Reading between the lines – Uncovering asymmetry in the central bank loss function

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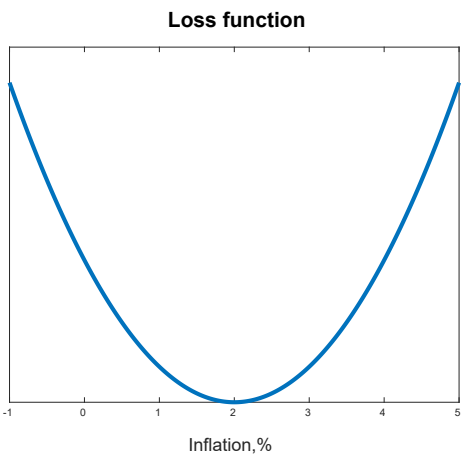
Background

- In macroeconomic models, it is typically assumed that central banks' (CB) preferences can be summarised through a loss function.
  - The loss function is usually assumed to be quadratic, U-shaped and **symmetric**. (E.g. Woodford 2003, Galí 2008)
  - However, a welfare-based loss function may exhibit **asymmetries**. (Yun 2006, Benigno and Rossi 2021, Gross and Hansen 2021)

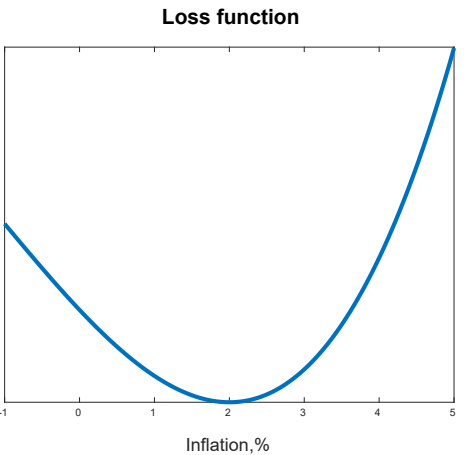
- In this paper we use text analysis to directly estimate the ECB's loss function during its first two decades.
  - Was the ECB's loss function **symmetric** or **asymmetric**?

Central bank loss function

Textbook type



Asymmetric welfare-based



ECB's definition of price stability

- In 1998, the GC **defined** price stability as a
  - *'year-on-year increase in the Harmonised Index of Consumer Prices (HICP) for the euro area of below 2%'*
- In 2003, the GC **clarified** that
  - *'in the pursuit of price stability it aims to maintain inflation rates below, but close to, 2% over the medium term'*
- In July 2021, the GC adopted a **new definition** of price stability
  - *'[GC] considers that price stability is best maintained by aiming for a 2% inflation target over the medium term. This target is symmetric, meaning negative and positive deviations of inflation from the target are equally undesirable.'*

This paper

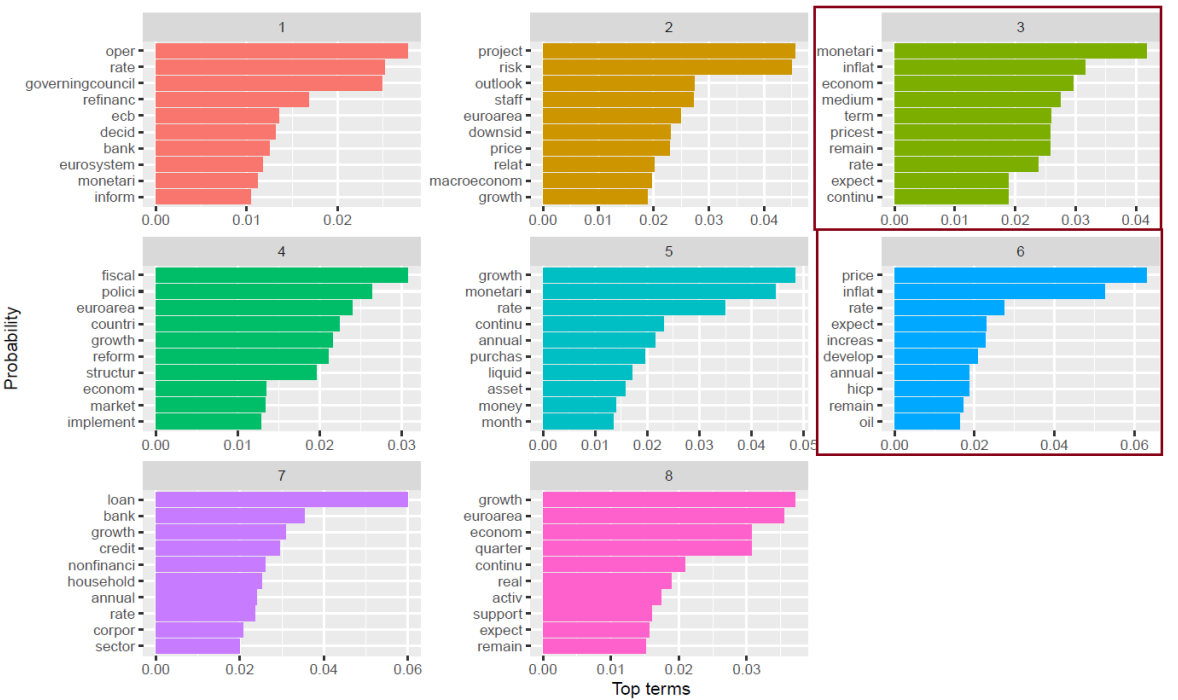
- We infer the ECB's policy preferences by analysing the key component of ECB's formal communication: the introductory statements.
- We use text analysis to extract the tone (sentiment) from those statements.
- We combine the tone with real-time information on inflation, the real economy and financial markets, and estimate the ECB's loss function.
- Time period analysed: **January 1999 – June 2021**.

Text analysis

1. Topic modelling: identifying inflation-focusing segments within introductory statements.
2. Sentiment analysis:
   - Lexicon-based approach
   - Language model FinBERT

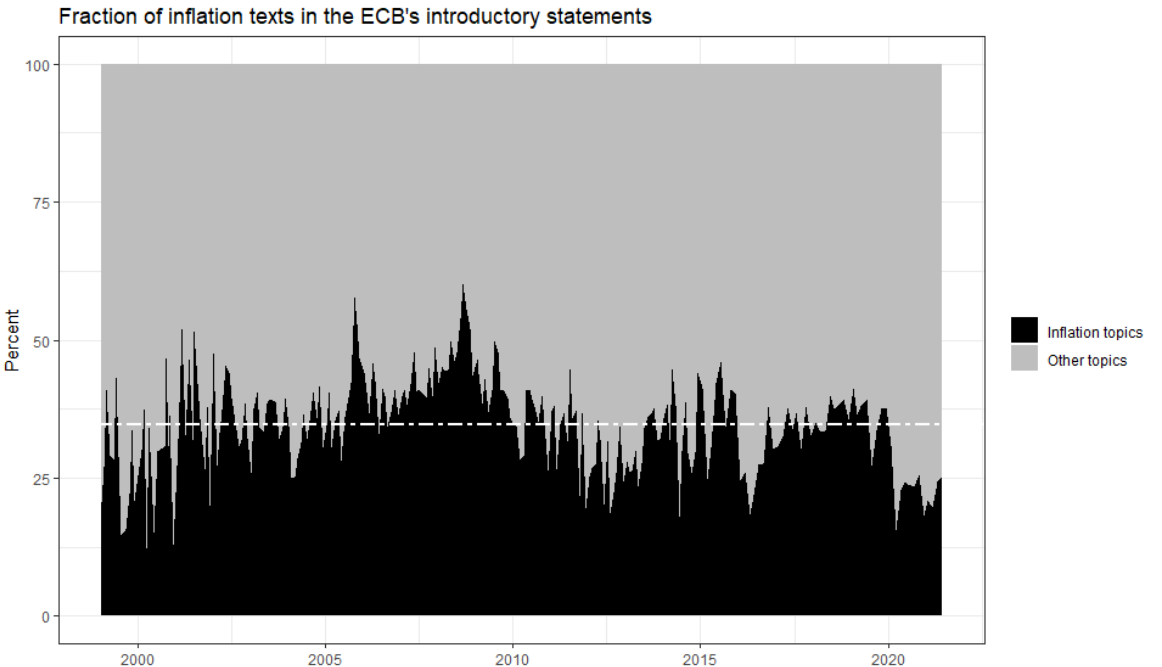
- 4 tone indices:
  1. Lexicon-based, inflation-focusing segments
  2. Lexicon-based, whole introductory statements
  3. FinBERT-based, inflation-focusing segments
  4. FinBERT-based, whole introductory statements

Topic modelling: identifying inflation texts



- **Method:** Latent Dirichlet Allocation (LDA).
- **Main idea:** Text paragraphs which share the same vocabulary are likely to belong to the same topic.
- **Inflation texts:** Topics 3, 6.

Share of inflation texts



- Inflation has been a prominent topic in the introductory statements over the years, with varying degrees of emphasis.

Lexicon-based sentiment analysis

- We follow Shapiro and Wilson (2022) and use Loughran and McDonald (2011) finance-specific dictionary...
- .. which we modify to better suit the ECB's communication:
  - British English
  - Add sentiment words, remove sentiment words
  - Bigrams, trigrams
  - Negations
- We define the tone index as the difference of the number of negative and positive words, normalized with the total number of words in the ECB introductory statement:

$$N_t = \frac{\#Neg - \#Pos}{\#Tot} \tag{1}$$

Sentiment analysis with FinBERT language model

- FinBERT is a language model tailored for financial texts and designed for sentiment analysis.
- FinBERT assigns the probability that a text is positive, negative or neutral.
- With FinBERT we can compute a context-aware tone index.

Scored example text

Introductory statement from 6.10.2011

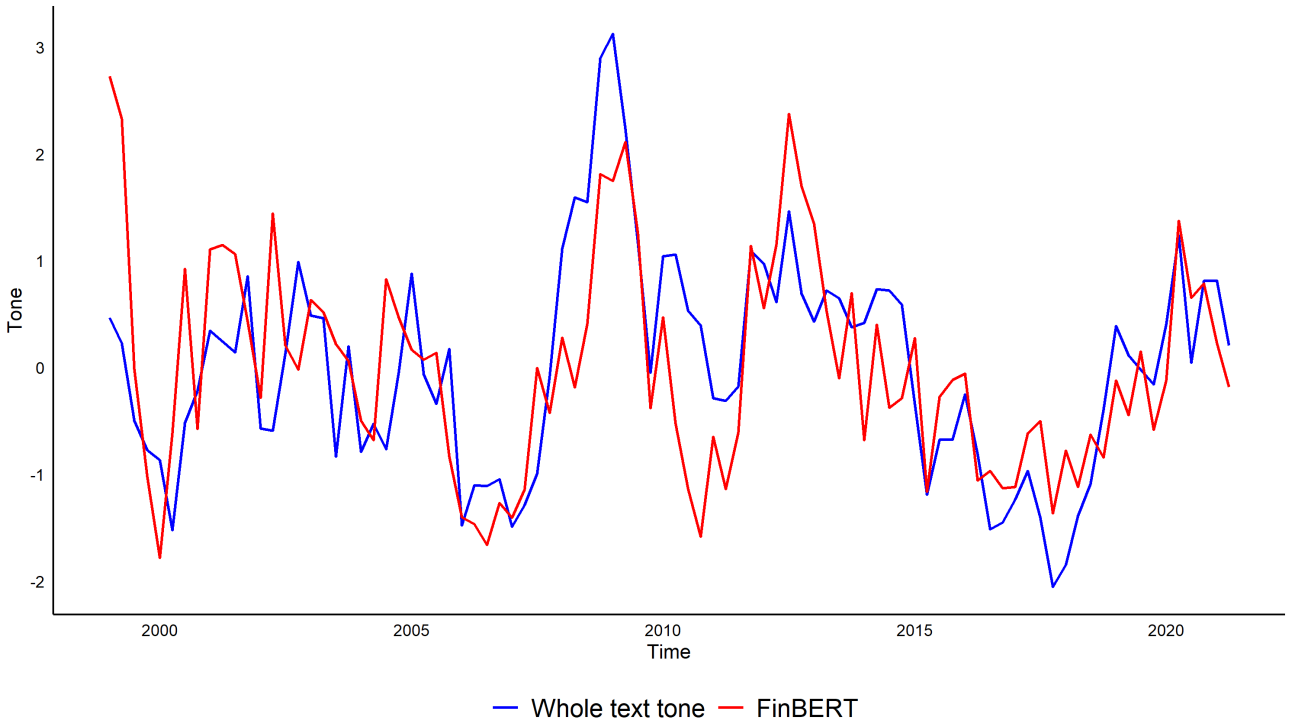
Example: Positive, **Negative**

*'Let me now explain our assessment in greater detail, starting with the economic analysis. Real GDP growth in the euro area, after **slowing** in the second quarter of 2011 to 0.2% quarter on quarter, is now expected to be very moderate in the second half of this year. In particular, a number of factors seem to be **dampening** the underlying growth momentum in the euro area, including a moderation in the pace of global demand, falling consumer and business confidence, and **unfavourable** effects on financing conditions resulting from ongoing **tensions** in a number of euro area sovereign debt markets. At the same time, we continue to expect euro area economic activity to benefit from continued positive growth in the emerging market economies as well as from the low short-term interest rates and the various measures taken to support the functioning of the financial sector.'*

Positive	*Negative*	*Neutral*	*sentiment*
0,15584138	*0,801850557*	*0,042308003*	*negative*

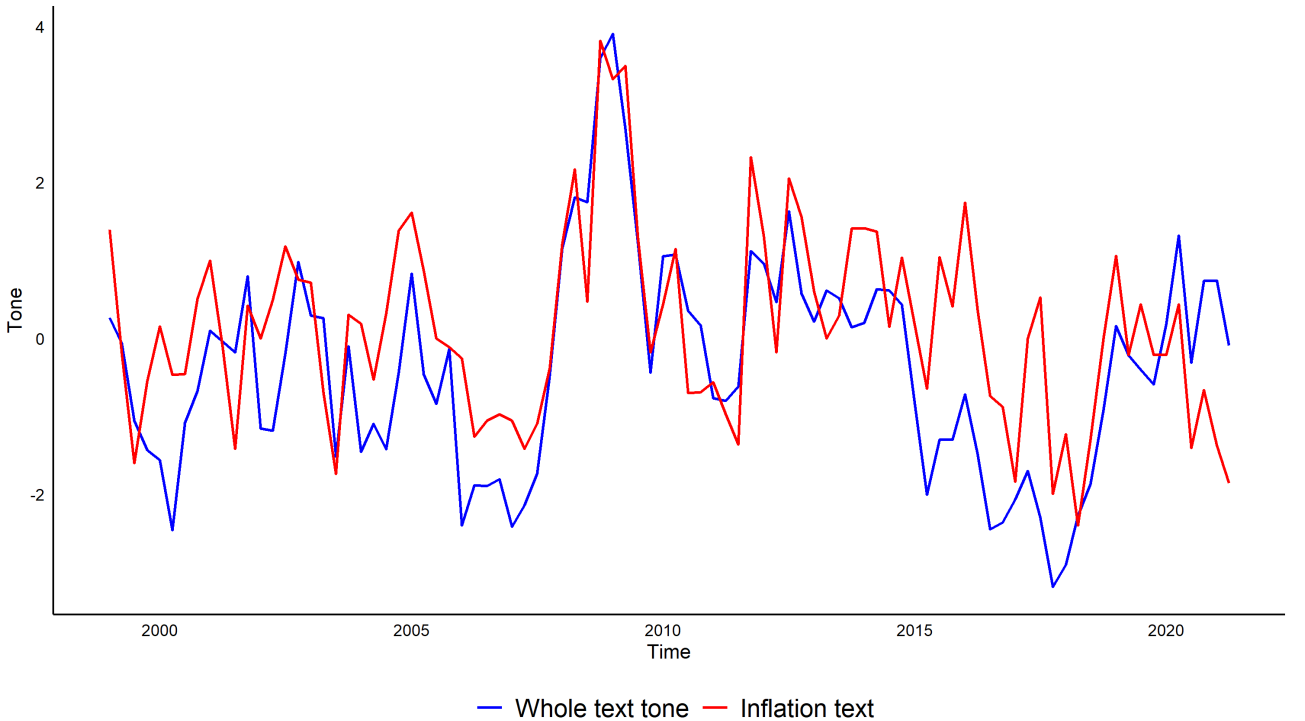
- The lexicon-based approach detects 2 **positive** and **4 negative** sentiment words.
- FinBERT assigns a high probability to the paragraph's sentiment being **negative**.

Lexicon-based and FinBERT-based tone, whole texts

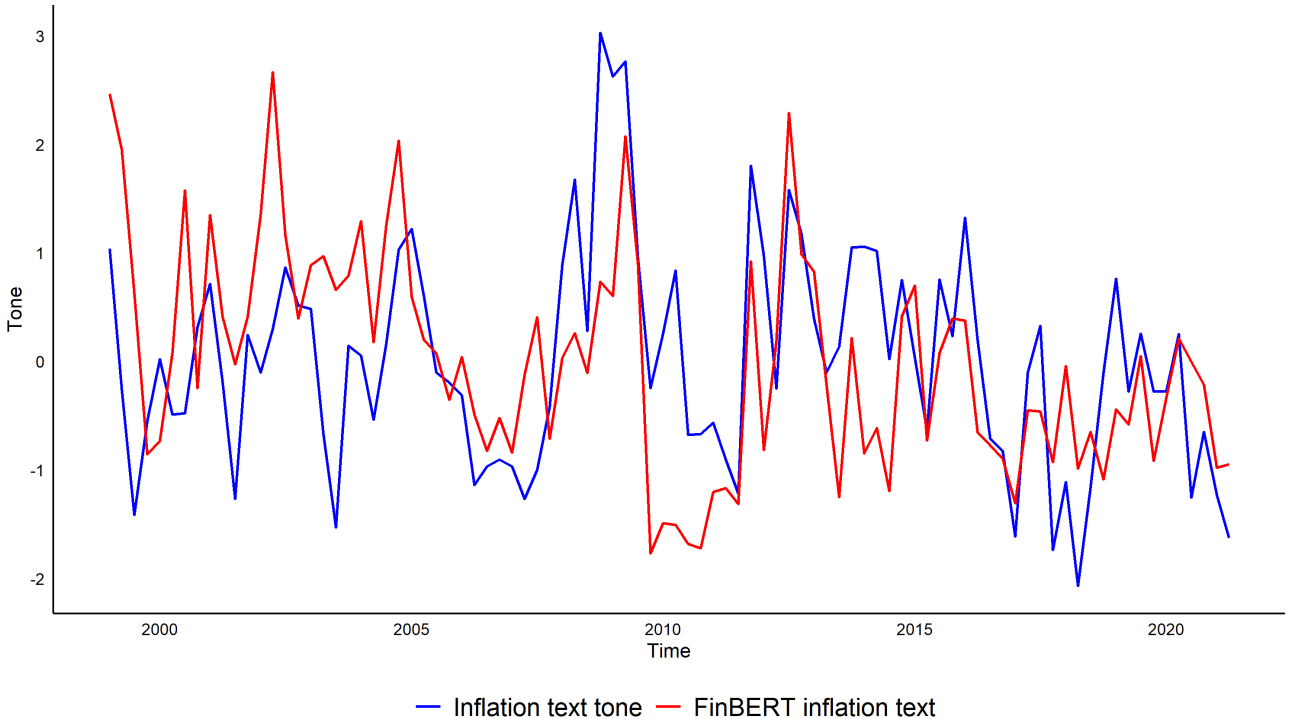


- Both series have been standardized so that they have the same scale.

Lexicon-based tone: whole texts and inflation texts

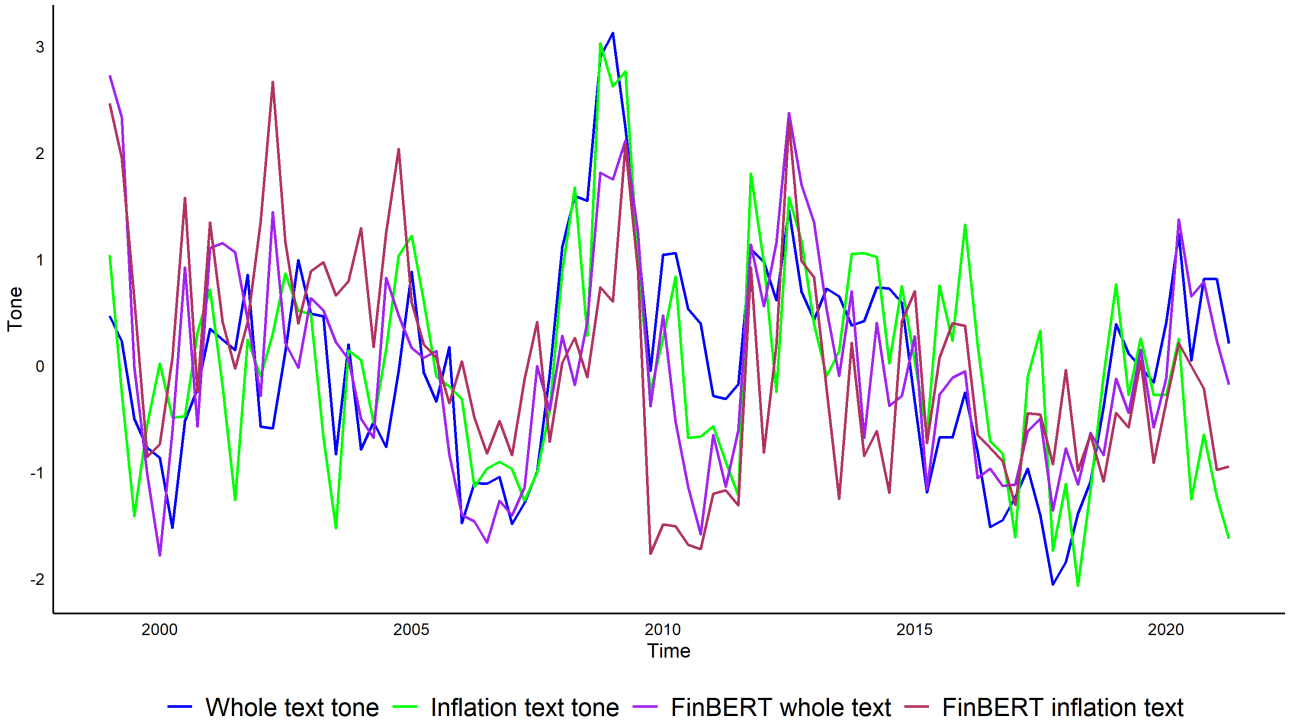


Lexicon-based and FinBERT-based tone, inflation texts



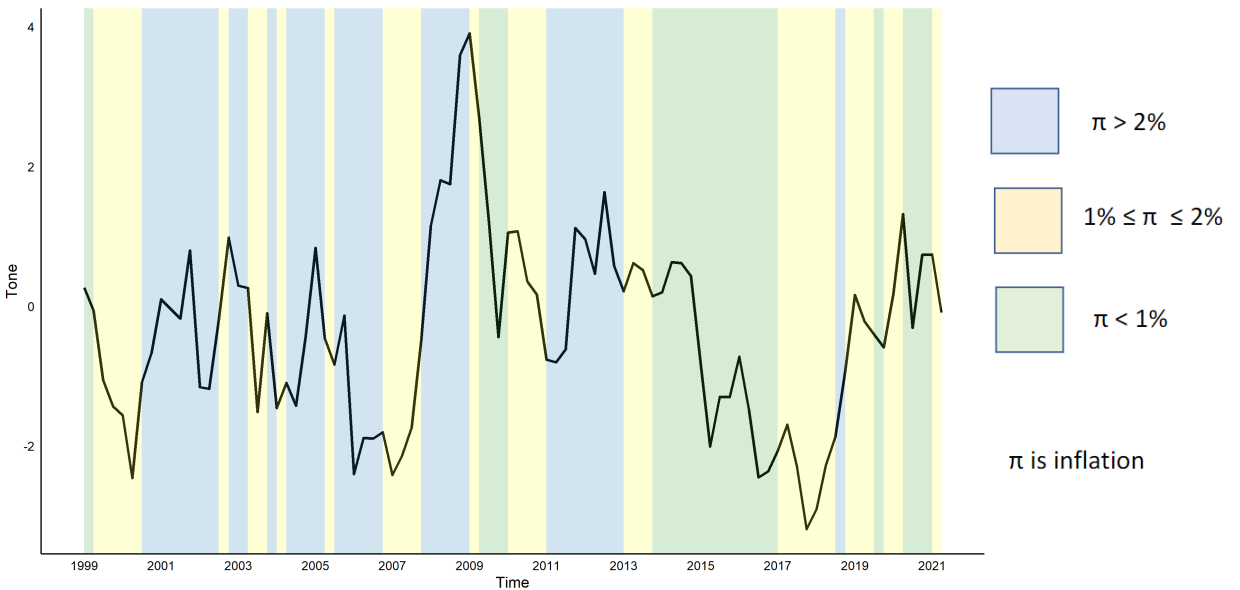
- Both series have been standardized so that they have the same scale.

4 tone indices



- All series have been standardized so that they have the same scale.

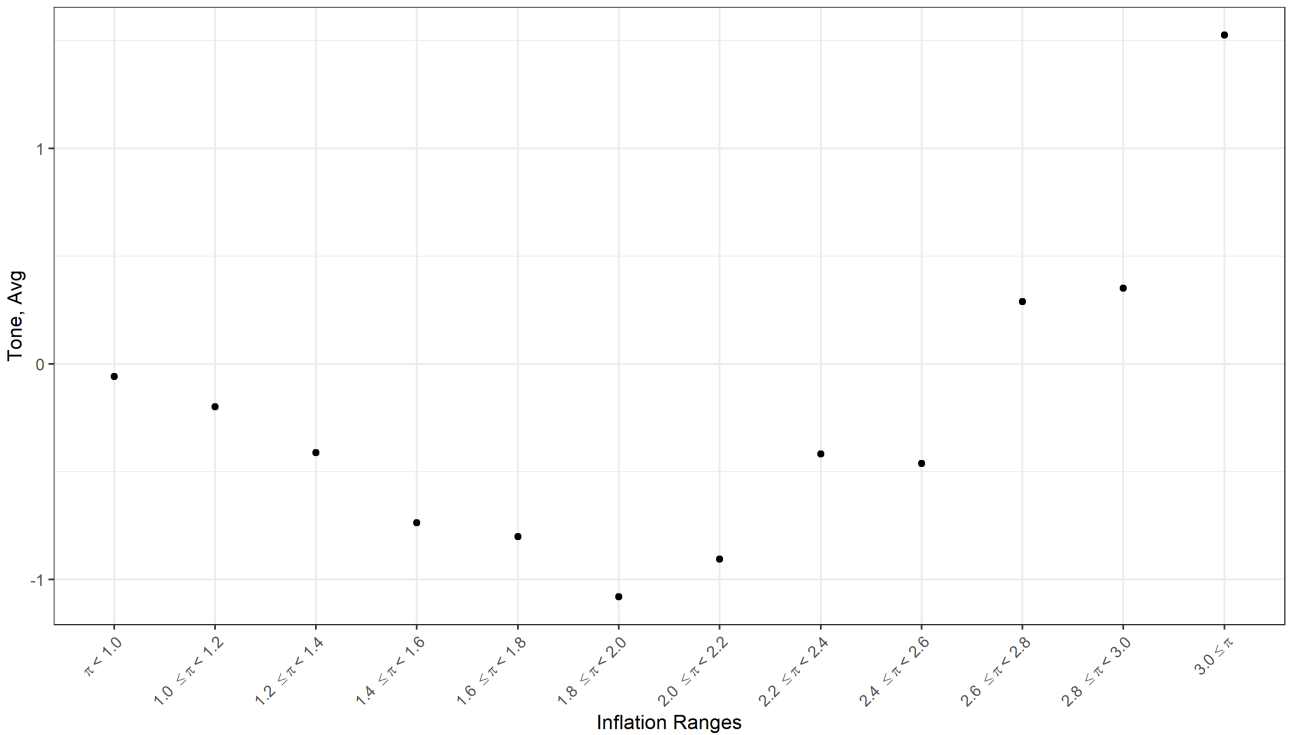
Lexicon-based tone, whole texts



- Periods of high inflation often correspond with more net negative tones, suggesting increased ECB concern.

Lexicon-based tone, inflation texts

Non-parametric estimate of the loss function

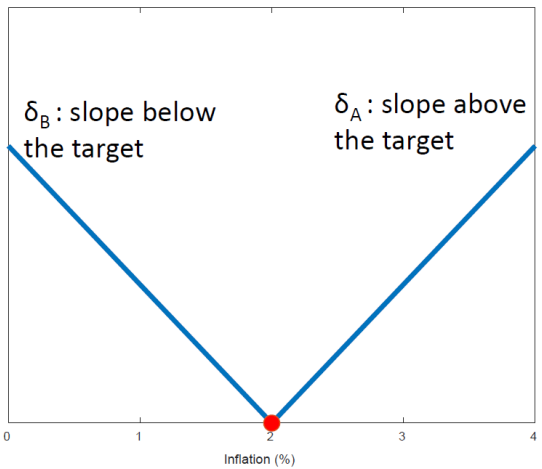


- Average **lexicon-based whole text tone** in inflation buckets.

Parametric estimates of the loss function

- Piecewise linear loss function (V-shaped).
- Linear exponential loss function (Linex; U-shaped).
- Control variables:
  - Real activity (unemployment, growth rate)
  - Financial markets
  - Economic uncertainty
- Test for (a)symmetry:
  - **F-test** for the difference between slopes.
  - **LR-test** for the difference between restricted (symmetric) and unrestricted (asymmetric) loss functions.

V-shaped loss function

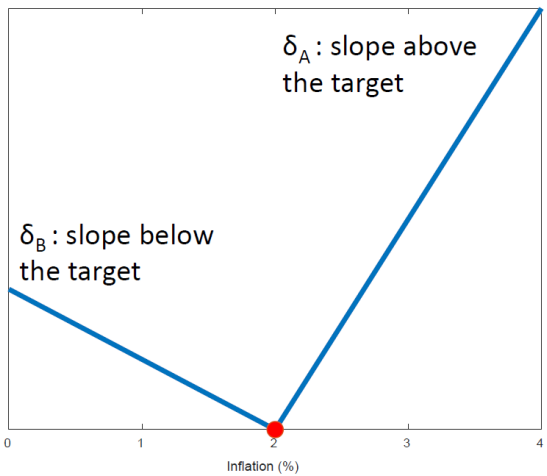


- If the loss function is **symmetric**:

$$\delta_B + \delta_A = 0$$

- **F-test** for (a)symmetry

V-shaped loss function



- If the loss function is **asymmetric**:

$$\delta_B + \delta_A \neq 0$$

- **F-test** for (a)symmetry

Piecewise linear (V), Lexicon-based tone (whole text)

	Dependent variable:			
	Tone			
	Symmetric V	Asymmetric V		
	(1)	(2)	(3)	(4)
Inflation	0.771***			
Inflation below the target		−0.483***	−0.427***	−0.062
Inflation above the target		1.531***	1.579***	0.871***
Industrial production (log-diff)			−13.128**	−0.023
Unemployment			0.090	0.102
Swapspread				−0.346
Corpspread				0.761***
EPU				0.002
Constant	−0.861***	−0.876***	−1.689***	−3.083***
Observations	238	238	238	226
R^2	0.084	0.140	0.165	0.473
Adjusted R^2	0.080	0.133	0.150	0.456
Estimated inflation target	1.71	2.00	2.00	2.00
F-test symmetry p-value		6.401e-06***	2.073e-06***	6.836e-05***
LR-test p-value (asym vs. sym)		0.000***	3.731e-05***	0.001***
LR-test p-value (est vs. fixed)	0.018**	1.000	1.000	1.000
Note:				*p<0.1; **p<0.05; ***p<0.01

- F-tests and LR-tests suggest asymmetric loss function.
- Slope is at least 3 times steeper above the target than below the target.

Piecewise linear (V), Lexicon-based tone (inflation texts)

	Dependent variable:			
	Tone			
	Symmetric V	Asymmetric V		
	(1)	(2)	(3)	(4)
Inflation	0.557***			
Inflation below the target		−0.312**	−0.228	0.057
Inflation above the target		1.012***	1.088***	0.584***
Industrial production (log-diff)			−14.437***	−4.913
Unemployment			0.141**	0.378***
Swapspread				0.553**
Corpspread				0.671***
EPU				0.001
Constant	−0.198	−0.165	−1.452**	−4.463***
Observations	238	238	238	226
R^2	0.050	0.084	0.131	0.374
Adjusted R^2	0.046	0.076	0.116	0.353
Estimated inflation target	1.43	1.90	1.90	1.90
F-test symmetry p-value		0.000***	3.384e-05***	0.001***
LR-test p-value (asym vs. sym)		0.003***	0.001***	0.003***
LR-test p-value (est vs. fixed)	0.012**	0.380	0.371	0.547
Note:				*p<0.1; **p<0.05; ***p<0.01

- F-tests and LR-tests suggest asymmetric loss function.
- Slope is at least 3 times steeper above the target than below the target.

Piecewise linear (V), FinBERT-based tone (whole text)

	Dependent variable:			
	Tone			
	Symmetric V	Asymmetric V		
	(1)	(2)	(3)	(4)
Inflation	11.137***			
Inflation below the target		−6.210**	−4.595	−2.153
Inflation above the target		15.396***	17.306***	12.146***
Industrial production (log-diff)			−225.261**	−58.752
Unemployment			3.759***	4.433***
Swapspread				−0.232
Corpspread				9.281***
EPU				−0.014
Constant	−39.464***	−38.511***	−73.813***	−93.671***
Observations	238	238	238	226
R^2	0.055	0.068	0.124	0.300
Adjusted R^2	0.051	0.060	0.109	0.278
Estimated inflation target	1.42	1.70	1.66	1.40
F-test symmetry p-value		0.008***	0.000***	0.002***
LR-test p-value (asym vs. sym)		0.072*	0.013**	0.057*
LR-test p-value (est vs. fixed)	0.001***	0.088*	0.059*	0.024**
Note:				*p<0.1; **p<0.05; ***p<0.01

- F-tests and LR-tests suggest asymmetric loss function.
- Slope is roughly 3 times steeper above the target than below the target.

Piecewise linear (V), FinBERT-based tone (inflation texts)

	Dependent variable:			
	Tone			
	Symmetric V		Asymmetric V	
	(1)	(2)	(3)	(4)
Inflation	11.437***			
Inflation below the target		−3.465	−2.575	−5.062
Inflation above the target		14.557***	16.046***	13.630***
Industrial production (log-diff)			−298.666*	−189.906
Unemployment			2.071	9.062***
Swapspread				25.671***
Corpspread				8.098***
EPU				−0.047
Constant	−38.297***	−36.071***	−55.892***	−123.501***
Observations	238	238	238	226
R^2	0.033	0.044	0.064	0.198
Adjusted R^2	0.029	0.036	0.047	0.172
Estimated inflation target	1.02	1.40	1.40	1.00
F-test symmetry p-value		0.033**	0.015**	0.200
LR-test p-value (asym vs. sym)		0.102	0.095*	0.593
LR-test p-value (est vs. fixed)	0.011**	0.054*	0.044**	0.089*
Note:				*p<0.1; **p<0.05; ***p<0.01

- F-tests and LR-tests mainly suggest asymmetric loss function.
- Slope is roughly 3 times steeper above the target than below the target.

Linex loss functions (U-shape)

- Linex loss function

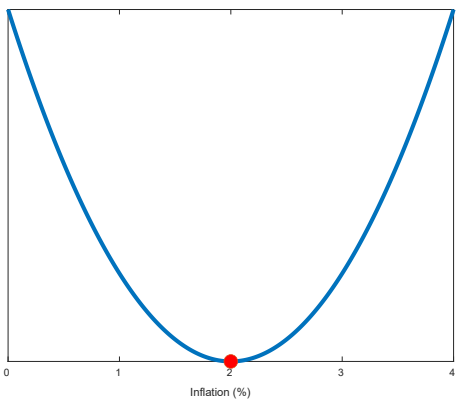
$$N_t = \alpha + \gamma \frac{exp\left[\theta\left(\pi_t - \pi^*\right)\right] - \theta\left(\pi_t - \pi^*\right) - 1}{\theta^2} + \varepsilon_t \qquad (2)$$

- The larger the parameter θ, the more averse the CB is to inflation rates above the target: asymmetry is captured by one parameter
- When $\theta \to 0$, we get a symmetric quadratic loss function

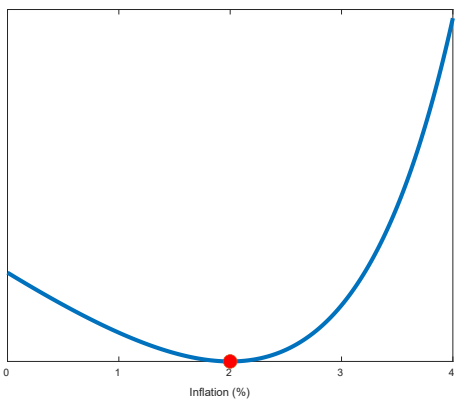
$$N_t = \alpha + \gamma\left(\pi_t - \pi^*\right)^2 + \varepsilon_t \qquad (3)$$

Linex: U-shaped loss function

Θ = 0



Θ = 1



Linex, Lexicon-based tone (whole text)

	(2)		(3)		(4)	
Target	θ	LR, p-value	θ	LR, p-value	θ	LR, p-value
2	1.190	0.000***	1.264	0.000***	1.827	0.001***
1.9	1.032	0.000***	1.106	0.000***	1.642	0.001***
1.8	0.887	0.001***	0.962	0.000***	1.478	0.001***
1.7	0.752	0.002***	0.829	0.001***	1.332	0.001***
1.6	0.629	0.012**	0.707	0.004***	1.204	0.003***
1.5	0.520	0.052*	0.598	0.022**	1.093	0.007***
1.4	0.432	0.161	0.507	0.081*	1.002	0.019**
1.3	0.388	0.316	0.448	0.196	0.934	0.044**

Note: $^{*}p < 0.1;^{**}p < 0.05;^{***}p < 0.01$

- We conduct a grid search for 'de facto' inflation targets ranging from 2.0 to 1.3 to assess the robustness of the asymmetric nature of the loss function.
- Results suggest asymmetric loss function even with control variables.

Linex, Lexicon-based tone (inflation texts)

	(2)		(3)		(4)	
Target	θ	LR, p-value	θ	LR, p-value	θ	LR, p-value
2	1.292	0.004***	1.436	0.001***	1.964	0.091*
1.9	1.135	0.004***	1.269	0.001***	1.773	0.047**
1.8	0.992	0.005***	1.117	0.001***	1.602	0.027**
1.7	0.863	0.010**	0.978	0.003***	1.448	0.020**
1.6	0.748	0.024**	0.853	0.006***	1.308	0.018**
1.5	0.649	0.059*	0.741	0.018**	1.182	0.022**
1.4	0.572	0.129	0.645	0.051*	1.069	0.033**
1.3	0.528	0.224	0.568	0.117	0.967	0.055*

Note: $^{*}p < 0.1;^{**}p < 0.05;^{***}p < 0.01$

- We conduct a grid search for 'de facto' inflation targets ranging from 2.0 to 1.3 to assess the robustness of the asymmetric nature of the loss function.
- Results suggest asymmetric loss function even with control variables.

Linex, FinBERT-based tone (whole text)

	(2)		(3)		(4)	
Target	θ	LR, p-value	θ	LR, p-value	θ	LR, p-value
2	1.230	0.090*	1.520	0.034**	2.000	0.669
1.9	1.026	0.081*	1.279	0.026**	1.698	0.306
1.8	0.844	0.089*	1.068	0.026**	1.349	0.192
1.7	0.677	0.120	0.878	0.033**	1.051	0.157
1.6	0.521	0.194	0.703	0.058*	0.794	0.171
1.5	0.373	0.338	0.539	0.122	0.568	0.244
1.4	0.229	0.563	0.382	0.265	0.361	0.406
1.3	0.100	0.835	0.230	0.515	0.165	0.686

Note: $^{*}p < 0.1;^{**}p < 0.05;^{***}p < 0.01$

- We conduct a grid search for 'de facto' inflation targets ranging from 2.0 to 1.3 to assess the robustness of the asymmetric nature of the loss function.
- Results mainly suggest asymmetric loss function.

Robustness checks

- Estimated piecewise-linear loss functions with quarterly datasets.
- Sensitivity of our control variables:
  - Selection of levels and first differences.
  - Additional control variables: P/E ratio, EURO STOXX and EuroUSD.
- Sensitivity of data:
  - Restricted the inflation to be equal or above 0.6 %.
  - Restricted the data to start from May 2003, when inflation aim was clarified by the GC.
  - Excluded ELB-period from our sample (excl. 2014:Q2 — 2021:Q2).
- Temporal dimensions:
  - We instruct the GPT-4.0 model to categorise sentences as 'forward-looking', 'backward-looking', or 'ambiguous'.
- In all of the cases, our results suggested asymmetric loss function.

Conclusions: What we do

- We extract the sentiment from the introductory statements of the ECB's press conferences Jan 1999 – Jun 2021.
  - Lexicon-based approach
  - Language model
- We combine the sentiment with real-time information available at the time of the GC meetings, and directly estimate the ECB's loss function.

Conclusions: What we find

- We find robust evidence that the ECB exhibited stronger aversion to inflation exceeding the target compared to inflation falling below the target.
- The departure from symmetry was sizeable: the slope of the loss function was roughly three times steeper when inflation was above the target than when it was below the target.
- Hence, the ECB's asymmetric loss function during its first two decades differed significantly from the quadratic and symmetric specification typically assumed in macro models.

Extra slides

Loss function vs. reaction function estimations

- The mapping from CB policy preferences (the loss function) to (optimal) policy reactions can be complex.
- (A)symmetric loss function $\nleftrightarrow$ (a)symmetric policy reactions
  - This is due to e.g the ELB
- Asymmetry of the loss function does not necessarily mean that optimal policy should have a similar bias.
  - Optimal policy may exhibit expansionary bias, while the welfare-based loss function has a contractionary bias

- Reaction function estimations
  - should end at ELB (2014Q2 in the euro area)
  - or rely on highly uncertain shadow rates

Loss functions

- Assume that CB's loss is a function of deviation of inflation from target such that

$$L_t = |\pi_t - \pi^*| \tag{4}$$

- and that we can relate the tone to this loss such that

$$N_t = \alpha + \delta L \tag{5}$$

- Then we can attempt to estimate a loss function such that

$$N_t = \alpha + \delta \left|\tilde{\pi}_t\right| + \varepsilon_t \tag{6}$$

- δ parameter reveals how strongly the CB feels about inflation deviating from the target
- We can also attempt to estimate π^*

Loss functions (2)

- Splitting the right hand side into two separate segments (piecewise linear loss function)

$$N_t = \alpha + \delta_B \tilde{\pi}_t (1 - D) + \delta_A \tilde{\pi}_t D + \varepsilon_t \tag{7}$$

- add additional control variables, e.g., macroeconomic variables

$$N_t = \alpha + \delta_B \tilde{\pi}_t (1 - D) + \delta_A \tilde{\pi}_t D + \beta_1 z_t + \varepsilon_t \tag{8}$$

- and we can estimate (and test) directly the degree of asymmetry in the CB's preferences.

Piecewise linear (V), Lexicon-based tone (whole texts)

	(2)			(3)			(4)		
Target	Above	Below	F-test, p-value	Above	Below	F-test, p-value	Above	Below	F-test, p-value
2	1.531***	-0.483***	6.401e-06***	1.579***	-0.427**	2.073e-06***	0.871***	-0.062	6.836e-05***
1.9	1.413***	-0.547***	6.292e-05***	1.461***	-0.493**	2.085e-05***	0.821***	-0.095	0.000***
1.8	1.271***	-0.591***	0.001***	1.323***	-0.537**	0.000***	0.750***	-0.110	0.000***
1.7	1.124***	-0.618***	0.010**	1.183***	-0.566**	0.003***	0.681***	-0.116	0.001***
1.6	0.978***	-0.627**	0.070*	1.041***	-0.576**	0.024**	0.608***	-0.110	0.004***
1.5	0.882***	-0.663**	0.259	0.948***	-0.615**	0.107	0.568***	-0.126	0.011**
1.4	0.785***	-0.685**	0.614	0.856***	-0.642**	0.312	0.524**	-0.132	0.026**
1.3	0.692***	-0.693**	0.994	0.768***	-0.660**	0.624	0.482**	-0.131	0.055*

Note: *p<0.1; **p<0.05; ***p<0.01

- We conduct a grid search for 'de facto' inflation targets ranging from 2.0 to 1.3 to assess the robustness of the asymmetric nature of the loss function.
- Results suggest asymmetric loss function even with control variables.

Piecewise linear (V), Lexicon-based tone (inflation texts)

	(2)			(3)			(4)		
Target	Above	Below	F-test, p-value	Above	Below	F-test, p-value	Above	Below	F-test, p-value
2	1.057***	-0.253	0.000***	1.134***	-0.169	1.310e-05***	0.593**	0.085	0.001***
1.9	1.012***	-0.312*	0.000***	1.088***	-0.228	3.384e-05***	0.584**	0.057	0.001***
1.8	0.931***	-0.352*	0.002***	1.012***	-0.269	0.000***	0.546**	0.047	0.001***
1.7	0.834***	-0.373*	0.011**	0.923***	-0.294	0.001***	0.498**	0.049	0.001***
1.6	0.734***	-0.380*	0.045**	0.828***	-0.304	0.005***	0.443**	0.065	0.002***
1.5	0.666***	-0.404*	0.139	0.764***	-0.333	0.021**	0.403*	0.077	0.004***
1.4	0.608***	-0.431*	0.327	0.711***	-0.366	0.070*	0.376*	0.083	0.007***
1.3	0.544***	-0.440*	0.582	0.652***	-0.386	0.177	0.343*	0.104	0.012**

Note: *p<0.1; **p<0.05; ***p<0.01

- We conduct a grid search for 'de facto' inflation targets ranging from 2.0 to 1.3 to assess the robustness of the asymmetric nature of the loss function.
- Results suggest asymmetric loss function even with control variables.

Piecewise linear (V), FinBERT-based tone (whole text)

	(2)			(3)			(4)		
Target	Above	Below	F-test, p-value	Above	Below	F-test, p-value	Above	Below	F-test, p-value
2	16.557***	-2.793	0.001***	18.571***	-0.684	2.477e-05***	10.778**	3.515	0.000***
1.9	16.624***	-4.056	0.001***	18.603***	-1.940	2.719e-05***	11.798**	2.469	6.755e-05***
1.8	16.111***	-5.161	0.002***	18.183***	-3.077	6.059e-05***	12.309***	1.494	5.144e-05***
1.7	15.396***	-6.210*	0.008***	17.639***	-4.207	0.000***	12.699***	0.427	6.581e-05***
1.6	14.378***	-7.036*	0.029**	16.730***	-5.115	0.001***	12.679***	-0.494	0.000***
1.5	13.422***	-7.874*	0.098*	15.844***	-6.041	0.005***	12.480***	-1.358	0.001***
1.4	12.282***	-8.422*	0.260	14.801***	-6.734	0.024**	12.146***	-2.153	0.002***
1.3	11.002***	-8.596*	0.503	13.621***	-7.117	0.080*	11.651***	-2.779	0.008***

Note: *p<0.1; **p<0.05; ***p<0.01

- We conduct a grid search for 'de facto' inflation targets ranging from 2.0 to 1.3 to assess the robustness of the asymmetric nature of the loss function.
- Results suggest asymmetric loss function even with control variables.

Piecewise linear (V), FinBERT-based tone (inflation text)

	(2)			(3)			(4)		
Target	Above	Below	F-test, p-value	Above	Below	F-test, p-value	Above	Below	F-test, p-value
2	8.518	5.798	0.021**	9.566	7.006	0.011**	4.726	9.644*	0.018**
1.9	10.813	4.389	0.009***	11.878	5.593	0.004***	7.489	8.416*	0.005***
1.8	12.330*	2.963	0.005***	13.467*	4.138	0.002***	9.415	7.195	0.002***
1.7	13.473*	1.380	0.005***	14.724*	2.498	0.002***	11.066*	5.744	0.002***
1.6	14.366**	-0.418	0.006***	15.702**	0.644	0.003***	12.441*	4.070	0.001***
1.5	14.796**	-2.174	0.013**	16.196**	-1.173	0.006***	13.263**	2.499	0.002***
1.4	14.557**	-3.465	0.033**	16.046**	-2.575	0.015**	13.601**	1.127	0.005***
1.3	13.770**	-4.109	0.075*	15.364**	-3.408	0.037**	13.562**	0.002	0.013**

Note: *p<0.1; **p<0.05; ***p<0.01

- We conduct a grid search for 'de facto' inflation targets ranging from 2.0 to 1.3 to assess the robustness of the asymmetric nature of the loss function.
- Results suggest asymmetric loss function even with control variables.

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