Modeling Industrial Production in the EU Countries: Autoregressive Models Versus Sentiment--Enhanced Regression

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Abstract

Motivated by rising demand for timely economic insights, we explore the predictive power of the Industrial Confidence Indicator (ICI) for forecasting the Industrial Production Index (IPI) across EU Member States. Our purpose is to assess whether business sentiment data can serve as a real-time leading indicator for industrial production and explore possible structural patterns across EU countries and over time. The study analyses monthly IPI and ICI data for 27 EU Member States from 2008 to 2024 (while also considering only the pre-pandemic part of the time series) using correlation analysis, ARIMA/ARIMAX forecasting methods (with expanding and rolling window techniques) and clustering. Our analysis results in rather weak linear correlation between ICI and IPI, very limited forecasting dominance of ARIMAX models over ARIMA models (especially during volatile periods), and identification of contextually fairly meaningful clusters. Using all three methods the pre-pandemic data turn out to better reflect expected relationships compared to the whole time series.

Keywords	***DOI***	***JEL code***
Business tendencies, time-series, timeliness, real-time estimates, nowcasting, clustering	*https://doi.org/10.54694/stat.2025.29*	*C10, C13, C22, E23*

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INTRODUCTION

Timeliness, one of the five principal quality dimensions of official statistics besides relevance, accuracy and reliability, coherence and comparability, and accessibility and clarity (Eurostat, 2018), has always been particularly relevant for short-term statistics. However, the perception of what constitutes "timely" has evolved significantly, and with it, expectations regarding statistical timeliness. A series of systemic shocks in the 21st century, from the financial crisis to the pandemic and recent wars, has intensified user demand for immediate economic insights. The heightened demand has also been enabled by the proliferation of novel data streams that permit faster, and in some cases, real-time statistical generation. Consequently, we observe a surge in academic and institutional interest in early estimates.

Short-term statistics are the fastest and most frequent official economic statistics, providing the empirical foundation for effective economic governance and analysis. For key stakeholders, including governments and financial institutions, they are fundamental to shaping monetary and fiscal policy, evaluating economic conditions, performing business cycle analysis, and forecasting. In the analysis of the real sector, two short-term indicators, the Gross Domestic Product (GDP) and the Industrial Production Index (IPI), are widely recognized for their extensive time series, broad usage, relative methodological stability, and long-standing tradition. These indicators are crucial as the GDP encompasses a wide range of economic activities and the IPI covers an economic sector that is sensitive to economic fluctuations, thus suitable for the identification of turning points, and has strong linkages to other sectors. While forecasting and nowcasting GDP and IPI have spurred research and academic literature, the GDP has attracted much more attention (Stundziene et al., 2024). We therefore turn our attention to the less researched IPI that is also interesting because of its monthly frequency (as compared to typical quarterly for the GDP), shorter publication lags and time-series properties (Moody et al., 1993). In this paper, we work from the assumption that the accuracy of any early economic estimate is inherently dependent on the timeliness and accuracy of its input data. Namely, our primary objective is to examine the predictive capacity of the Industrial Confidence Indicator (ICI), one of the earliest monthly indicators available (if not the earliest), on the future trajectory of the IPI.

The remainder of this paper is structured as follows: Section 1 provides the literature review and articulates the research questions. Section 2 details the data sources, along with some background information on both studied indicators, the IPI and the ICI, and our methodological approach. Section 3 presents empirical results, followed by a discussion of their implications in Section 4 and the concluding section.

1 LITERATURE REVIEW

As already mentioned, general interest for timelier indicators primarily comes from turbulent environment and timelier new data sources. But the pursuit of accurate early estimates and robust forecasts of the IPI has long been seen in research covering major economies, such as the United States, Germany, the United Kingdom, France, and Italy (e.g. Bruno and Lupi, 2004; Hassani et al., 2009). Such interest is also driven by institutional changes, as was the creation of the Euro area (Bodo et al., 2000; Čižmešija et al., 2011).

Besides testing various methods, research has examined the predictive power of qualitative business surveys, also known as business tendency surveys, that provide qualitative or "soft" data for concurrent indicators (e.g. sales evolvement) and leading indicators (e.g. evolvement of orders or investment). Among the more recent studies, Boshnakov (2018) observed anticipated favourable effect of the business climate, as perceived by the managers in the industrial sector, on the production volume shifts at lag of one month for Bulgaria. Chipeva and Chavdarov (2019) similarly found that selected business indicators help explain the IPI variation in Bulgaria. Ptáčková and Fischer (2020) concluded for Czechia that the individual confidence indicator in the industry well predicts the monthly industrial production index and that the results are significant for the following month and the predictions two months ahead.

Reviewing studies assessing the forecasting power of the ifo Business Survey conducted by the German Ifo Institute, Lehmann (2023) concluded that several ifo indicators have been proven in the literature to be good leading indicators for industrial production despite some studies with contrary results.

However, as systemic shocks jeopardise the performance of forecasting and nowcasting in general, they also trigger debates about the relationship between the qualitative and quantitative data in such periods (see e.g. Bruno et al., 2019; and Sorić et al., 2022; for the 2008 financial crisis). While the effect of the COVID-19 pandemic period on predicting the industrial production has been researched, especially in the context of new data sources, the ability of traditional qualitative survey data to capture major shocks has been modestly investigated. For example, Furukawa and colleagues (2024) concluded that qualitative forecasts are unlikely to capture well changes in Japan industrial production, and Lehmann and Möhrle (2024) showed that high-frequency electricity consumption data beat qualitative ifo indicators for the German state of Bavaria. To the best of our knowledge, the predicting power of qualitative data for industrial production forecasting and nowcasting of the EU Member States has not yet been examined for the periods including the COVID-19 pandemic period. Focusing on the Industrial Production (Volume) Index (IPI) as a quantitative measure of industrial production and the Industrial Confidence Indicator (ICI) as a qualitative measure of business tendencies in industry, we formulated the following research questions (RQs):

RQ1: How do the IPI and the ICI correlate in the period 2008–2024 vs. 2008–2019?

RQ2: How does the inclusion of the ICI impact the accuracy of IPI predictions in the period 2008–2024 vs. 2008–2019?

RQ3: How do countries cluster with respect to their IPI and ICI movement in the period 2008–2024 vs. 2008–2019?

2 DATA AND METHODS

2.1 Data

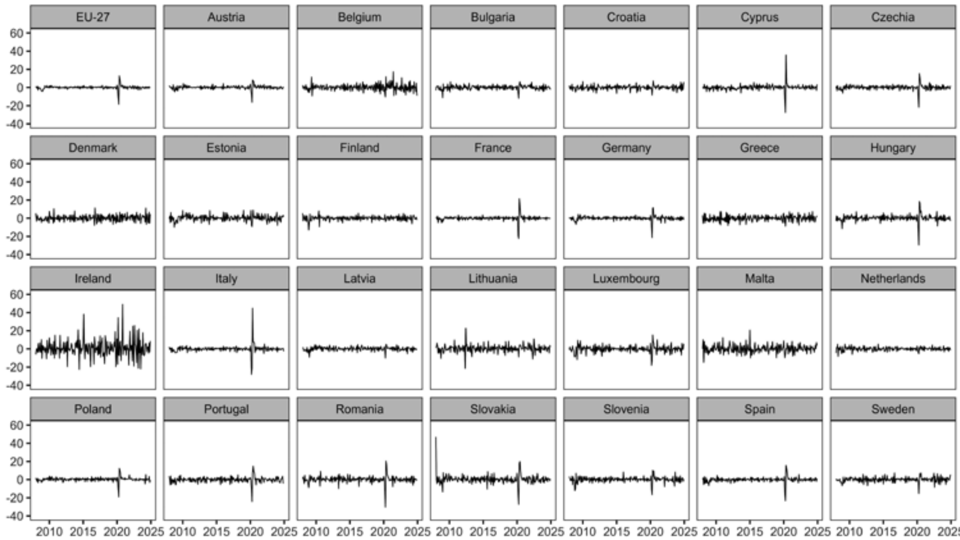
The analysis covers 27 EU Member States in the period between January 2008 and December 2024. The IPI measures monthly changes in the price-adjusted output of industry, with the purpose of tracking the development of value added. The index is calculated in the form of a Laspeyres type index and published with 40-day lag. Although countries may use different data sources (e.g. surveys and administrative data) and different calculation procedures, the geographical and temporal comparability is considered good (Eurostat, 2025c).

The ICI comes from the Joint Harmonised EU Programme of Business and Consumer Surveys that the European Commission launched in 1961 as a timely complement to official statistics (European Commission, 2025). The data are derived from (mostly voluntary) harmonised national surveys based on harmonised questionnaires and a common timetable. A high degree of representativeness is sought in national samples that altogether constitute a nominal sample of 38 000 units and an effective sample of 30 000 units. Answers obtained from the surveys are aggregated in the form of "balances". Balances are constructed as the difference between the percentages of respondents giving positive and negative replies. The ICI is the arithmetic average of the balances (in percentage points) of the answers to the survey questions on production expectations, order books and stocks of finished products (the last with inverted sign) addressed to representatives of the industry (Eurostat, 2024). Fieldwork for the monthly surveys is generally performed in the first two to three weeks of each month, so that the results are sent by email to Directorate-General for Economic and Financial Affairs (DG ECFIN) at least five working days before the end of the reference month (Eurostat, 2025c).

The time-series for the IPI and the ICI were downloaded from the Eurostat website. For the IPI (see Figure 1), we used seasonally and calendar adjusted data in the form of percentage change on previous period (Eurostat, 2025b). For the ICI (see Figure 2), we used seasonally adjusted monthly balances

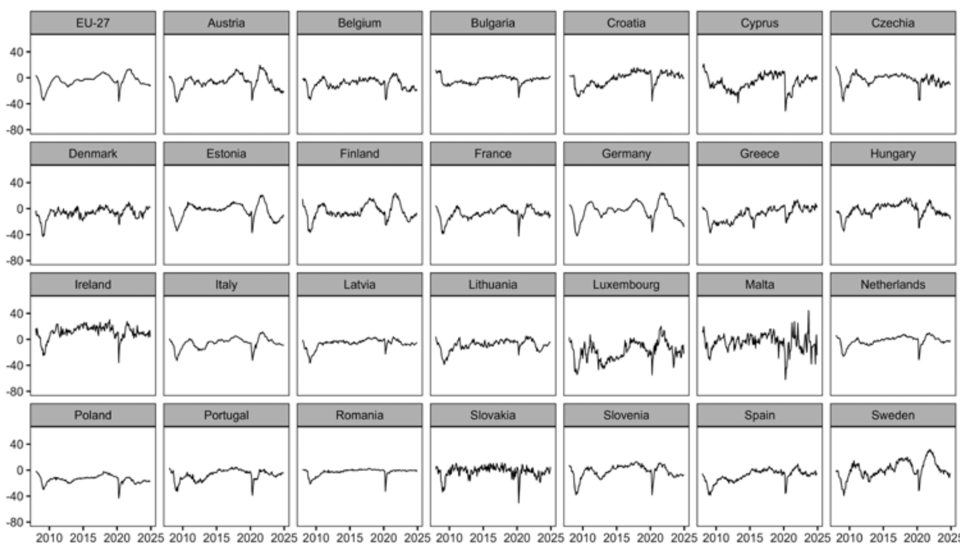
(Eurostat, 2025a). Missing values between January 2008 and April 2008 for Croatia were imputed using the average of May 2008 and December 2008 (all months before the crisis). The missing value for Italy for April 2020 was imputed using the average of March 2020 and May 2020. We can clearly observe the largest disruption in the industrial production at the outburst of the COVID-19 pandemic.

Figure 1 Industrial Production (Volume) Index (IPI) (percentage change on previous period, seasonally and calendar adjusted) by country, January 2008–December 2024



Source: Eurostat (sts_inpr_m, 2025)

Figure 2 Industrial Confidence Indicator (ICI) (seasonally adjusted monthly balances) by country, January 2008–December 2024



Source: Eurostat (ei_bsin_m_r2, 2025)

2.2 Methods

2.2.1 Correlation

To evaluate the relationship between the current business sentiment and the future production values (RQ1), we calculate Pearson's correlation coefficients between the IPI and the ICI. To analyse the forecasting power of business tendency data, we calculate correlations using the leads of 0 to 3 months in the industrial production data. We calculate the correlations for each EU Member State as well as the EU-27 aggregate. The calculations are carried out on the entire period 2008–2024, and separately for the pre-pandemic period 2008–2019. The analysis was performed using the open-source statistical software environment R using the `cor()` function.

2.2.2 Autoregressive integrated moving average (ARIMA) and autoregressive integrated moving average with exogenous inputs (ARIMAX)

To assess the forecasting power of business tendencies in the context of industrial production (RQ2), we compare forecast accuracy for models with and without the ICI as an exogenous variable. For each EU member state, as well as the EU-27 aggregate, we build an autoregressive integrated moving average model (ARIMA) (Box and Jenkins, 1970) on the IPI series and an autoregressive integrated moving average model with exogenous variables (ARIMAX) (Box and Tiao, 1975) that includes the ICI as the exogenous variable. Both models are constructed using the `auto.arima()` function in R with the `stepwise=F` option to improve the model selection by comparing all possible combinations of AR and MA terms (up to order 5).

We use both models independently to forecast industrial production for horizons of 1, 2 and 3 months ahead. Forecast accuracy is evaluated using Root Mean Squared Error (RMSE) as the criterium. Lower RMSE values indicate more accurate models and forecasts.

2.2.3 Expanding (EWF) and rolling window forecasts (RWF)

The principle that more data always leads to better results does not necessarily hold because of volatile data, reflecting financial crises, booms, the pandemic etc. Therefore, we forecast production using both Expanding Window Forecasts (EWF) and Rolling Window Forecasts (RWF) for each country. When EWF outperforms RWF, historic data provides valuable insights into the industrial production forecasts, while when RWF outperforms EWF, past data disturbs the current forecasting accuracy, possibly due to structural changes in the phenomenon.

For the EWF, the starting point remains fixed in January 2008, while the training window is increased by one month of data in each iteration. In each iteration, we fit both ARIMA and ARIMAX models independently, and use the models to generate forecasts for 1, 2 and 3 months ahead. We then use the resulting forecasts for the RMSE calculation. We exclude the initial three years from the RMSE calculation due to the volatile nature of the forecasts attributed to a small data size. The forecasts are prepared for the entire period 2008–2024, and separately for the pre-pandemic period 2008–2019.

While the EWF approach continuously extends its training window, the RWF employs a fixed window size. We choose the window size of 100 months to ensure a sufficient amount of data for reliable model estimation. For both methods, the training window endpoint is moved forward by one month in each iteration. The subsequent processes of model fitting, forecasting, and evaluation are conducted identically for both the EWF and RWF approaches.

2.2.4 Clustering

Clustering (RQ3) is performed on the IPI and ICI standardized data series, using the `scale()` function in R, ensuring that all variables contribute equally to distance calculations regardless of their original scale. Distances are calculated using the Euclidean method using the `dist()` function in R (option `method="euclidean")`. We first apply Ward's method of hierarchical clustering (Ward, 1963) to determine the initial clusters using the `hclust()` function in R (`method="ward.D2"`) for hierarchical clustering and the `cuttree()` function for determining initial groups. We use those clusters to calculate the centres of each cluster that are then used as seeds for *k*-means clustering (MacQueen, 1967) that assigns countries to their final group using the `kmeans()` function.

The clustering is conducted on the entire period 2008–2024 and also on the pre-pandemic period 2008–2019. Highly volatile data for Ireland (see Figures 1 and 2) led to its consistent classification into a separate group, therefore it is excluded from the cluster analysis.

3 RESULTS

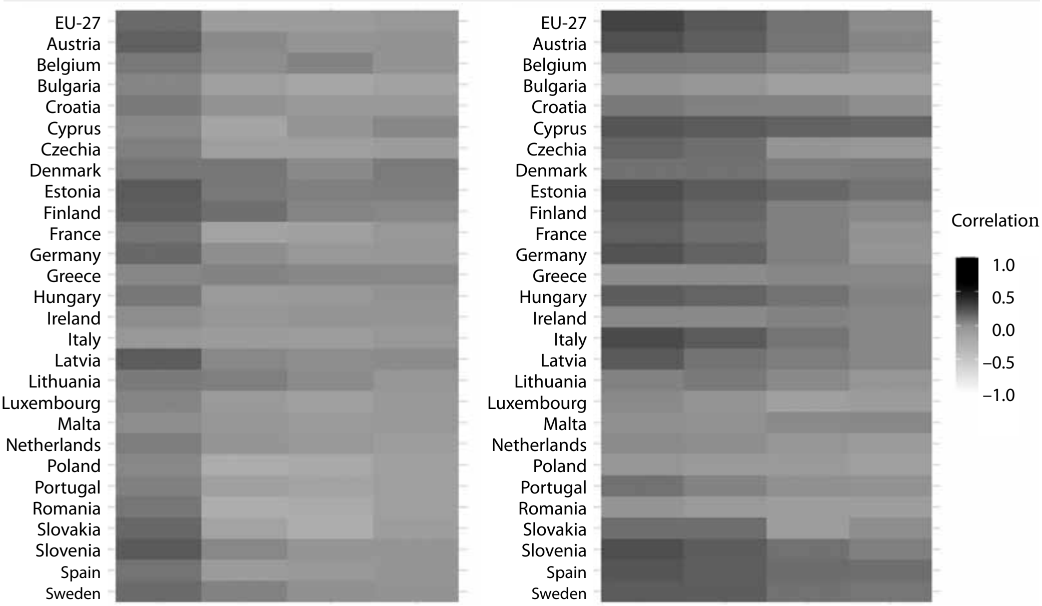
3.1 Correlations

With respect to RQ1, we expect to observe positive correlations between the ICI and IPI. For the contemporaneous relationship, this means that when businesses are more confident, the growth of industrial production tends to be higher, and vice-versa. From the forecasting perspective, this indicates that optimistic business sentiment tends to lead to a higher growth of industrial production, and vice versa. We also expect the strength of relationship to diminish with the length of forecast horizon.

The results for RQ1 show that none of the linear correlations between the IPI and the ICI is considered moderate, given the highest correlation coefficient of 0.29 (EU-27 and lead = 0). Out of 142 positive correlation coefficients 89 have values between 0 and 0.1, and further 53 out of 72 negative correlation coefficients have values between –0.1 and 0, meaning that nearly two thirds exhibit very weak or negligible linear correlation (see Figure 3 and detailed data in Table A1 in the Appendix).

We notice different patterns between countries. Countries with negative correlations for all leads, be it for the entire period or the pre-pandemic period, are Bulgaria, Luxembourg, Poland, Romania and Slovakia. Some other countries (Croatia, Cyprus, Czechia, France, Hungary, Italy, Malta, Portugal

Figure 3 Correlations between the Industrial Production (Volume) Index (IPI) and the Industrial Confidence Indicator (ICI) by country and lead, the entire period (left, 2008–2024) and the pre-pandemic period (right, 2008–2019)



Source: Own calculations based on Eurostat (sts_inpr_m, 2025; ei_bsin_m_r2, 2025) and Spain) show negative correlations only when the entire period is observed, indicating a possible major bias in assessing the effects of the Covid pandemic on industrial production. At least some positive correlations between 0.2 and 0.3 are observed in Austria, Cyprus, Estonia, Finland, Germany, Italy, Latvia, Slovenia and Spain. Generally, we observe the highest correlations when we use the contemporaneous values of the IPI and the ICI, with some exceptions (e.g. Slovakia with the strongest correlation of 0.26 at lead1).

The EU-27 aggregate reflects our previous finding that when analysing the entire period 2008–2024 this correlation is negative for all leads, but when we analyse only the pre-pandemic period 2008–2019, we see a positive correlation that diminishes with higher leads.

3.2 ARIMA and ARIMAX models

3.2.1 Models with an expanding window

To address RQ2, we first present models with an expanding window and then models with a rolling window. For the EFW setting for the entire period 2008–2024 (see Table 1), we find that ARIMAX models fit the data better in almost all cases (except for Bulgaria, Greece, and Slovakia), but the forecasting does not

Table 1 Root Mean Squared Error (RMSE) for ARIMA and ARIMAX models with an expanding window (entire period 2008–2024)

Country	ARIMA				ARIMAX			
	Model	h = 1	h = 2	h = 3	Model	h = 1	h = 2	h = 3
EU-27	1.436	**3.091**	**2.859**	**2.667**	**1.397**	3.283	3.391	2.900
Austria	2.811	**2.799**	2.311	2.252	**2.764**	2.817	**2.257**	**2.217**
Belgium	**2.354**	**3.857**	**3.876**	**3.897**	2.360	3.988	3.893	3.943
Bulgaria	2.176	**2.878**	**2.577**	**2.277**	**2.133**	3.084	2.925	2.319
Croatia	2.714	**2.968**	2.533	2.528	**2.518**	3.117	**2.422**	**2.447**
Cyprus	2.007	**4.769**	**4.357**	**4.227**	**1.964**	5.241	4.684	4.528
Czechia	3.122	**3.225**	3.234	**3.050**	**3.037**	3.284	**3.204**	3.127
Denmark	7.126	**5.230**	4.006	**3.727**	**7.091**	5.584	**3.973**	3.939
Estonia	**2.550**	3.908	**3.233**	**3.176**	2.589	**3.872**	3.287	3.208
Finland	2.289	**2.529**	**2.508**	**2.082**	**2.225**	2.790	2.926	2.519
France	1.975	**4.211**	**3.939**	**3.611**	**1.942**	4.546	4.500	4.028
Germany	2.141	**2.852**	**2.792**	2.773	**2.111**	2.875	2.797	**2.773**
Greece	2.619	**4.954**	**4.524**	**4.088**	**2.573**	5.718	5.531	5.007
Hungary	2.547	**5.682**	**4.533**	**4.045**	**2.523**	6.070	4.947	4.301
Ireland	2.097	10.403	10.381	10.383	**2.024**	**10.334**	**10.372**	**10.329**
Italy	4.140	**4.915**	**4.861**	**4.839**	**4.100**	4.982	4.872	4.844
Latvia	3.641	**2.461**	**2.242**	**2.243**	**3.632**	2.492	2.271	2.246
Lithuania	3.070	**4.614**	**4.628**	**4.378**	**3.011**	4.871	4.849	4.437
Luxembourg	4.229	**4.197**	3.889	3.988	**4.201**	4.305	**3.865**	**3.954**
Malta	2.290	**4.388**	**4.321**	**4.297**	**2.286**	4.392	4.325	4.301
Netherlands	1.748	**1.998**	**1.886**	**1.874**	**1.694**	2.148	2.016	2.000
Poland	1.754	**3.223**	**3.078**	**2.694**	**1.751**	3.596	3.447	2.939
Portugal	2.571	**3.629**	**3.546**	**3.384**	**2.537**	4.018	3.967	3.588
Romania	3.187	**4.411**	**4.322**	**4.214**	**3.182**	4.976	4.608	4.317
Slovakia	2.962	**4.502**	**4.441**	**4.384**	**2.828**	4.611	4.497	4.386
Slovenia	**5.805**	4.198	3.717	3.183	5.822	**4.051**	**3.676**	**3.067**
Spain	2.673	**3.063**	**3.144**	**3.122**	**2.529**	3.184	3.214	3.169
Sweden	2.367	2.956	3.049	2.992	**2.314**	**2.804**	**2.907**	**2.895**

Note: Bolded RMSE signals which model (ARIMA or ARIMAX) performs better in terms of a lower RMSE. For example, for EU-27, ARIMAX better describes the IPI of the same month, while ARIMA better predicts one (h = 1), two (h = 2) or three (h = 3) months ahead.
Source: Own calculations

reflect that as in most cases ARIMAX models produce less accurate forecasts reflected in higher RMSEs. The dominance of the ICI over univariate ARIMA models in terms of forecasting power can be observed for Belgium, Denmark (for h=1), Estonia, Croatia, Lithuania, Malta, Slovenia (all for h = 1 and h = 2), Ireland (for h = 2), Greece (for h = 2 and h = 3), and Slovakia and Sweden (for h = 1, h = 2 and h = 3).

The results for the pre-pandemic period 2008–2019 are similar (see Table 2). ARIMA models performed worse in the sense of model fitting, with exceptions again being Bulgaria, Greece and Slovakia; however, the forecasting accuracy does not show a clear pattern. Most countries, except for France, Italy, Romania and Finland, show at least one forecasting horizon in which the accuracy of ARIMAX models is higher compared to ARIMA models. But only in Greece, Cyprus, Malta, Austria, Portugal, Slovenia, Slovakia and Sweden some forecasting power of business tendencies can be observed regardless of the forecasting horizon.

Table 2 Root Mean Squared Error (RMSE) for ARIMA and ARIMAX models with an expanding window (pre-pandemic period 2008–2019)

Country	ARIMA				ARIMAX			
	Model	h = 1	h = 2	h = 3	Model	h = 1	h = 2	h = 3
EU-27	1.061	**0.931**	**0.919**	**0.863**	**1.016**	0.934	0.924	0.880
Austria	2.592	**1.548**	**1.381**	**1.344**	**2.536**	1.612	1.420	1.365
Belgium	2.347	**2.806**	2.812	2.769	**2.347**	2.809	**2.793**	**2.763**
Bulgaria	1.819	1.971	1.895	1.857	**1.763**	**1.969**	**1.878**	**1.856**
Croatia	2.641	**2.906**	2.529	2.498	**2.406**	3.046	**2.396**	**2.383**
Cyprus	1.699	2.179	2.191	2.167	**1.654**	**2.141**	**2.142**	**2.114**
Czechia	3.093	**1.994**	**1.871**	**1.748**	**3.003**	2.074	1.957	1.919
Denmark	6.318	**4.850**	3.487	**3.481**	**6.267**	5.260	**3.339**	3.859
Estonia	**2.488**	3.603	3.015	2.900	2.543	**3.541**	**2.997**	**2.872**
Finland	1.901	1.856	**1.880**	**1.857**	**1.843**	**1.856**	1.892	1.873
France	1.469	**1.393**	**1.438**	**1.357**	**1.435**	1.403	1.457	1.397
Germany	2.111	1.660	1.442	**1.431**	**2.075**	**1.636**	**1.434**	1.448
Greece	1.731	**2.752**	**2.778**	**2.781**	**1.670**	2.779	2.790	2.817
Hungary	1.909	**2.542**	**2.276**	**2.202**	**1.876**	2.601	2.279	2.227
Ireland	2.090	8.469	8.661	8.629	**1.985**	**8.397**	**8.637**	**8.570**
Italy	4.274	**2.178**	**1.531**	**1.403**	**4.239**	2.219	1.552	1.439
Latvia	3.596	**1.878**	**1.852**	**1.881**	**3.587**	1.917	1.892	1.895
Lithuania	2.676	4.539	**4.497**	4.491	**2.602**	**4.510**	4.499	**4.477**
Luxembourg	4.248	3.632	3.136	3.150	**4.224**	**3.585**	**2.929**	**2.990**
Malta	2.428	**4.720**	4.556	**4.499**	**2.426**	4.721	**4.556**	4.500
Netherlands	1.545	**1.779**	**1.744**	**1.759**	**1.493**	1.815	1.782	1.764
Poland	1.432	**1.308**	1.395	1.378	**1.424**	1.325	**1.389**	**1.378**
Portugal	2.282	2.114	2.287	2.221	**2.244**	**2.046**	**2.233**	**2.194**
Romania	2.829	**2.373**	**2.524**	**2.524**	**2.825**	2.375	2.528	2.536
Slovakia	2.933	**2.885**	**2.945**	**2.947**	**2.793**	3.006	2.981	2.977
Slovenia	**6.031**	2.637	2.355	2.217	6.042	**2.433**	**2.204**	**2.131**
Spain	2.864	**1.426**	**1.448**	**1.424**	**2.690**	1.621	1.562	1.499
Sweden	2.242	2.262	2.418	2.424	**2.197**	**2.178**	**2.362**	**2.374**

Note: Bolded RMSE signals which model (ARIMA or ARIMAX) performs better in terms of a lower RMSE. For example, for EU-27, ARIMAX better describes the IPI of the same month, while ARIMA better predicts one (h = 1), two (h = 2) or three (h = 3) months ahead.
Source: Own calculations

3.2.2 Models with a rolling window

For the RWF, setting the results are more conclusive. Here ARIMAX performs better in fitting the data in the entire period 2008–2024 (see Table A2 in the Appendix), with exceptions being Greece and France. But similarly to EWF, forecasts are predominantly more accurate using ARIMA models. Only in Estonia, Luxembourg and Finland, the ICI has some forecasting power for the IPI.

Results for the pre-pandemic period 2008–2019 (see Table A3 in the Appendix) are more in line with the expectations. Greece and Luxembourg are the only countries where business tendencies do not improve the model fit. Except for Ireland, Lithuania, Luxembourg and Netherlands, at least one forecasting horizon shows better forecasting accuracy when including business tendency data in the model. However, only for Belgium, Hungary, Slovenia, Slovakia and Sweden, there is noticeable forecasting power of business tendencies regardless of the forecasting horizon. This is not true for the EU-27 aggregate.

3.3 Clustering

This section presents the results of clustering, which was designed to answer RQ3. After excluding Ireland due to high volatility of its data, the cluster analysis result with three groups (see Table 3 and Figure A1 in the Appendix) turns out to be the most contextually meaningful, although one of the three groups is again a single country, Luxembourg.

Table 3 Three clusters based on the ICI and IPI

Cluster	Entire period 2008–2024			
	Mean ICI	Var ICI	Mean IPI	Var IPI
1: Austria, Bulgaria, Croatia, Czechia, Estonia, Finland, Germany, Hungary, Malta, Netherlands, Romania, Slovakia, Slovenia, Sweden	–2.7	108.8	0.110	10.643
2: Belgium, Cyprus, Denmark, France, Greece, Italy, Latvia, Lithuania, Poland, Portugal, Spain	–8.0	80.9	0.089	11.628
3: Luxembourg	–18.5	217.2	–0.055	14.627
Cluster	**Pre-pandemic period 2008–2019**			
	Mean ICI	Var ICI	Mean IPI	Var IPI
1: Austria, Bulgaria, Croatia, Czechia, Estonia, Finland, Germany, Hungary, Malta, Netherlands, Romania, Slovakia, Slovenia, Sweden	–2.4	91.8	0.095	8.007
2: Belgium, Cyprus, Denmark, France, Greece, Italy, Latvia, Lithuania, Poland, Portugal, Spain	–8.4	79.2	0.023	6.429
3: Luxembourg	–21.0	194.4	–0.128	10.175

Source: Own calculations

The differences between groups stem mainly from the differences in the ICI, however Luxembourg's IPI is negative as opposed to the other two groups. Performing the analysis taking only the pre-pandemic period into account doesn't change the allocation into clusters compared to the entire period, though. However, for the pre-pandemic period the mean of IPI is considerably larger in group 2 compared to group 1 with considerably lower mean of ICI, worse sentiment coupled with worse industrial production. The results based on the entire period show that the mean of ICI worsens for group 2 where the mean of IPI is slightly reduced while improves for group 1 where the mean of IPI considerably improves.

The relatively more stable pre-pandemic period reveals the relationship between the mean ICI and the mean IPI across the groups that can be expected from the contextual point of view: higher (less negative) mean ICI corresponds to higher mean IPI. Similar, but much less pronounced pattern can be observed also for the entire period.

DISCUSSION AND CONCLUSION

Persistently repetitive shocks in the business cycles, caused by various disruptions (financial crisis, COVID pandemic, recent wars), have intensified the need for immediate economic insights. This study aimed to evaluate the relationship between business tendencies, as captured by the ICI, one of the earliest and most frequent sentiment indicators, and actual industrial production, as captured by the IPI, across the EU Member States, using monthly data from the period 2008–2024. Besides the initial correlation analysis, we also investigated the utility of incorporating the ICI as an exogenous variable in ARIMA forecasting models for industrial production. In addition, we performed clustering analysis for the EU Member States.

Our analysis reveals generally weak linear correlations between the ICI and IPI across the EU Member States in the entire studied period 2008–2024 as in the pre-pandemic period 2008–2019. This finding is somewhat unexpected, as we initially anticipated a stronger positive correlation, given that business tendencies are in principle considered a leading indicator of economic activity.

The analysis of the time series using the classical univariate ARIMA models as a forecasting tool aimed at improving the forecasts by including the ICI as an exogenous explanatory variable within ARIMAX models. Consistent with the weak observed correlation, including the ICI as an exogenous variable in the ARIMAX forecasting models did not yield a convincing improvement in forecasting accuracy, particularly when evaluated over the entire period 2008–2024.

However, the cluster analysis results are more in line with the expected positive relationship between the ICI and the IPI. After excluding Ireland as an outlier (due to its considerably higher IPI volatility), we ended up with three clusters of EU Member States, where again one of the clusters consisted only of one country, i.e. Luxembourg, which is consistent with its distinctiveness in economic research due to the dominating financial sector (e.g. Böwer and Guillemineau, 2006; Lehwald, 2013). But for the other two clusters the relationship between the mean IPI and the mean ICI is rather clear: the higher the ICI, the higher the IPI. This holds for both studied periods but is much more pronounced for the pre-pandemic period 2008–2019.

The study acknowledges several limitations. Not only the entire period 2008–2024, also the pre-pandemic period was marked with turbulences (e.g. the global financial crisis and euro-zone debt crisis), which represent inherent challenges for identifying stable statistical relationships. The assumption of linearity in Pearson correlation and standard ARIMA models may also not capture the complex relationship between qualitative assessments and quantitative measures. Furthermore, while the ICI is a valuable indicator, it reflects sentiment and expectations, which might not always perfectly translate to real economic output. We recommend that official statistics institutions further assess the relationship between the ICI and IPI, explore alternative operationalisations of the business tendencies and produce other real-time indicators to supplement sentiment data, while policymakers rely on a broader set of evidence beyond a single sentiment indicator.

In conclusion, this study successfully achieved its primary goal of assessing the predictive power of the ICI as a leading indicator for the IPI across EU countries and over time. While business sentiment theoretically holds promise as a leading indicator for industrial production, its practical utility in a highly volatile period like 2008–2024 appears limited when assessed through traditional linear correlation and inclusion of an exogenous variable in ARIMA models. Future research should delve into the limitations of the current study to better understand the outcomes of this study.

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APPENDIX

Table A1 Correlations between the Industrial Production (Volume) Index (IPI) and the Industrial Confidence Indicator (ICI) by country and lead, entire period (2008–2024) and pre-pandemic period (2008–2019)

Country	Entire period				Pre-pandemic period			
	Lead = 0	Lead = 1	Lead = 2	Lead = 3	Lead = 0	Lead = 1	Lead = 2	Lead = 3
EU-27	0.14	**–0.07**	**–0.08**	**–0.03**	0.29	0.21	0.11	0.03
Austria	0.17	0.03	0.00	0.01	0.23	0.18	0.11	0.05
Belgium	0.09	0.02	0.06	0.00	0.09	0.08	0.04	0.00
Bulgaria	0.05	**–0.11**	**–0.19**	**–0.15**	0.01	**–0.01**	**–0.12**	**–0.11**
Croatia	0.09	0.01	**–0.04**	**–0.04**	0.09	0.07	0.06	0.02
Cyprus	0.04	**–0.17**	**–0.01**	0.04	0.21	0.20	0.17	0.15
Czechia	0.07	**–0.11**	**–0.11**	**–0.08**	0.16	0.12	0.00	**–0.03**
Denmark	0.10	0.10	0.03	0.08	0.11	0.12	0.07	0.08
Estonia	0.19	0.09	0.07	0.07	0.24	0.19	0.14	0.11
Finland	0.18	0.12	0.05	0.04	0.21	0.15	0.06	0.04
France	0.11	**–0.16**	**–0.12**	**–0.03**	0.17	0.13	0.07	0.00
Germany	0.14	0.02	**–0.03**	**–0.02**	0.23	0.17	0.07	**–0.01**
Greece	0.04	0.06	0.04	0.04	0.03	0.03	0.04	0.04
Hungary	0.10	**–0.07**	**–0.04**	0.01	0.18	0.16	0.11	0.06
Ireland	0.03	**–0.01**	0.00	0.00	0.04	0.03	0.06	0.04
Italy	–0.04	**–0.09**	**–0.10**	**–0.03**	0.25	0.19	0.11	0.04
Latvia	0.19	0.04	0.02	0.03	0.20	0.11	0.08	0.04
Lithuania	0.09	0.07	0.03	**–0.01**	0.06	0.08	0.04	**–0.02**
Luxembourg	0.05	**–0.06**	**–0.12**	**–0.05**	0.03	–0.01	–0.13	–0.08
Malta	0.02	**–0.02**	**–0.06**	**–0.03**	0.02	0.01	0.03	0.04
Netherlands	0.08	0.00	**–0.03**	**–0.10**	0.03	0.02	**–0.01**	**–0.08**
Poland	0.04	**–0.25**	**–0.20**	**–0.12**	**–0.02**	**–0.06**	**–0.07**	**–0.11**
Portugal	0.07	**–0.13**	**–0.16**	**–0.11**	0.11	0.05	0.02	0.01
Romania	0.10	**–0.27**	**–0.22**	**–0.13**	0.00	**–0.07**	**–0.09**	**–0.10**
Slovakia	0.15	**–0.16**	**–0.26**	**–0.10**	0.12	0.13	**–0.10**	0.02
Slovenia	0.20	0.04	0.00	**–0.01**	0.24	0.18	0.11	0.07
Spain	0.11	**–0.08**	**–0.05**	0.00	0.21	0.18	0.13	0.12
Sweden	0.14	0.06	0.01	0.00	0.19	0.18	0.12	0.10

Source: Own calculations

Table A2 Root Mean Squared Error (RMSE) for ARIMA and ARIMAX models with a rolling window (entire period 2008–2024)

Country	ARIMA				ARIMAX			
	Model	**h = 1**	**h = 2**	**h = 3**	**Model**	**h = 1**	**h = 2**	**h = 3**
EU-27	1.776	**4.240**	**3.590**	**3.270**	1.756	4.534	4.539	3.815
Austria	2.998	**3.540**	**2.657**	2.610	**2.982**	3.602	2.689	**2.610**
Belgium	2.065	**4.676**	**4.648**	**4.692**	**2.049**	4.924	4.710	4.738
Bulgaria	2.496	**3.511**	**3.120**	**2.490**	**2.468**	4.161	4.234	2.637
Croatia	2.786	3.266	2.523	2.576	**2.752**	**3.253**	**2.456**	**2.495**
Cyprus	2.165	**6.327**	**5.199**	**5.248**	**2.132**	6.778	5.765	5.343
Czechia	2.851	**3.608**	**3.719**	3.678	**2.818**	3.860	3.761	**3.678**
Denmark	8.983	**5.384**	**4.755**	4.097	**8.848**	5.970	4.941	**4.066**
Estonia	**2.517**	**3.793**	**3.358**	3.352	2.541	3.808	3.381	**3.345**
Finland	2.481	**3.411**	**2.896**	**2.660**	**2.454**	3.662	3.415	2.940
France	**2.451**	**5.898**	**4.993**	**4.708**	2.522	6.020	5.192	4.817
Germany	2.103	**3.320**	**3.357**	**3.327**	**2.067**	3.613	3.449	3.341
Greece	3.544	7.039	**4.998**	5.441	**3.472**	**7.006**	6.904	**5.268**
Hungary	3.342	**7.512**	**5.601**	**4.735**	**3.305**	7.610	6.563	5.493
Ireland	1.913	11.351	**11.369**	**11.287**	**1.906**	**11.331**	11.382	11.300
Italy	3.633	5.944	6.033	6.031	**3.606**	**5.882**	**6.019**	**6.030**
Latvia	3.144	3.505	2.917	2.600	**3.143**	**3.298**	**2.685**	**2.522**
Lithuania	3.338	**5.178**	**4.664**	**4.111**	**3.312**	5.639	5.511	4.664
Luxembourg	4.118	**4.203**	**3.968**	**4.206**	**4.094**	4.493	4.135	4.245
Malta	1.722	3.664	3.747	**3.772**	**1.707**	**3.655**	**3.740**	3.795
Netherlands	1.844	**2.461**	**2.044**	**1.984**	**1.803**	2.752	2.362	2.351
Poland	2.119	**4.210**	**3.744**	**3.315**	**2.097**	4.755	4.573	3.606
Portugal	2.795	**4.357**	**4.254**	**4.155**	**2.771**	5.435	5.272	4.584
Romania	3.498	**5.775**	**5.346**	**4.971**	**3.473**	7.402	6.872	5.050
Slovakia	2.554	**5.364**	**5.137**	**4.982**	**2.465**	5.959	5.664	5.140
Slovenia	3.795	**4.796**	**4.423**	3.695	**3.741**	5.040	5.094	**3.630**
Spain	1.829	**3.735**	**3.841**	**3.828**	**1.790**	3.795	3.863	3.845
Sweden	2.390	**3.230**	**3.175**	**3.188**	**2.361**	3.233	3.240	3.243

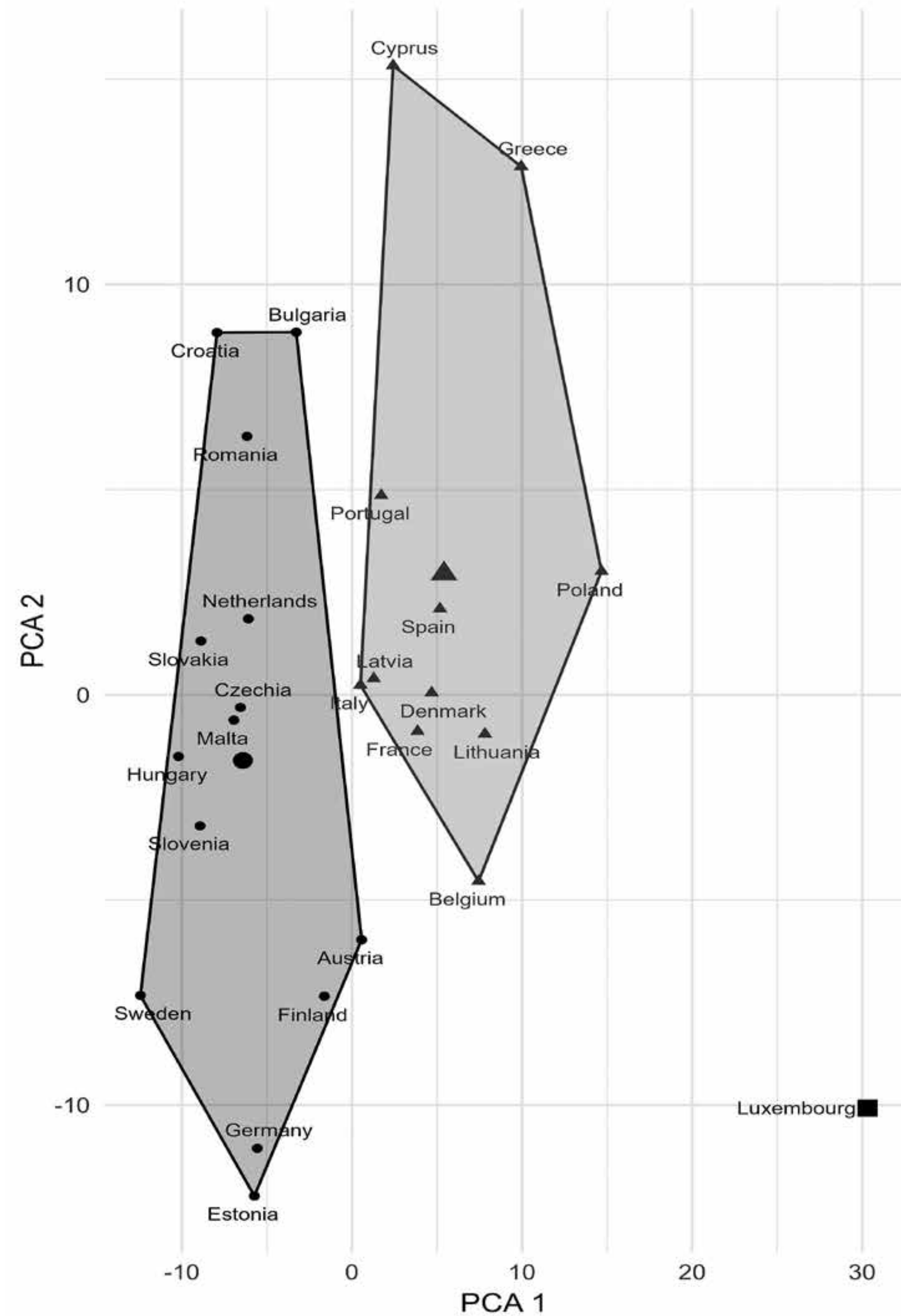
Note: Bolded RMSE signals which model (ARIMA or ARIMAX) performs better in terms of a lower RMSE. For example, for EU-27, ARIMAX better describes the IPI of the same month, while ARIMA better predicts one (h = 1), two (h = 2) or three (h = 3) months ahead.
Source: Own calculations

Table A3 Root Mean Squared Error (RMSE) for ARIMA and ARIMAX models with a rolling window (pre-pandemic period 2008–2019)

Country	ARIMA				ARIMAX			
	Model	**h = 1**	**h = 2**	**h = 3**	**Model**	**h = 1**	**h = 2**	**h = 3**
EU-27	0.819	**0.876**	**0.872**	**0.868**	**0.803**	0.908	0.881	0.880
Austria	2.230	**2.038**	1.301	1.267	**2.199**	2.118	**1.282**	**1.218**
Belgium	1.838	**3.538**	**3.481**	3.529	**1.833**	3.573	3.527	**3.518**
Bulgaria	1.558	**1.888**	1.836	1.772	**1.526**	1.906	**1.795**	**1.772**
Croatia	2.572	3.188	2.467	2.495	**2.515**	**3.155**	**2.299**	**2.303**
Cyprus	1.309	**1.962**	1.913	1.746	**1.293**	1.975	**1.907**	**1.723**
Czechia	2.643	2.171	**1.894**	1.932	**2.620**	**2.113**	1.937	**1.891**
Denmark	7.748	**4.817**	4.261	4.076	**7.654**	5.092	**4.129**	**3.971**
Estonia	**2.452**	**2.949**	**2.798**	**2.831**	2.526	3.080	2.832	2.833
Finland	1.425	**1.733**	1.871	**1.797**	**1.390**	1.776	**1.794**	1.829
France	1.239	**1.147**	1.313	**1.346**	**1.222**	1.189	**1.309**	1.348
Germany	2.047	**1.470**	1.439	**1.468**	**1.996**	1.743	**1.367**	1.477
Greece	1.395	**1.878**	2.013	**2.147**	**1.366**	1.913	**1.999**	2.157
Hungary	1.978	**2.104**	2.017	**1.948**	**1.936**	2.208	**1.996**	2.051
Ireland	1.826	8.068	**8.583**	8.485	**1.811**	**8.030**	8.609	**8.476**
Italy	3.953	**2.171**	1.446	1.523	**3.936**	2.270	**1.352**	**1.475**
Latvia	**2.585**	**2.142**	1.828	**1.783**	2.590	2.191	**1.788**	1.815
Lithuania	2.132	3.327	3.258	3.321	**2.103**	**3.302**	**3.244**	**3.304**
Luxembourg	4.282	2.657	2.296	2.267	**4.257**	**2.636**	**2.266**	**2.253**
Malta	1.870	**3.609**	3.635	**3.584**	**1.862**	3.621	**3.624**	3.586
Netherlands	1.226	**1.430**	**1.295**	1.357	**1.191**	1.493	1.345	**1.344**
Poland	1.285	**1.265**	**1.440**	**1.452**	**1.271**	1.287	1.458	1.488
Portugal	1.995	**2.076**	2.294	2.258	**1.962**	2.127	**2.288**	**2.249**
Romania	2.376	2.365	**2.117**	**2.104**	**2.371**	**2.343**	2.133	2.114
Slovakia	2.057	**2.643**	**2.686**	**2.680**	**1.968**	2.788	2.689	2.691
Slovenia	2.819	2.276	1.659	**1.502**	**2.788**	**2.268**	**1.606**	1.579
Spain	2.044	**1.591**	**1.458**	**1.448**	**1.999**	1.655	1.494	1.459
Sweden	2.040	1.895	2.170	2.187	**2.036**	**1.799**	**2.071**	**2.102**

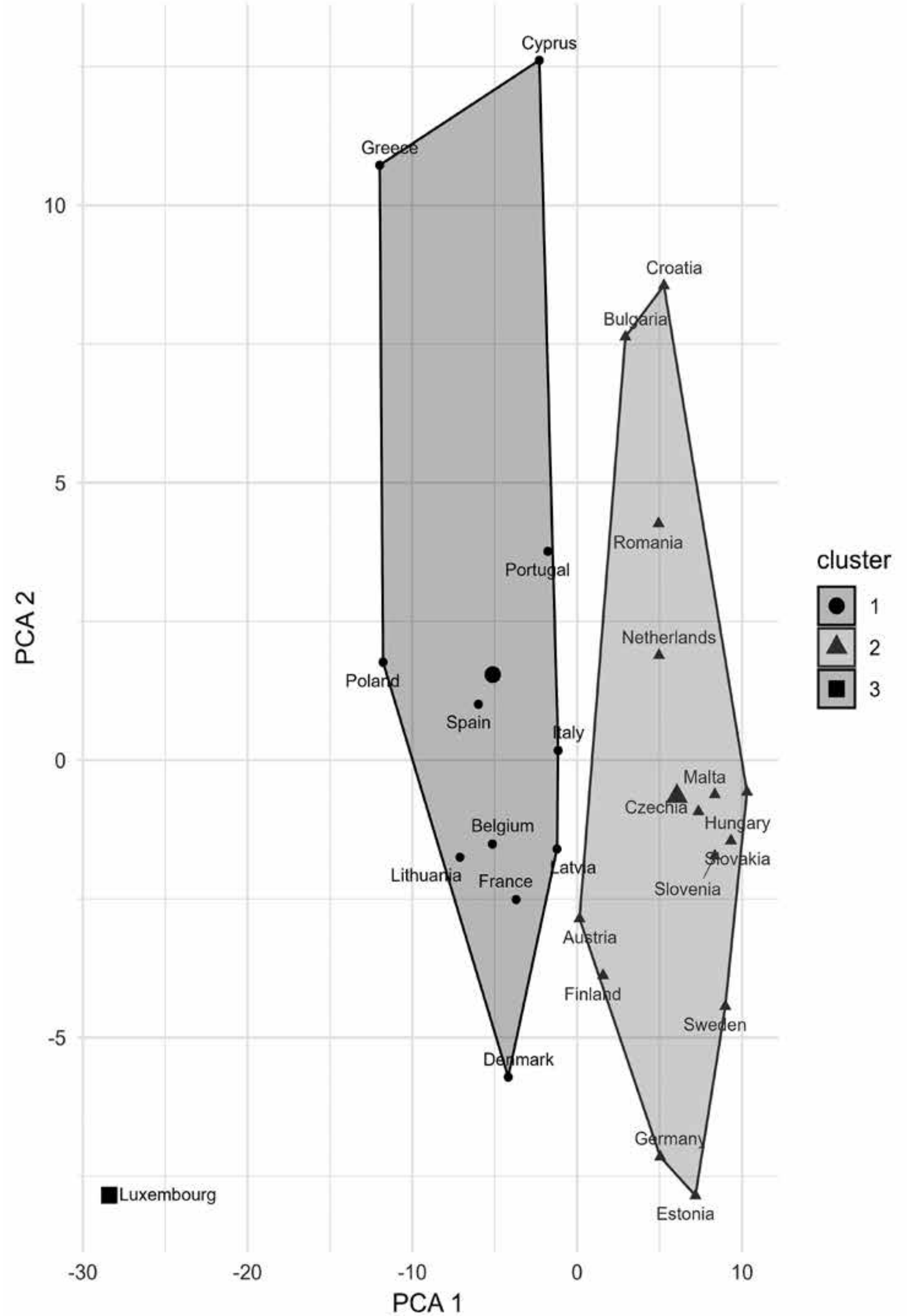
Note: Bolded RMSE signals which model (ARIMA or ARIMAX) performs better in terms of a lower RMSE. For example, for EU-27, ARIMAX better describes the IPI of the same month, while ARIMA better predicts one (h = 1), two (h = 2) or three (h = 3) months ahead.
Source: Own calculations

Figure A1 Three clusters based on the ICI and IPI (left: the pre-pandemic period 2008–2019; right: the entire period 2008–2024)



Note: The clusters 1 and 2 on the right are labelled 2 and 1 in Table 3.
Source: Own calculations

Figure A1 (continuation)



Note: The clusters 1 and 2 on the right are labelled 2 and 1 in Table 3.
Source: Own calculations