendency towards lower skewness imply a smaller effect of relative prices on the rate of inflation.

Graph 8

Actual and filtered standard deviation of relative price changes



During the late 1990s, inflation was overpredicted by many forecasters. During this period skewness was rather large but declining according to the quarterly data in Graph 6. If forecasts were done with models that neglected the effect of skewness and the forecasts were based on current information, it is likely that inflation forecasts one to two years ahead were too high, since current inflation was due to the high but decreasing skewness. Likewise, current forecasts that neglect skewness may underpredict inflation one to two years ahead since skewness is currently negative and probably increasing.

We now turn to the regression equations, where lagged inflation and the second and third moments as well as the interaction between the moments are included as regressors. Regressions are run for the whole data period 1980-2002 and are also divided into two sub-periods: 1980-89 and 1990-2002. The division is carried out in order to distinguish between the high- and low-inflation periods with different monetary policy regimes. Unrestricted regressions are run as well as restricted regressions in which only skewness is included and the effects of variance excluded. The difference between the even and odd-numbered columns in Table 1 is therefore the effect of the standard deviation of relative price changes: a direct effect and an indirect effect through skewness as discussed above. The regression equation can be written $\pi_t = \alpha_0 + \alpha_1 \pi_{t-1} + \alpha_2 \sqrt{\sigma_{rp}^2} + \alpha_3 \sigma_{rp}^3 + \alpha_4 \sqrt{\sigma_{rp}^2}\sigma_{rp}^3 + \varepsilon_t$ and the partial effect of skewness in the unrestricted regressions can be calculated as $\alpha_3 + \alpha_4 \sqrt{\sigma_{rp}^2}$. The effect varies over time. The effect and the corresponding p-value is calculated at the mean value of $\sqrt{\sigma_{rp}^2}$.

Table 1

Dependent variable: inflation π

Monthly data

	(1) 1980-2002	**(2) 1980-2002**	**(3) 1980-89**	**(4) 1980-89**	**(5) 1990-2002**	**(6) 1990-2002**
Constant	–0.001464 (0.1419)	0.000397 (0.6918)	0.000416 (0.7678)	0.002188 (0.1186)	–0.004570 (0.0003)	–0.000752 (0.5777)
π_{t-1}	0.282825 (0.0000)	0.258330 (0.0000)	0.166770 (0.0374)	0.101641 (0.2420)	0.157248 (0.0124)	0.233702 (0.0032)
$\sqrt{\sigma_{rp}^2}$	0.145803 (0.0000)		0.156398 (0.0009)		0.268787 (0.0000)	
σ_{rp}^3	–0.000059 (0.7684)	0.000800 (0.0000)	–0.000045 (0.8974)	0.001058 (0.0000)	–0.000199 (0.3991)	0.000587 (0.0001)
$\sqrt{\sigma_{rp}^2}\sigma_{rp}^3$	0.036917 (0.0000)		0.049156 (0.0001)		0.030531 (0.0020)	
R^2	0.527	0.411	0.582	0.478	0.653	0.417
Ser	0.004188	0.004657	0.003771	0.004175	0.003624	0.004662
Effect of skewness	0.000630 (0.0000)	–	0.000820 (0.0001)	–	0.000396 (0.0008)	–

Note: p-values in parentheses. Effect of skewness at mean standard deviation.

Notation: π_{t-1} = lagged inflation; $\sqrt{\sigma_{rp}^2}$ = standard deviation of relative price changes; σ_{rp}^3 = Skewness of relative price changes; R^2 = multiple correlation coefficient; Ser = standard error of regression.

Column (1) in Table 1 shows the unrestricted regression for the sample period 1980-2002. Column (2) excludes the standard deviation. Columns (3) and (4) show the corresponding results for the high-inflation period 1980-89 and columns (5) and (6) the results for the later low-inflation period 1990-2002. From what can be seen in Table 1, the effect of the variance is more important in the later period, where the standard error of regression decreases relatively more than in the earlier period. The effect of skewness is also smaller in the later period.

The relative importance of lagged inflation as compared to variance and skewness can be evaluated by excluding lagged inflation. Then R^2 drops from 0.53 to 0.46 while if the distribution variables are excluded R^2 drops to 0.31. Therefore variance and skewness seem potentially important in explaining inflation. During the later period this is even more pronounced, where R^2 drops from 0.65 to 0.42 when the distribution variables are excluded but only to 0.64 when lagged inflation is excluded. This is consistent with the view that nominal rigidities become more important in low-inflation regimes.

Nominal rigidities are likely to be more important at high than at low data frequencies. Table 2 shows the results for quarterly data, which are rather similar to the results for monthly data, but somewhat weaker. Skewness is now significant at the 7% significance level during the whole sample period and during the later period. Again, when the lagged inflation term is excluded, R^2 drops from 0.48 to 0.36, while the fall is to 0.32 when the distribution terms are excluded. For the later period the drop is from 0.70 to 0.67 when the lagged inflation term is excluded but down to 0.35 when the distribution terms are dropped. Therefore, the same conclusions hold with quarterly data: the distribution terms are important, particularly during the later period.

Table 2

Dependent variable: inflation π

Quarterly data

	(1) 1980-2002	**(2) 1980-2002**	**(3) 1980-89**	**(4) 1980-89**	**(5) 1990-2002**	**(6) 1990-2002**
Constant	–0.001303 (0.0597)	0.000617 (0.2279)	0.001458 (0.3263)	0.002733 (0.0053)	0.002677 (0.0003)	–0.000100 (0.8558)
π_{t-1}	0.390698 (0.0000)	0.403508 (0.0001)	0.137296 (0.4525)	0.123480 (0.4928)	0.186582 (0.0755)	0.291859 (0.0396)
$\sqrt{\sigma_{rp}^2}$	0.080404 (0.0006)		0.050997 (0.2774)		0.113101 (0.0000)	
σ_{rp}^3	0.000065 (0.7992)	0.000212 (0.0423)	0.000075 (0.8826)	0.000342 (0.0951)	0.000302 (0.2858)	0.000247 (0.0447)
$\sqrt{\sigma_{rp}^2}\,\sigma_{rp}^3$	0.003344 (0.6590)		0.008423 (0.5591)		–0.004519	
R^2	0.484	0.351	0.322	0.290	0.695	0.407
Ser	0.001904	0.002110	0.002000	0.001981	0.001458	0.001986
Effect of skewness	0.000166 (0.0769)	–	0.000320 (0.1200)	–	0.000161 (0.0700)	–

For an explanation of the notation, see Table 1.

5. Empirical results II: higher moments of relative price changes in the Phillips curve

We now turn to the Phillips curve estimations. We follow Ball and Mankiw (1993) and specify a simple version which includes a lagged inflation term (to capture expected inflation), an excess demand or output gap term (the actual rate of unemployment) and the change in oil prices to capture supply shocks. To this we add the distribution terms (Table 3). The distribution terms are significant in all the regressions. Again, the direct effect of standard deviation is significant in all regressions except for the earlier data period with quarterly data.

It is interesting to compare the performance of a traditional Phillips curve to that of an extended version with distribution terms. For quarterly data (Table 4), R^2 drops from 0.65 to 0.36 when the conventional variables are excluded[15] and to 0.53 when the distribution terms are excluded. For the later period, however, the results are different: R^2 drops from 0.82 to 0.58 when the conventional

[15] That is, all variables except the distribution variables.

Phillips curve is used but is 0.67 for the Phillips curve with only the distribution terms. Hence, again the results are consistent with the view that nominal rigidity has become more important during the low-inflation regime. The results are similar for monthly data.[16]

Table 3

Phillips curve estimation. Dependent variable: inflation π

Monthly data

	(1) 1980-2002	**(2) 1980-2002**	**(3) 1980-2002**	**(4) 1980-89**	**(5) 1990-2002**
Constant	0.001885 (0.0528)	0.003822 (0.0001)	0.004368 (0.0000)	0.000908 (0.6056)	–0.000649 (0.5772)
π_{t-1}	0.160577 (0.0006)	0.148808 (0.0037)	0.155670 (0.0038)	0.158096 (0.0414)	0.118720 (0.0188)
u_t	–0.068174 (0.0000)	–0.067698 (0.0000)	–0.072206 (0.0000)	–0.022215 (0.6636)	–0.034799 (0.0025)
Δp_t^{oil}	0.043815 (0.0000)	0.052289 (0.0000)	0.060115 (0.0000)	0.029176 (0.0027)	0.073302 (0.0000)
$\sqrt{\sigma_{rp}^2}$	0.148276 (0.0000)			0.145888 (0.0016)	0.210507 (0.0000)
σ_{rp}^3	0.000016 (0.9271)	0.000538 (0.0000)		0.000249 (0.4734)	–0.000313 (0.0837)
$\sqrt{\sigma_{rp}^2}\,\sigma_{rp}^3$	0.023019 (0.0011)			0.024273 (0.0957)	0.030731 (0.0001)
R^2	0.663	0.586	0.542	0.620	0.807
Ser	0.003564	0.003935	0.004131	0.003633	0.002749
Effect of skewness	0.000445 (0.0000)	–	–	0.000676 (0.0011)	0.000286 (0.0020)

Note: p-values in parentheses. Effect of skewness at mean standard deviation.
Notation: π_{t-1} = lagged inflation; $\sqrt{\sigma_{rp}^2}$ = standard deviation of relative price changes; σ_{rp}^3 = skewness of relative price changes; u_t = unemployment rate; Δp_t^{oil} = relative change in oil price; R^2 = multiple correlation coefficient; Ser = standard error of regression.

The results in Tables 3 and 4 are preferred in the estimations, though this implies a rejection of the non-accelerationist hypothesis and there is a long-run relationship between inflation and unemployment as in the preferred specification the actual unemployment rate was preferred to the unemployment gap $u_t - u_t^*$. If we instead estimate the equation $\Delta\pi_t = \alpha_0 + \alpha_1 [u_t - u_t^*] + \alpha_2 z_t + \alpha_3 \sigma_{rp}^2 + \alpha_4 \sigma_{rp}^3 + \alpha_5 \sigma_{rp}^2 \sigma_{rp}^3$ the results are similar compared to those in the tables: the distribution variables are statistically important and relatively more important in the later data period.[17]

[16] R^2 drops from 0.66 to 0.54 if the conventional model is used and to 0.46 with only the distribution terms. For the later period the graphs are 0.61 and 0.64 respectively. Hence, the distribution terms seem to be quite important in terms of goodness of fit.

[17] A theoretically reasonable estimation of this equation would show $\alpha_0 = 0; \alpha_1 < 0; \alpha_2 > 0$. The last three terms would drop out in the long run with $\sigma_{rp}^2 = \sigma_{rp}^3 = 0$. The theoretically correct parameters cannot be rejected, except for α_1 which is positive but insignificant.

Table 4

Phillips curve estimation. Dependent variable: inflation π

Quarterly data

	(1) **1980-2002**	**(2)** **1980-2002**	**(3)** **1980-2002**	**(4)** **1980-1989**	**(5)** **1990-2002**
Constant	0.001391 (0.0704)	0.003066 (0.0000)	0.002837 (0.0001)	0.001339 (0.4487)	–0.000607 (0.4539)
π_{t-1}	0.135228 (0.1247)	0.118209 (0.2202)	0.119785 (0.2262)	0.048983 (0.7950)	0.034754 (0.7029)
u_t	–0.040360 (0.0000)	–0.043313 (0.0000)	–0.040052 (0.0001)	0.014761 (0.7700)	–0.021676 (0.0176)
Δp_t^{oil}	0.014357 (0.0006)	0.016683 (0.0003)	0.018776 (0.0000)	0.015924 (0.0958)	0.015445 (0.0003)
$\sqrt{\sigma_{rp}^2}$	0.062134 (0.0020)			0.038558 (0.4106)	0.092936 (0.0000)
σ_{rp}^3	0.000024 (0.9165)	0.000207 (0.0225)		–0.000123 (0.8112)	0.000159 (0.4934)
$\sqrt{\sigma_{rp}^2}\sigma_{rp}^3$	0.004816 (0.4528)			0.012492 (0.3888)	–0.000778 (0.9146)
R^2	0.649	0.563	0.533	0.387	0.817
Ser	0.001597	0.001760	0.001807	0.001968	0.001168
Effect of skewness	0.000169 (0.0413)			0.000241 (0.2593)	0.000135 (0.0611)

For an explanation of the notation, see Table 3.

6. Conclusions

Several studies for various countries show that inflation is significantly correlated with both the variance and the skewness of relative price changes. One explanation for this is nominal rigidities in prices - due to menu costs - but other explanations exist as well. The present paper has shown that the relationships for Swedish data are quite strong. Phillips curves can be seen as price setting curves, where the price is basically a markup on marginal cost and the markup depends on the degree of competition and the price elasticity of demand. Nominal rigidities have been introduced into Phillips curves in various ways, but there is presently no consensus about the best way. New Keynesian Phillips curves are based on forward-looking elements and are difficult to estimate.

In this paper the inclusion of higher moments of the distribution of relative price changes are proposed as an alternative to capture the effects on inflation of nominal rigidity, in line with the theory in Ball and Mankiw (1993). The empirical results show that these distribution variables - variance, skewness and the interaction between them - has quite a strong influence on the Phillips curves estimated for Swedish monthly as well as quarterly data. There is a significant positive relationship between skewness/variance and the rate of inflation. Skewness appears to be positive *in the long run* in monthly data but zero in quarterly data. Neglecting skewness/variance in the Phillips curve seems to be a possible explanation for previous inflation forecast errors in Sweden.
A drawback with the distribution variables in the Phillips curve is that they, as in the present paper, are

exogenous and less useful when forecasting. However, endogenous models for relative prices and hence for the higher moments of relative prices exist but tend to become very complex.[18]

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[18] A possible endogenous model can be found in Bils and Klenow (1998), who show that relative prices on durables and luxuries move disproportionately and procyclically so that both inflation and skewness may be driven by the cycle and aggregate shocks. This hypothesis cannot be rejected for Swedish data using $u_t - u_t^*$ as the measure of the cycle. However, the relationship is not very strong.

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