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# THE ECB IN THE FACE OF AN UNPRECEDENTED ENERGY PRICE SHOCK

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## Introduction and summary

In 2022 the ECB seemed helpless in the face of an unprecedented energy price shock as euro area inflation neared 10%. However, the attention on energy prices has obscured the fact that the real surprise was that all other prices, the so-called core inflation, also started to increase at unprecedented rates, reaching 7% at its peak. Should the ECB have seen this increase in core inflation coming?

We answer this question by emphasizing the difference between hindsight and the information the ECB had at the time of the energy price shock. We show that a model trained only on data until end-2021 would have predicted a much smaller increase in core inflation even with the extraordinary increase in energy prices that materialized in mid-2022. The relationship between energy and core inflation thus changed over the last 2 year. Not surprisingly, a model estimated on a period that includes data up to mid-2023 would have been able to predict the recent movements of core inflation (and thus overall inflation).

Additionally, we show that core inflation is normally stickier during periods of high growth, and a bit less responsive to energy price shocks when they put downwards pressure. This might in part explain some of the delay the EA is experiencing in the speed of disinflation compared to the inflationary steepness of the spike.

To provide a formal test whether the 2022-2023 period was exceptional and unpredictable, we use a Markov autoregressive switching model, which suggests indeed there has been a shift in several aspects of core inflation behavior: its magnitude, its rate of change and its stickiness as well as its responsiveness to energy prices.

Using the coefficients from the updated model we then simulate the path of core inflation up to 2024 finding that core inflation should rather quickly approach the policy target of 2%, assuming that energy prices continue to fall slowly.

## Inflation Patterns

With the post-Covid resumption of economic activity in 2021, both energy prices and core inflation had begun to rise again,. By end-2021 energy prices were still low, but they already had begun to increase strongly after the pandemic-induced slump. However, the ECB waited for almost half a year before starting its tightening cycle because its models showed a rapid return of inflation to the 2% target. (Gros-Shamsfakhr, 2022).

What was the basis for confidence that rising energy prices would not lead to a sharp increase in inflation? One simple explanation is that in the past even high energy prices inflation had not led core inflation to rise above 2%.

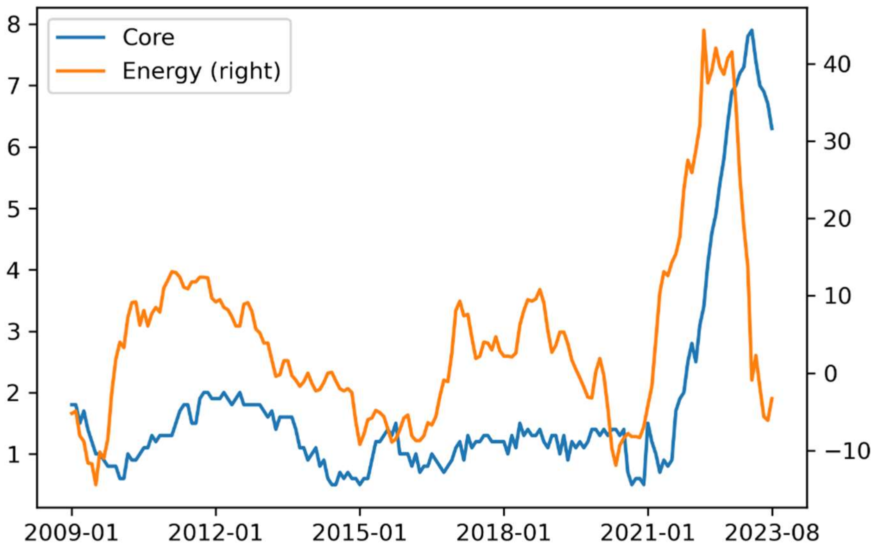
This is illustrated in Figure 1 that shows monthly inflation figures from Eurostat focusing on full HICP and energy-HICP, beginning in January 2009. Clearly the response in core inflation to energy prices in 2021-2023 surpasses any previous relationship between the two variables. The periods of high energy price inflation around 2012 and 2018 had not been associated with a noticeable increase in core inflation.

An important point of our analysis is that we use the energy price component of the HICP as the main indicator, not the spot market prices for oil and natural gas. This difference is important because the prices for natural gas paid by households, which enter the HICP, react only with considerable lag the spot prices as consumer energy prices are highly regulated. Once market price for natural gas had increase (this was the case already by end 2021) the ECB could have anticipated much of the increase in the energy HICP over the following months.

**Figure 1:**

Monthly inflation from HICP index excluding energy (core) and HICP only energy prices

(Measure: percentage changes compared to the same month in the previous year.)




As we show in a recent paper (Galeone-Gros, 2023), core inflation responds to energy prices with a lag, mediated mainly by changes in short-run expectations. Chart 1 seems to confirm this story. What would like to explore further, however, is if this relationship has changed its magnitude in the recent inflation episode.

## Forecasting 2022-2023

Judging in hindsight is a rather easy task. Many commentators have argued that the ECB's response to the price shock came too late and was too weak at the onset. We do not wish to exploit hindsight and therefore try to assess whether the ECB could have forecasted the coming increase in core inflation, based on the available data at the end of 2021.

To do so, we run an OLS regression using the available monthly inflation data up to December 2021, as shown in the first column Table 1.[1] We then simulate the path of core inflation going forward into 2022-2023 by using the estimated parameters, including the autoregressive pattern) combined with the realized values for (HICP) energy prices. In Figure 2, the panel on the left shows that the prediction based only on the patterns observed until 2021 grossly underestimates the rise in core inflation in response to the energy shock.  This is consistent with the general finding of the pre-2022 literature that energy prices had little impact on core inflation (ECB 2016, Abdih et al. 2018).

**Table 1:**

OLS estimation of Euro area core inflation explained by energy HICP and 1-month lag of core inflation

(The dependent variable and "Lag1" refer to HICP excluding energy prices, from Eurostat. "Energy" refers to the energy prices component of the HICP from the same source.)

| | 2009-2021 | 2009-2023 |
|---|---|---|
| **Energy** | 0.011*** | 0.011*** |
| | (0.002) | (0.002) |
| **Lag1** | 0.819*** | 0.976*** |
| | (0.041) | (0.011) |
| **Intercept** | 0.206*** | 0.019 |
| | (0.051) | (0.024) |
| **R-squared** | 0.799 | 0.984 |
| **R-squared Adjusted** | 0.796 | 0.983 |
| **F-statistic** | 303.292 | 5158.186 |

[1] The observation period starts in 2009 to exclude the impact of the euro sovereign debt crisis.

The result changes completely if one uses hindsight. When we include the 2022-2023 observations in the regression we obtain different parameters as can be seen in the right-hand column of Table 1 and they clearly show that the strength of the autoregressive component increases noticeably when including the 2022-2023 period.

Figure 2's right-hand panel shows graphically that when we use the estimate that includes 2022-23 data the projected increase in (core) inflation is much higher (with the same path of energy prices) and much closer to the actual path. In other words, it seems that it would have been hard for the ECB to predict the strength of the core inflation response, unless, of course it had reason to suspect a structural break in the relationship between energy and core inflation.

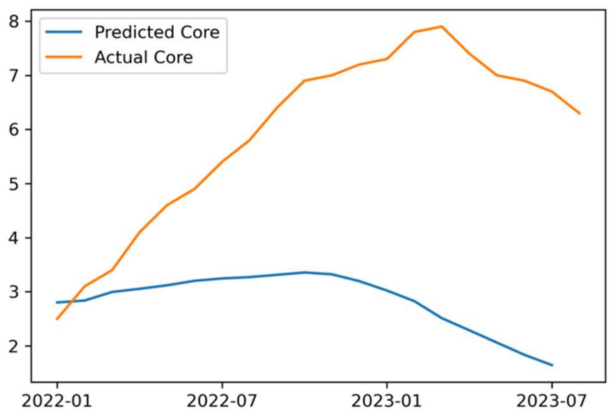
One key reason to suspect a structural break is the fact that the 2022 spike in energy inflation came from increases in the price of natural gas which is an important input in the production of many goods (steel, tiles, etc.) and some services (hotels, restaurants). Moreover, the price of natural gas for industry and commercial users increased much more along with the spot prices than those for household consumers that are reflected in the HICP. With the spot market price of natural down from its 2022 peak one would thus expect at least initially a strong impact on core inflation.

**Figure 2:**

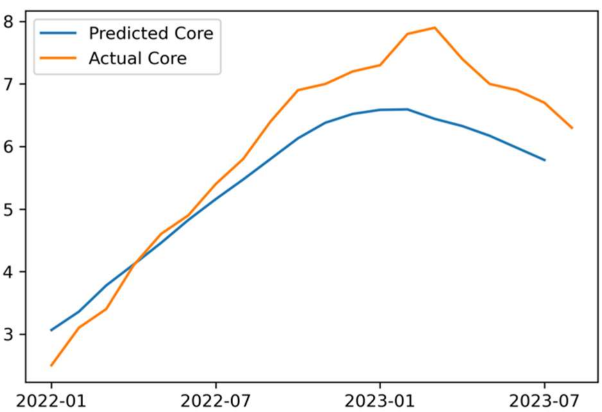
Predicted path of core inflation estimated using 1-month lagged values and energy prices

(Measure: percentage changes compared to the same month in the previous year.)

Using 2009-2021 data:




Using 2009-2023 data:

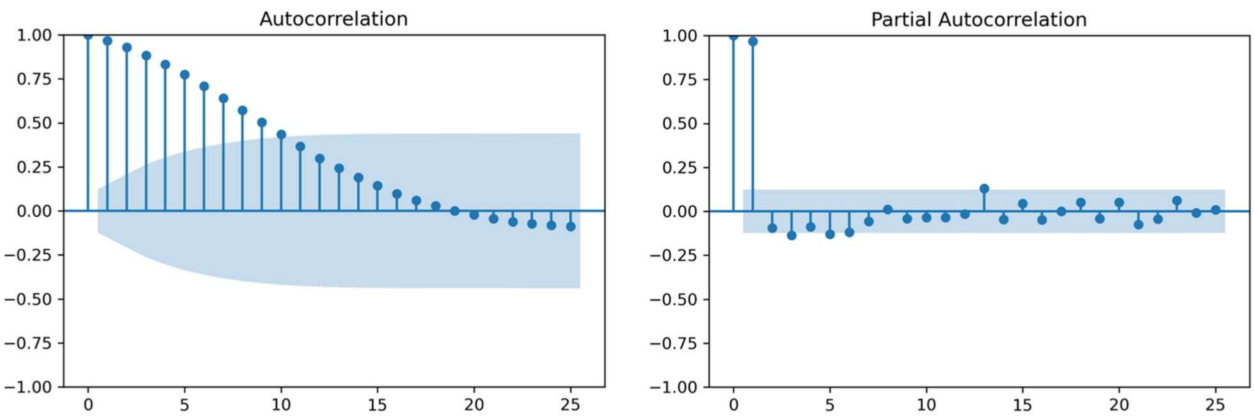


## How sticky is inflation?

The estimates that comprise also the 2022-2023 period find that the previous-month value of core inflation became much more significant during the energy crisis. This speaks to a degree of stickiness of core inflation, which might help explain part of the delay in the expected inflation reduction.

**Figure 3:**

Autocorrelation plots for core inflation.




First of all, to ensure the use of the right number of lags, as shown in Figure 3, we calculate the autocorrelation and partial autocorrelation coefficients for the first few lags of core inflation and it is immediately visible that the strong stickiness in core inflation is explained mostly through the first monthly lag.

As the previous section showed us, however, this stickiness might be varying over time. To check whether that is the case, we run a similar regression but now include a term to incorporate growing inflation. We create a dummy variable that takes value 1 if the 12-month rolling average of core inflation is greater than the one of the previous month ("Growing"). We show the resulting regression in column I of Table 2 below. We also check using a similar dummy for the growth of energy prices.

As Table 2 shows, in periods of growing prices, inflation is indeed stickier than in usual times. Additionally, since core inflation follows energy inflation with a lag, as Figure 1 showed, as energy prices decrease from an inflationary spike, core inflation is a bit stickier on the way down as well. The combination of these two factors could help explain why many observers were worried about the lack of response by core inflation to the falling energy inflation in 2023.

**Table 2:**

OLS estimation of Euro area core inflation explained by energy HICP, 1-month lag of core inflation, and a growth dummy for core inflation and energy prices.

(The dependent variable and "Lag1" refer to HICP excluding energy prices, from Eurostat. "Energy" refers to the energy prices component of the HICP from the same source. "Growing" and "Enrg_grow" refer to the 12-month rolling average of core inflation and energy price inflation, respectively, being greater than the previous month's.)

| | Core Inflation (I) | Core Inflation (II) |
|---|---|---|
| **Energy** | 0.002 | 0.010*** |
| | (0.002) | (0.002) |
| **Lag1** | 0.919*** | 0.983*** |
| | (0.011) | (0.012) |
| **Growing*Energy** | 0.004 | |
| | (0.003) | |
| **Growing*Lag1** | 0.112*** | |
| | (0.014) | |
| **Enrg_grow*Energy** | | 0.002 |
| | | (0.003) |
| **Enrg_grow*Lag1** | | -0.030* |
| | | (0.018) |
| **Intercept** | 0.049** | 0.024 |
| | (0.020) | (0.024) |
| **R-squared** | 0.989 | 0.984 |
| **R-squared Adjusted** | 0.989 | 0.983 |
| **F-statistic** | 3892.104 | 2593.653 |

## Regime shift: Markov switching model

As already mentioned, the last two years have not witnessed a simple rise in inflation. The response of core inflation to energy prices has been stronger than it was in the pre-war period. To test more precisely whether there has been a regime shift, we use a Markov switching model, an estimation technique which allows us to check for two states of different inflation behavior.

First, we estimate an autoregressive Markov switching model, using only lags of core inflation and find a statistically significant existence of two states: a low-inflation state, with a core inflation intercept below 2%, and a high-inflation one with intercept above 2%. Moreover, the strength of the first lag signals a strong autocorrelation.  The two states are rather sticky, with a transition matrix probability from each state of a switch to the other one below 10%. Appendix Table A1 shows the estimation coefficients and transition matrix and Figure A1 shows the filtered marginal probabilities of being in the low-inflation regime.

This specification suggests a key regime change; however, is not informative enough. The analysis from the previous section suggests that the significance of the lag is different across regimes. For this reason, we further allow the Lag parameters to change across states, and find that in the high-inflation regime, the first lag is statistically very significant, while in the low-inflation regime it isn't. This suggests that the low inflation regime is rather stationary, while in the high-inflation regime core inflation is much stickier. Appendix Table A2 shows the coefficients and transition probabilities in this case.

As a final check, we use a different model, no longer autoregressive, with the dependent variable expressed in inflation changes with respect to four months prior (the choice of lag is the one that allows for the highest explanatory power). The goal is to check whether there are different inflation patterns based on whether inflation, rather than being high or low, is growing or declining. We run two versions of this model: one with fixed variance and one allowing variance to change across regimes.

Table 3 below shows something key for our analysis. The EU inflation path in the past 15 years can be divided into two clearly distinct regimes: one state in which inflation is rather stationary and variance is low, and one high-variance state in which inflation is growing.

The resulting simulated marginal probabilities of being in the non-increasing inflation state are depicted in the following Figure 4. As it's apparent from the Figure, the past two years have been a period of unprecedented inflation growth that could have been difficultly predicted using the instruments, and estimation coefficients, of previous periods.

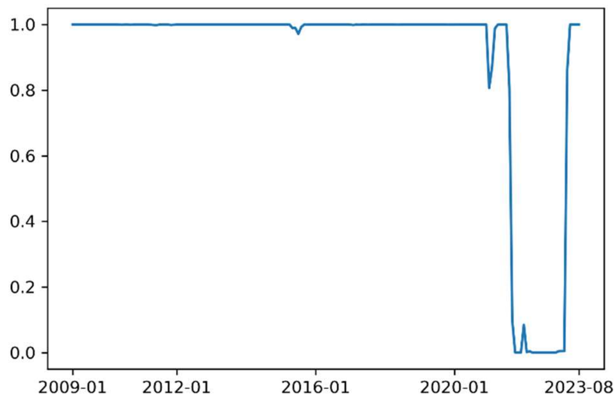
**Table 3:**

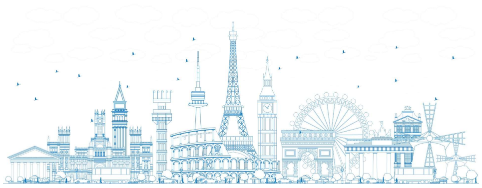
Markov switching autoregressive model on core inflation changes, with fixed and switching variance.

| | Regime 0 | Regime 1 |
|---|---|---|
| **Non-switching variance** | | |
| **Intercept** | -0.061** | 1.346*** |
| | (0.030) | (0.084) |
| **Variance** | 0.137*** | |
| | (0.015) | |
| Transition probabilities | | |
| | **p[->0]** | **p[->1]** |
| **p[0->]** | 0.994 | 0.006 |
| **p[1->]** | 0.056 | 0.944 |
| **Regime-switching variance** | | |
| **Intercept** | -0.004 | 0.363** |
| | (0.036) | (0.145) |
| **Variance** | 0.065*** | 0.937*** |
| | (0.020) | (0.235) |
| Transition probabilities | | |
| | **p[->0]** | **p[->1]** |
| **p[0->]** | 0.982 | 0.018 |
| **p[1->]** | 0.025 | 0.975 |

**Figure 4:**

Smoothed marginal probabilities of being in an increasing inflation state.



## Going forward

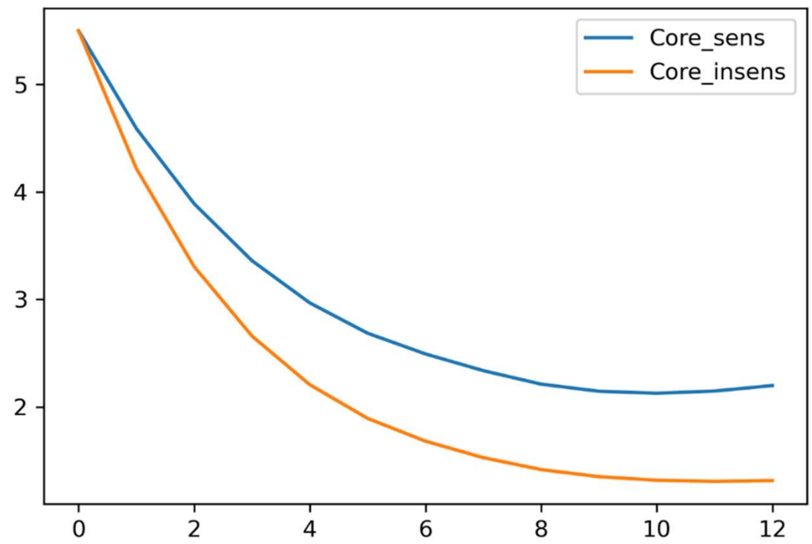
What does this model tell us about the path of future inflation? In order to make a prediction about the next 12 months, we need to make two assumptions. The first is about the evolution of energy prices. We set our assumed values for energy inflation in line with the European Commission, which predicts the following: "Energy prices are set to continue declining for the remainder of 2023, but at a slowing pace. They are projected to increase slightly again in 2024, driven by higher oil prices."

As a result, we assume a smooth approach from the current -5% in October 2023 towards 0% energy inflation in March 2024 through a monthly reduction of 1 percentage point, stay at 0 for three months and then climb up to 4% through a monthly rise of 1 percentage point until the end of the 12-month prediction window (October 2023 – September 2024).

Secondly, we need to choose what coefficients to use. In order to combine a regime shift with the path of energy inflation, we run a Markov switching model that includes both one-period core inflation lag and energy inflation. The estimation suggests the presence of two regimes: one with a higher sensitivity of core inflation to energy prices and greater stickiness, and one lower-sensitivity "regular" state. The resulting coefficients and smoothed marginal probabilities plot are reported in the Appendix. As the plot shows, the high-sensitivity state begins in 2021 and continues until present.

**Figure 5:**

Prediction of core inflation for the next 12 months



We use these coefficients, and the projected path of energy inflation, to simulate the path of core inflation starting from September 2023's value. The path, however, depends on whether the economy switches out of the high-sensitivity regime or stays in it. In Figure 5, we plot the projected path in both cases: both whether core inflation stays in the high-sensitivity regime or whether it reverts to the low-sensitivity regime.

As it is apparent from the plots, core inflation should continue decreasing. The exact magnitude of the decrease depends on whether the economy reverts to the previous low-sensitivity state or whether it stays in the high-sensitivity state. The difference in magnitude at the end of the projection 12 months ahead is only about 1 percentage point. But this 1 percentage point interval comprises the 2% inflation target.  This implies that in one state inflation will stop its decline (and will start increasing again towards the end of the forecasting horizon) whereas in the other it will bottom out below 2%.

We use these coefficients, and the projected path of energy inflation, to simulate the path of core inflation starting from September 2023's value. The path, however, depends on whether the economy switches out of the high-sensitivity regime or stays in it. In Figure 5, we plot the projected path in both cases: both whether core inflation stays in the high-sensitivity regime or whether it reverts to the low-sensitivity regime.

# Conclusion

Our starting point was the stark increase in non-energy price inflation, which is the key element for the ECB since monetary policy cannot do anything about energy prices. Could the ECB have foreseen this development? Our analysis suggests that this would have been difficult based on past experience. The fundamental challenge for the ECB was to recognize early a regime shift in inflation.

We document this shift. We find also that in times of high-inflation and growing inflation, the degree of stickiness of core inflation increases, i.e. the magnitude of the autoregressive component of inflation increases. Additionally, the data suggests that the euro area economy has entered a regime of both higher inflation and higher inflation growth, in which the sensitivity of core inflation to both energy prices and its lags is stronger.

The causes of this sensitivity are an interesting topic to explore. As mentioned above, the role of natural gas prices as an input for both some goods and some services might be one reason, but a deeper investigation is outside of the scope of this paper.

In hindsight, of course, we can explain the patterns of the past few months, but the analysis and the calculated coefficients also allow us to predict the path of inflation. The main open question is whether the high-sensitivity regime will persist or whether we will return to "normal times". Either way, however, the projected path of core inflation is strongly downwards, approaching – or possibly going below – the ECB's target in the next 12 months.

Recognizing regime shifts is the key reason why monetary policy remains so difficult. But this is what central bankers are paid for.

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# APPENDIX

**Table A1:**

Markov switching autoregression model on core inflation, fixed parameters and variance.

| | Regime 0 (low inflation) | Regime 1 (high inflation) |
|---|---|---|
| **Intercept** | 1.890*** (0.533) | 2.437*** (0.534) |
| **Lag1** | 0.914*** (0.061) | |
| **Lag2** | 0.591*** (0.086) | |
| **Lag3** | -0.237*** (0.089) | |
| **Lag4** | -0.287*** (0.066) | |
| **Variance** | 0.024*** (0.002) | |
| **Transition probabilities** | | |
| | **p[->0]** | **p[->1]** |
| **p[0->]** | 0.970 | 0.030 |
| **p[1->]** | 0.096 | 0.904 |

**Figure A1:**

Filtered marginal probabilities of being in the low-inflation state.

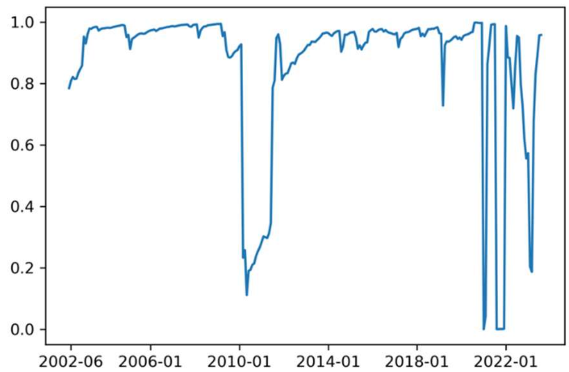

**Table A2:**

Markov switching autoregression model on core inflation, fixed parameters.

| | Regime 0 (low inflation) | Regime 1 (high inflation) |
|---|---|---|
| **Intercept** | 0.564*** | 1.620*** |
| | (0.098) | (0.309) |
| **Lag1** | -0.452 | 1.046*** |
| | (0.697) | (0.081) |
| **Lag2** | -0.078 | 0.269** |
| | (0.629) | (0.118) |
| **Lag3** | 0.167 | -0.110 |
| | (0.612) | (0.122) |
| **Lag4** | -0.164 | -0.217** |
| | (0.622) | (0.092) |
| **Variance** | 0.041*** | |
| | (0.005) | |
| **Transition probabilities** | | |
| | **p[->0]** | **p[->1]** |
| **p[0->]** | 0.779 | 0.221 |
| **p[1->]** | 0.007 | 0.993 |

**Table A3:**

Markov switching autoregression model using core inflation and energy inflation.

| | Regime 0 (low sensitivity) | Regime 1 (high sensitivity) |
|---|---|---|
| **Intercept** | 0.312*** | 0.324*** |
| | (0.074) | (0.079) |
| **Lag1** | 0.723*** | 0.807*** |
| | (0.064) | (0.023) |
| **Energy** | 0.014*** | 0.035*** |
| | (0.004) | (0.004) |
| **Transition probabilities** | | |
| | **p[->0]** | **p[->1]** |
| **p[0->]** | 0.987 | 0.013 |
| **p[1->]** | 0.006 | 0.994 |

**Figure A2:**

Smoothed marginal probabilities of being in the high-sensitivity state.