BANCO DE ESPAÑA
Eurosistema

SENTIMENT AND UNCERTAINTY INDICATORS USING ARTIFICIAL INTELLIGENCE

Morteza Ghomi (BdE), Samuel Hurtado (BdE)

Bank of England, June 25, 2025

The views expressed in this presentation are those of the authors and do not necessarily represent the views of the Bank of Spain or the Eurosystem.

OUTLINE

1. Introduction

2. Constructed Indicators

3. Effect on Forecast Errors

4. Conclusion

INTRODUCTION

- The usual methodology for calculating sentiment and uncertainty indicators is based on **counting words**, in two stages
  1. Selection of relevant news articles: using a dictionary of words that define a topic
  2. Quantification: using dictionaries of positive/negative terms, or terms that capture uncertainty
- An LLM model could improve both the selection and the quantification steps
  - Problem: if the database is very big, asking an LLM about every news piece is not feasible
- But we can use **AI techniques** to improve in both steps:
  1. **Selection:** Retrieval Augmented Generation (RAG) technique and embedding models
  2. **Quantification:** Using GPT-4o-mini to quantify sentiment and uncertainty in each article
- Finally, we estimate how uncertainty indicators affect **GDP forecast errors**

STEP 1: SELECTION

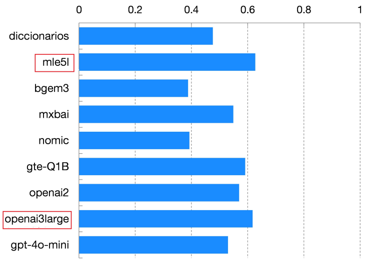
- **Retrieval Augmented Generation**: a technique in NLP that combines two powerful components:
  1. **Retrieval**: Finding relevant documents or information from a large knowledge base
  2. **Generation**: Using a language model (like GPT) to generate an answer based on the retrieved information

- The source retrieval part is done through semantic search, using an **embedding model**
  - A text embedding model is a function that transforms text into numbers
  - It projects news articles and economic topic definitions into a multidimensional space (e.g. 4096 dimensions)
  - Each article is then classified into a topic based on cosine similarity

STEP 1: SELECTION

- Which embedding model performs best for our task? (Identifying news articles about specific economic topics in a Spanish-language database)

- We compare several embedding models using a random sample of 443 manually classified news articles and build an index to measure their relative performance



STEP 1: SELECTION

- Embeddings model selected: **multilingual-e5-large**: Strong performance; Free to use; Small (560M parameters); Fast (9 days to process the full >4M articles of the 2000-2025 database)

- Topics to be used in our sentiment and uncertainty indicators:

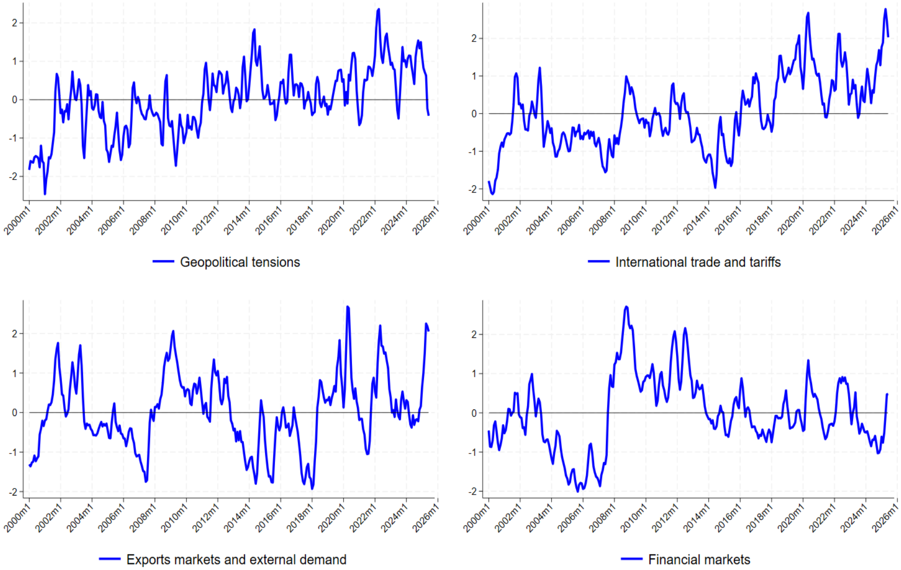
  1. Geopolitical tensions
  2. International trade and tariffs
  3. Exports markets and external demand
  4. Financial markets
  5. Prices of energy and other raw materials
  6. Inflation, prices and markups
  7. Wages and collective bargaining
  8. Fiscal policy and sustainability of public finances
  9. Housing market
  10. Confidence of agents and internal demand

STEP 2: QUANTIFICATION

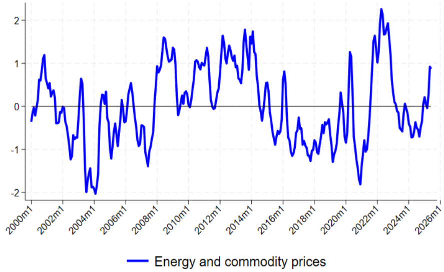
- Once the relevant news articles have been selected...
  - 130.000 for each of the 10 topics (on average, 100 articles per week)
- We ask **GPT-4o-mini** to quantify the level of sentiment and uncertainty in each article
- The prompt is long and detailed
  - It includes a step to verify that the article is relevant to the assigned topic
  - It contains ten examples (different for each topic) of headlines and the value of sentiment and uncertainty that we would assign to them
- For each topic and month, we calculate the average sentiment and uncertainty scores across all relevant articles

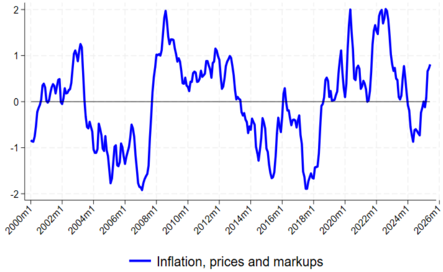
OUTLINE

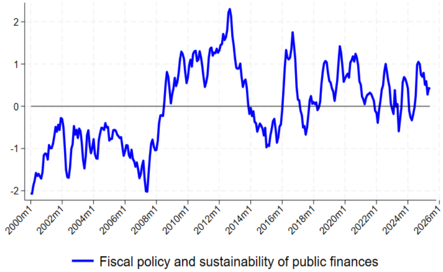
UNCERTAINTY INDICATORS



UNCERTAINTY INDICATORS

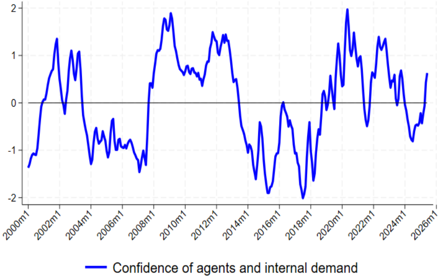






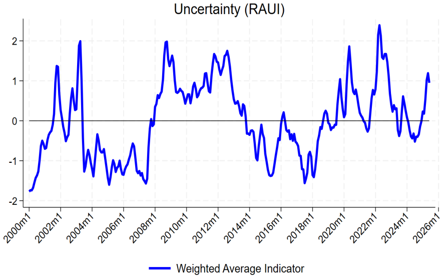
UNCERTAINTY INDICATORS

BANCO DE ESPAÑA
Eurosistema

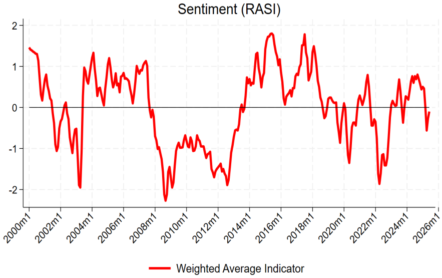


UNCERTAINTY AND SENTIMENT INDICATORS

BANCO DE ESPAÑA
Eurosistema



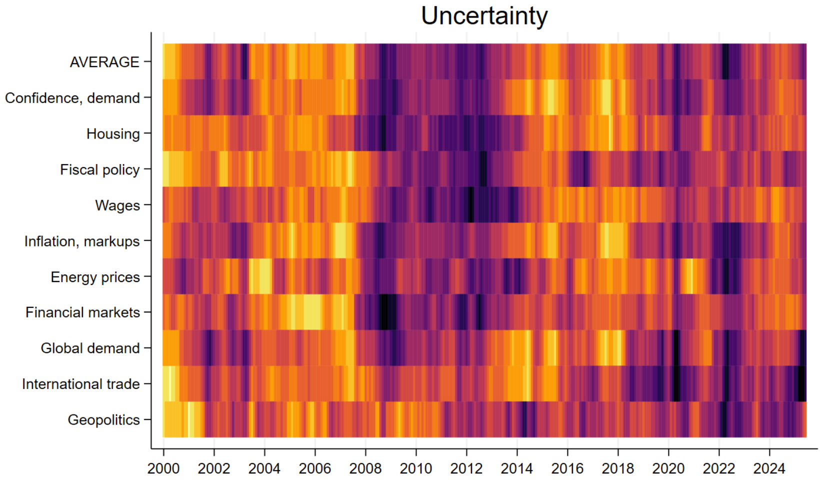
(k) Uncertainty



(l) Sentiment

UNCERTAINTY INDICATORS

BANCO DE ESPAÑA
Eurosistema

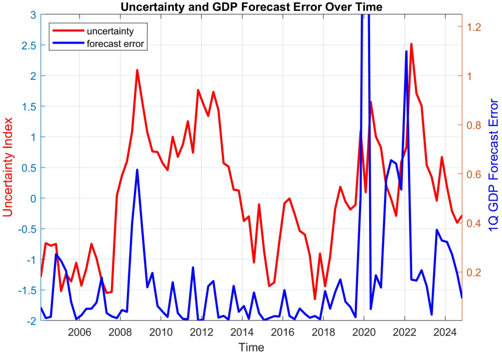


sentiment

OUTLINE

UNCERTAINTY AND FORECAST ERROR

How does uncertainty affect GDP forecast error? $\mathrm{FE}_t = \alpha + \beta U_t + \Gamma X + \varepsilon_t$



	1 quarter ahead GDP forecast error		
	(1)	(2)	(3)
Uncertainty	**0.050*****	**0.040***	**0.039***
	(0.018)	(0.022)	(0.021)
dummy 2020q1	3.138***	3.113***	3.229***
	(0.021)	(0.053)	(0.066)
forecast error(t-1)		0.078	0.205
		(0.116)	(0.140)
gdp growth			0.028
			(0.019)
Constant	0.143***	0.130***	0.094***
	(0.020)	(0.024)	(0.027)
R-squared	0.778	0.783	0.805
Observations	84	83	83

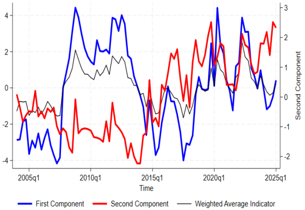
EFFECT ON FORECAST ERROR

Which measures contribute the most? We analyze the first two principal components (74 % of total variance)

→ PC 1: reflects mainly internal factors (Spanish economy)

→ PC 2: captures mainly external influences

Variable	PC 1	PC 2
Geopolitics	0.23	0.57
International trade	0.52	0.80
Global demand	0.83	0.32
Financial markets	0.85	-0.21
Energy prices	0.66	-0.34
Inflation, markups	0.94	0.13
Wages	0.73	-0.48
Fiscal policy	0.75	0.15
Housing market	0.83	-0.41
Confidence, demand	0.94	0.04

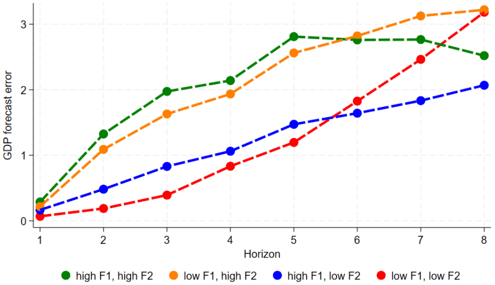


	1 quarter ahead GDP forecast error		
	(1)	(2)	(3)
PC 1	**0.014**		**0.016***
	(0.009)		(0.009)
PC 2		**0.028****	**0.031****
		(0.013)	(0.013)
Constant	0.131***	0.132***	0.137***
	(0.025)	(0.025)	(0.024)
Controls	YES	YES	YES
R-squared	0.780	0.782	0.790
Observations	83	83	83

FORECAST ERROR AT HIGHER HORIZONS

	FE(1)	FE(2)	FE(3)	FE(4)
PC1	**0.019****	**0.075****	**0.108****	**0.074**
	(0.008)	(0.038)	(0.045)	(0.069)
PC2	**0.033***	**0.232*****	**0.315*****	**0.299****
	(0.018)	(0.079)	(0.094)	(0.144)
Constant	0.144***	0.541***	0.890***	1.218***
	(0.021)	(0.095)	(0.113)	(0.175)
Dummy 2020Q2	YES	YES	YES	YES
R^2	0.795	0.524	0.858	0.742
N	77	77	77	77

	FE(5)	FE(6)	FE(7)	FE(8)
PC1	**0.091**	**0.015**	**-0.058**	**-0.147**
	(0.085)	(0.105)	(0.117)	(0.130)
PC2	**0.371****	**0.316**	**0.271**	**0.143**
	(0.177)	(0.217)	(0.242)	(0.268)
Constant	1.670***	2.032***	2.416***	2.788***
	(0.215)	(0.264)	(0.294)	(0.326)
Dummy 2020Q2	YES	YES	YES	YES
R^2	0.644	0.544	0.486	0.438
N	77	77	77	77



- 2006Q4: Low PC1, Low PC2 2012Q4: High PC1, Low PC2
- 2022Q4: High PC1, High PC2 2024Q4: Low PC1, High PC2

OUTLINE

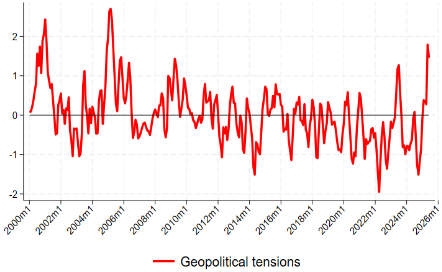
CONCLUSION

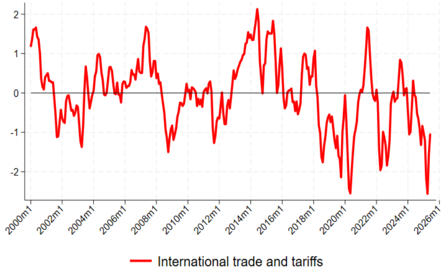
- We apply recent AI techniques to construct uncertainty and sentiment indicators for the Spanish economy
- Using text embedding models, we classify >4 million news pieces into 10 different topics, using ChatGPT models we quantify their uncertainty and sentiment measures
- The constructed uncertainty indicators correlate strongly with GDP forecast errors, with international uncertainty showing a particularly large impact
- Next steps:
  - We can use the indicators for different topics to generate risk scenarios, e.g., to accompany our forecasts, or for stress testing
  - Analyze the effect of different uncertainty measures on economic activities

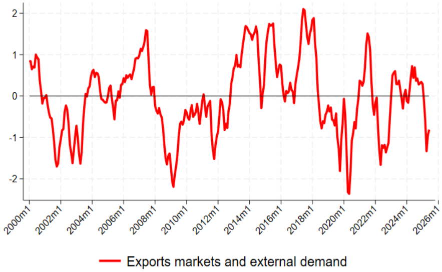
Thank you for your attention!

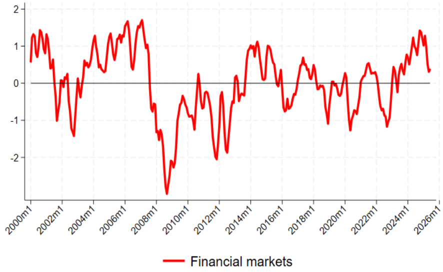
SENTIMENT INDICATORS

BANCO DE ESPAÑA
Eurosistema



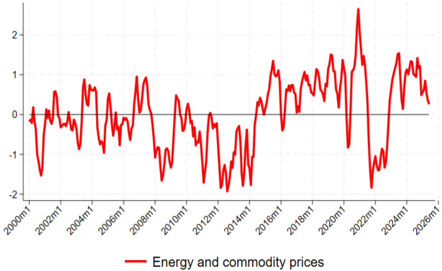


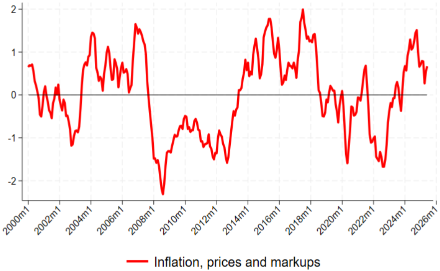


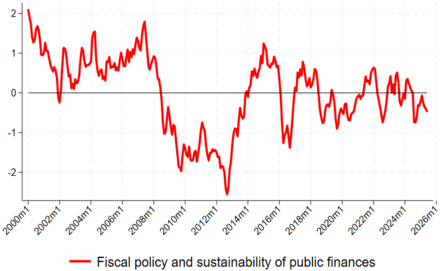


SENTIMENT INDICATORS

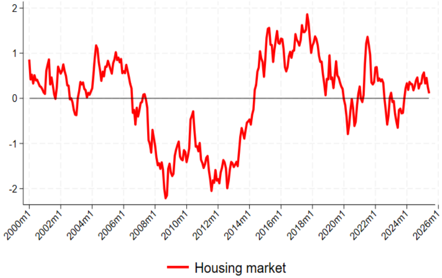
BANCO DE ESPAÑA
Eurosistema

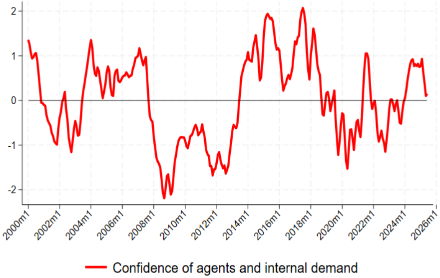




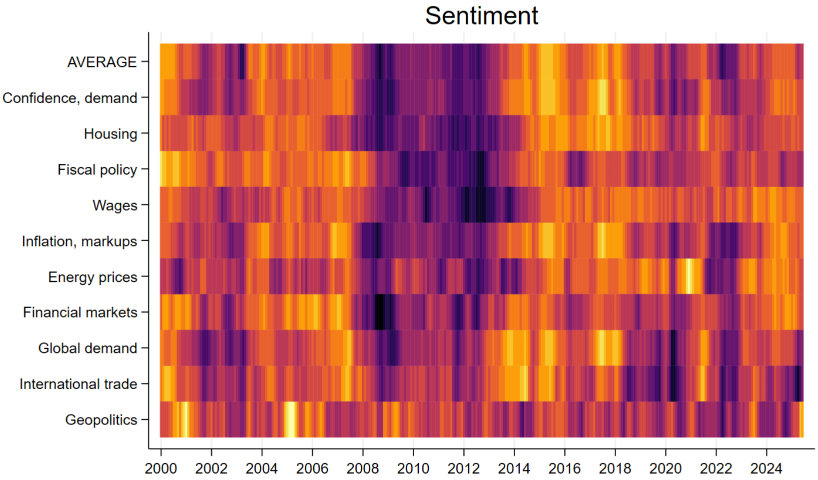


SENTIMENT INDICATORS





SENTIMENT INDICATORS



back