

In this Economic Commentary the authors try to estimate how persistent inflation in Sweden is and how its persistence has changed over time. Their study shows that the persistence in Swedish inflation has declined since the inflation target was introduced and that it must now be regarded as moderate. Inflation has normalised relatively quickly after being pushed up or down by shocks.

## How persistent is inflation in Sweden?<sup>1</sup>

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After a long period at a low level, the inflation rate rose sharply in Sweden in 2008 and reached its highest level since the mid-1990s (see Figures 1 and 2). The rest of the world followed the same pattern. Rising energy and food prices in particular pushed up inflation. The Riksbank's assessment was that these were temporary price rises and inflation fell already in autumn 2008.

The Riksbank's target is to limit the annual change in the consumer price index (CPI) to two per cent a couple of years ahead. Consequently, it is important for the Riksbank to know the usual size and duration of deviations in inflation after a disturbance in the economy. This is called inflation persistence in the literature. It concerns the propensity of inflation to return to its long-term level after a disturbance. If persistence is high, inflation only falls slowly back to its long-term level after a disturbance, while low persistence means that inflation reverts faster. The duration of inflation, i.e. the degree of inflation persistence, is affected by monetary policy.

There are few previous studies of inflation persistence in Sweden and those that exist do not extend very far in time.<sup>2</sup> In this economic commentary we therefore try to estimate the degree of persistence in Sweden and how it has changed over time. It is reasonable to expect that inflation in Sweden became less persistent after Swedish monetary policy was realigned in the early 1990s, from an exchange rate target to a price stability target.

The main result of our study shows that the degree of persistence of Swedish inflation seems to have decreased since the inflation target was introduced and that it can now be regarded as moderate. However, from this simple analysis we cannot draw the conclusion that the decrease in persistence is due to the realignment of Swedish monetary policy.

### Why does inflation become persistent?

The design of monetary policy affects the degree of inflation persistence. A central bank that pursues a strict inflation target policy and lays great weight on stabilising inflation combats inflationary disturbances more actively than a central bank with a more flexible inflation target policy that also takes into account how production and employment are developing. With a strict inflation target policy the disturbances have less durable effects on inflation, which becomes less persistent.

The economic literature usually distinguishes three different explanations for why inflation persistence arises.<sup>3</sup> One explanation is based on firms for various reasons not changing their prices every day. This means that prices over time deviate from what would otherwise have been expected on the basis of the current economic situation. Since firms expect their prices to be fixed for a period their price setting

<sup>1</sup> We thank Joanna Gerwin, Ulf Söderström and Anders Vredin for valuable comments on earlier drafts.

<sup>2</sup> Adolfson and Söderström (2003) found it difficult to establish that a change in inflation persistence had taken place after the introduction of an inflation target. Their analysis is based on data extending to 2001.

<sup>3</sup> See Whelan (2004).

takes into account the expected future development of relevant economic variables such as the price of raw materials. Since all firms do not react at the same time to changes in the economic situation, price-setting can lead to inflation becoming persistent. In that case inflation inherits the persistence of its determining factors, that is, it becomes as persistent as the factors that govern the development of inflation. This is called “extrinsic persistence”.

Another explanation, “intrinsic persistence” is based on firms partly determining their prices using different rules of thumb or indexing so that today's prices depend on the prices that applied in previous periods. In that way previous inflation influences current inflation.

A third explanation takes as its starting point the fact that firms and households do not have perfect information about the economy and the nature of economic relationships. When a disturbance occurs (for example a change in demand) the actors do not know if the disturbance is permanent or temporary. They therefore try to form an understanding of the nature of the disturbance and meanwhile use historical inflation to forecast future inflation. This form of persistence is called “expectations-based persistence”.

How monetary policy should react after a disturbance depends on what type of persistence is involved. In the case of external persistence monetary policy should not be affected by the permanence of the disturbance in itself, but the central bank's reaction becomes persistent only because the disturbance is persistent. For inherent or expectations-based persistence there may, however, be reason for the central bank to react more vigorously to a disturbance in order to avoid the change in inflation from taking root.<sup>4</sup> However, there is no clear empirical and theoretical boundary between the three types of persistence.<sup>5</sup> Previous studies in the euro area show that the element of extrinsic and expectations-based persistency predominates.<sup>6</sup>

### How is persistence measured?

By persistence is meant purely statistically how lasting the deviations from a long-term mean value will be after a shock. A normal way of measuring the degree of persistence of inflation is to estimate autoregressive models. In these, today's inflation is explained by inflation in earlier periods. The sum of the coefficients for inflation in previous periods functions as a measurement of the degree of persistence.<sup>7</sup> High persistence in the inflation rate means that after a shock it will take a long time before inflation returns to equilibrium (the long-term mean value) and that the long-term effect on the price level will be greater than if the persistence is low. Whether estimated persistence qualifies as high or low is, however, to a great extent subjective. One reference point could be that persistence approaching 1 means that a shock will have a permanent effect, that is, inflation will never return to its original equilibrium level.

Autoregressive models give a purely descriptive measurement of persistence and show how inflation has behaved historically. The models cannot, however, say anything about why persistence arises. To be able to explain that, structural models are required, in which all components of the economy are included.<sup>8</sup>

Estimating the persistence of inflation is associated with considerable methodological problems. An examination of previous empirical studies shows that the results are

<sup>4</sup> Levin and Moessner (2005) discuss optimal monetary policy under different scenarios where there is uncertainty concerning inflation and its persistence.

<sup>5</sup> See Angeloni et al. (2006).

<sup>6</sup> See Dossche and Everaert (2005).

<sup>7</sup> An autoregressive model for inflation ( $\pi_t$ ) at the time  $t$  can be expressed as  $\pi_t = \mu + \sum_{j=1}^K \phi_j \pi_{t-j} + \varepsilon_t$ .

Persistence ( $\rho$ ) can then be measured as  $\rho = \sum_{j=1}^K \phi_j$ . Examples of studies using autoregressive models are Batini (2002), Cecchetti and

Debelle (2005) and Pivetta and Reis (2007).

<sup>8</sup> For example general equilibrium models or structural vector autoregressive (VAR) models, see Cogley et al. (2008).

sensitive to the period of time selected and the inflation series used. The fundamental problem is how the mean value of inflation is to be handled when estimating the model.<sup>9</sup> An attempt must be made to differentiate between inflation with high persistence and inflation with lower persistence, though with different mean values in different periods. An obvious example of an event that affects the mean value of inflation is a change in the inflation target. Previous studies also show that changes in the mean value of inflation are normally linked to changes in the monetary policy regime.<sup>10</sup> If structural changes affect the mean value of inflation, but this value is incorrectly assumed to be constant over longer periods of time, the estimated persistence will be higher. If, on the other hand, when estimating the model allowances are made for changes in the mean value or a shorter time period is used, the persistence measured will often decrease.

### How high is persistence in Sweden?

To measure how persistent Swedish inflation is we have estimated autoregressive inflation models for Sweden. As a measure of inflation we use seasonally adjusted quarterly changes in the consumer price index (CPI) and four other price indices: CPIX, CPIX excluding energy, CPIF and HICP.<sup>11</sup> Figures 1 and 2 show the inflation rate according to the CPI and HICP, for quarterly changes (calculated at an annual rate), and for annual changes.

We decided to study quarterly changes instead of the annual change, which is the most common measure of inflation, since most previous studies have used quarterly data. In all models we have included three lags (time-displaced previous inflation outcomes), but the results are similar even with more lags.<sup>12</sup> We study the period from the first quarter of 1982 up to and including the fourth quarter of 2008. To study the effects of changes in the mean value of inflation we also decided to both allow different mean values before and after the first quarter of 1995, and estimate the models separately from 1995 up to and including 2008. In that way we take into account the realignment of monetary policy when the inflation target was introduced in 1995.<sup>13</sup>

The results of our estimates are presented in Table 1. The estimates for the degree of persistence in the different inflation measures are considerably lower when we allow different mean values before and after 1995 than when the model is estimated for the entire period. The persistency measured for CPI is 0.84 for the entire period, but it falls to 0.65 if we extend the model to capture a lower mean value since 1995.<sup>14</sup> However, it is not only the mean value that seems to have become lower, but also the persistence, which is shown by the fact that the estimate in which only data from 1995 onwards was used is 0.49. This indicates that inflation has become less persistent since the inflation target was introduced. This conclusion also applies to all other measures of inflation reported in Table 1. However, the difference in estimated persistence between the periods in some cases is not statistically significant.<sup>15</sup>

Our results also show that the inflation measurements that are not affected by variations in the mortgage rate for owner-occupied homes – CPIX, CPIF and HICP – show lower persistence than the CPI for the period from 1995. This is because changes in mortgage rates are very persistent.<sup>16</sup>

The estimated persistence rises instead when energy prices are excluded from the inflation measurement; for CPIX excluding energy, it is 0.53, while for the CPIX in

<sup>9</sup> See Perron (1990).

<sup>10</sup> See Bilke (2005) and Levin and Piger (2004).

<sup>11</sup> CPIX is the CPI excluding household mortgage interest costs and the direct effects of changes in indirect taxes and subsidies. The CPIF is the CPI with a fixed mortgage rate. HICP is the harmonised index for consumer prices as defined by Eurostat. See Hansson et al. (2008).

<sup>12</sup> The residuals show no strong signs of series correlation with three lags and further lags have no statistically significant effects.

<sup>13</sup> The Riksbank announced the inflation target in January 1993, but started to apply it from 1995 onwards. Statistical tests date the most probable time for a change in the mean value of Swedish inflation at between 1992 and 1994, depending on the inflation measure used. The estimate of persistence is not especially affected by the exact time chosen.

<sup>14</sup> Different disturbances have different persistent effects on inflation. This is the average persistence for the disturbances occurring during the period.

<sup>15</sup> A change is often regarded as being statistically significant if it is double the size of the estimated standard error.

<sup>16</sup> It is important to remember that the Swedish CPI is fairly unusual in the world in this respect. In the euro area and the USA the CPI is not directly affected by variations in market rates. In international comparisons it is therefore better to study the results for the HICP. Measured in this way inflation persistence is low in Sweden compared with other countries.

total it is 0.19 in the period from 1995. This may in turn be explained by the volatility of energy prices. Historically, steep rises in energy prices are often followed by falling energy prices, which helps reduce the estimated persistence.

Results from previous studies made for the euro area show the same pattern as for Sweden, even though the fall in persistence is somewhat less. The Inflation Persistence Network, a research project initiated by the European Central Bank (ECB), has compiled previous research in the area and found that estimates of inflation persistence are of the order of 0.40–0.60 when the regime shift in monetary policy is taken into account.<sup>17</sup> These results are confirmed by our own analysis for the HICP in the euro area. The estimated persistence for the HICP in the euro area in the period 1995–2008 is 0.42 in our calculations, which is higher than for the HICP in Sweden (see Table 1).

What qualifies as a high or low degree of persistence respectively is, as previously mentioned, subjective. The conclusion of the ECB Inflation Persistence Network in their review is that persistence in the euro area was in the interval 0.40–0.60 and was "moderate". A persistence of 0.49, corresponding to persistence for CPI inflation in Sweden after the Riksbank introduced the inflation target, can therefore also be regarded as moderate. At the same time, persistence of 0.84 for the entire period from 1982 would seem to be relatively high. On the other hand, persistence in Sweden is considerably lower if inflation is measured by the HICP, the measurement used in the ECB studies.<sup>18</sup> Measured in this way, the persistence of Swedish inflation is on average 0.21 after the introduction of the inflation target.

### **What does high or low persistence mean?**

To illustrate the dynamics in the process of inflation adjustment in different degrees of persistence, in Figure 3 we show how inflation develops after an unexpected shock. The figure is based on some of our estimates for different inflation measurements and periods. It shows that the effects of a shock that pushes up inflation by one percentage point in the first quarter will quickly subside when there is moderate persistence for CPI inflation. Already in the following quarter about three quarters of the shock will disappear, and after one and a half years inflation will be less than 0.1 percentage points higher than in equilibrium.<sup>19</sup>

When instead we measure inflation by the HICP, persistence is even lower for the period from 1995 and the effect of a shock subsides very quickly. Already after one year the inflation is only insignificantly higher than in equilibrium.

When persistence is high, for example the persistence we measured for the entire period from 1982, the shock has a considerably more long-lived effect on inflation. After five years 10 per cent of the effect of the shock on inflation still remains.

The most common measurement of inflation is, however, the annual percentage change in the CPI or another index, which approximately corresponds to the sum of the percentage changes in price level in the four last quarters. Measured in this way the effects on inflation will of course be considerably more long-lasting, but that is only an effect of a technical nature. Figure 4 shows that it takes much longer for the effects of a shock to subside when we convert the dynamics of the inflation adjustment process to an annual change.

<sup>17</sup> See Altissimo et al. (2006) for an overview of studies made for the euro area.

<sup>18</sup> The HICP does not include mortgage interest costs for home owners.

<sup>19</sup> The estimates of the three autoregressive coefficients are 0.34; 0.20 and 0.29 for the CPI for the entire period 1982–2008. For the shorter period 1995–2008 the estimates for the CPI are 0.27; 0.09 and 0.24 and for the HICP 0.14; 0.15 and 0.05.



## Concluding remarks

Our study indicates that persistence in Swedish inflation has decreased since the introduction of the inflation target and that it is now moderate. This is confirmed by the fact that inflation in Sweden rose steeply from the end of 2007, but quickly subsided already in autumn 2008. However, we cannot draw any conclusions from this analysis concerning the reasons for the observed decrease in persistence. Since the realignment of monetary policy other types of changes to the functioning of the economy can have taken place, which may have affected the relationships we have investigated. For example, the shocks that took place can have become less long-lasting, which would have led to lower persistence in inflation even if monetary policy had not changed. Several studies show, however, that persistence is lower in countries with inflation targets than in other countries.<sup>20</sup>

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<sup>20</sup> See for example Mishkin and Schmidt-Hebbel (2006).

**Table 1. Estimated persistence of inflation in Sweden**

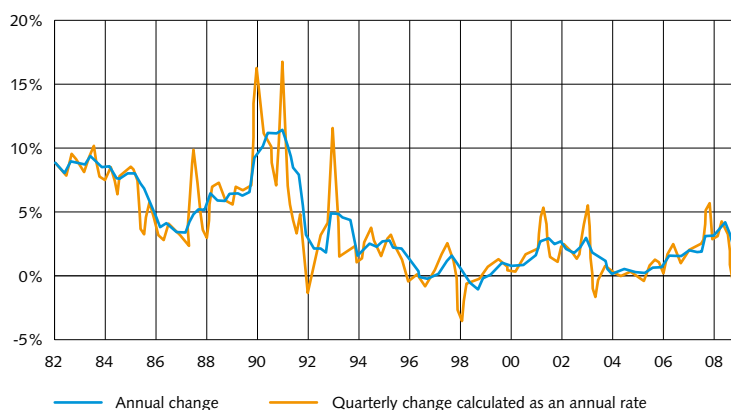
Total of autoregressive coefficients and standard error

	1982–2008	1982–2008 with change in mean 1995	1995–2008
CPI	0.84 (0.07)	0.65 (0.11)	0.49 (0.18)
CPIX	0.85 (0.06)	0.71 (0.10)	0.19 (0.22)
CPIX excl. energy	0.89 (0.05)	0.75 (0.09)	0.53 (0.16)
CPIF	0.83 (0.07)	0.65 (0.11)	0.14 (0.22)
HICP	0.84 (0.07)	0.67 (0.11)	0.21 (0.21)

Note: The CPIX is the CPI excluding household mortgage interest costs and the direct effects of changes in indirect taxes and subsidies. The CPIF is the CPI with a fixed mortgage rate. The HICP is the harmonised index for consumer prices as defined by Eurostat. All data is seasonally adjusted using the X12 method. Estimated standard error for the coefficients is given in brackets.

**Figure 1. CPI in Sweden**

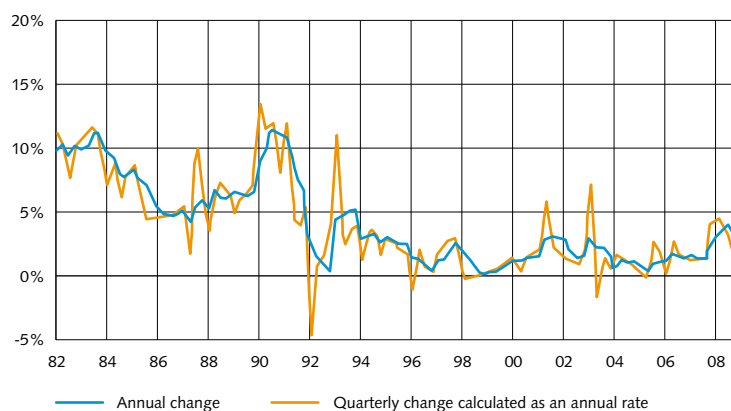
Percentage change, seasonally adjusted quarterly data



Sources: Statistics Sweden and the Riksbank.

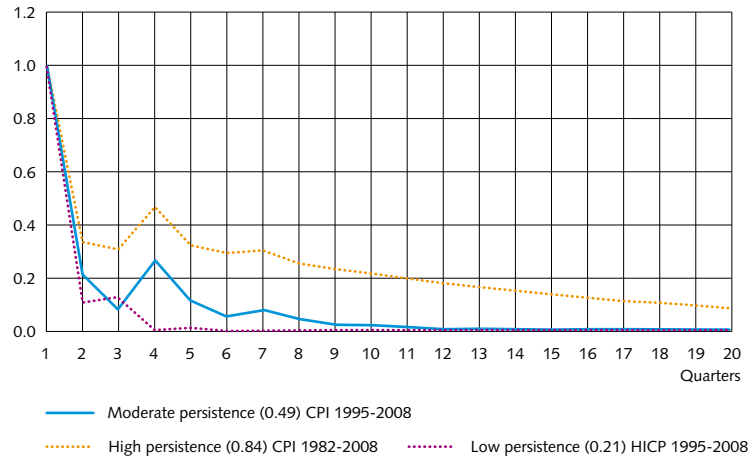
**Figure 2. HICP in Sweden**

Percentage change, seasonally adjusted quarterly data

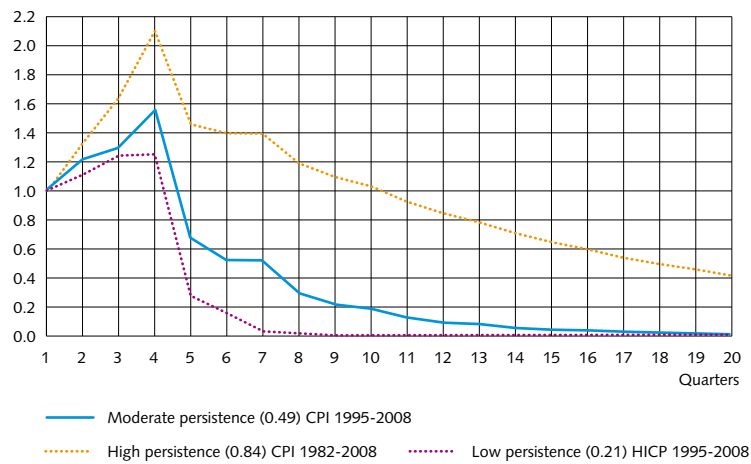


Sources: Statistics Sweden and the Riksbank.

**Figure 3. Dynamics of inflation after a positive shock, quarterly change**  
Per cent



**Figure 4. Dynamics of inflation after a positive shock, annual change**  
Per cent



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