# Trends in childhood vaccination coverage in the European Union, 1980–2024: an ecological time-series study

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The Lancet Regional Health - Europe 2026;■: 101834

Published Online XXX

https://doi.org/10.1016/j.lanepe.2026.101834

## Summary

**Background** Vaccination is among the most effective public health interventions, yet vaccine hesitancy in the European Union (EU) has driven declining coverage and resurgences of vaccine-preventable diseases. Trend assessments are essential for informing strategies to maintain high coverage levels.

**Methods** We analyzed WHO/UNICEF Estimates of National Immunization Coverage data (as of September 2025) for 27 EU countries from 1980 to 2024. Coverage for seven first-year antigens (DTP-3, HEPB-3, HIB-3, POL-3, PCV-3, MCV-1, RCV-1) was evaluated using Joinpoint regression for Average Annual Percent Change (AAPC) overall and recent Annual Percent Change (APC) shifts.

**Findings** Of 183 country–vaccine time series, 128 showed positive AAPCs and 55 negative AAPCs, indicating substantial long-term gains but heterogeneous trajectories. In the most recent segment, APCs revealed predominantly declining trends, with 119 decreasing and only 64 increasing trends; 16 countries had four or more decreasing trends across antigens. In 2024, 71 country–antigen combinations reached at least 95% coverage and 62 were between 90% and 94%; in that year, Luxembourg and Portugal achieved at least 95% for all seven antigens, while Romania reported less than 80% for all. The most marked recent declines were observed for HIB-3 and POL-3, with 20 countries each showing decreasing trends, followed by HEPB-3 (18) and DTP-3 (17) whereas measles- and rubella-containing vaccines showed relatively more favorable recent trajectories. Most of these declining segments started between 2019 and 2022, coinciding with the COVID-19 pandemic and its immediate aftermath, and may reflect pandemic-related disruptions to routine childhood vaccination services.

**Interpretation** Despite long-term gains, recent EU-wide coverage declines signal increasing risks to herd and individual immunity. International, national and community actions are needed to reverse trends.

**Funding** Università Cattolica del Sacro Cuore contributed to the funding of this research project and its publication, Linea D3.1 2025 and Linea D3.1 2026.



**Keywords:** Vaccination; Childhood; European Union; Public health; Trend analysis

## Introduction

Vaccinations represent one of the most successful and cost-effective public health interventions and have led to the eradication, elimination, and control of many infectious diseases in the last few decades.[1] The relevance of vaccination is testified by its contribution to eradicating smallpox in 1980, while nowadays it is a key tool for eliminating wild polio.[2,3] Vaccinations have reduced the burden of diseases such as tetanus, whooping cough, pneumonia, measles, influenza, and diphtheria, annually preventing 4–5 million deaths worldwide,[4] and over 154 million deaths in the last 50 years, especially among children.[5] In addition, vaccination is one of the most cost-effective interventions, reducing direct and indirect costs related to infectious diseases.[6]

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## Research in context

### Evidence before this study

Vaccination stands as one of the most successful public health interventions globally, significantly reducing the burden of infectious diseases. However, in recent years, the European Union (EU) has faced significant challenges, including rising vaccine hesitancy and the resurgence of vaccine-preventable disease outbreaks. To provide updated data on childhood vaccination coverage trends in the EU, we searched PubMed, Scopus, and official institutional databases (WHO, ECDC, UNICEF) up to August 2025, without language restrictions. The search combined free-text and controlled vocabulary terms for "vaccination coverage", "immunization coverage", "trend", "trend analysis", and "European Union". While existing research often focuses on specific countries, single antigens, or shorter timeframes, there is a lack of comprehensive, multi-antigen longitudinal analyses covering the entire EU block over several decades. Most available evidence highlights recent declines, particularly following the COVID-19 pandemic, but does not systematically contrast these with long-term historical trajectories across different geographical regions.

### Added value of this study

To our knowledge, this study represents the first comprehensive analysis of childhood vaccination coverage at the EU level to include seven different antigens (DTP-3, HEPB-3, HIB-3, POL-3, PCV-3, MCV-1, and RCV-1) over a period exceeding 40 years, from 1980 to 2024. Beyond describing long-term trends, our study combines estimates of both long-term patterns and recent changes, allowing the identification of countries and antigens experiencing recent reversals in vaccination coverage. Our findings reveal a complex landscape: while most country–antigen combinations showed a significant long-term increase, a concerning and widespread recent deterioration in vaccination trends across the EU, potentially influenced by pandemic-related disruptions and other contextual factors. By providing a standardized comparison across countries and antigens using a consistent analytical framework, this study identifies early warning signals that may not be apparent from absolute coverage estimates alone and provides evidence to support the timely strengthening of immunization programmes and surveillance systems.

### Implications of all the available evidence

Our findings demonstrate that while the EU has achieved historically high vaccination rates, the recent downward trends in several Member States pose a serious threat to herd immunity and regional health security. These results have direct implications for policymakers, as they highlight the urgent need for tailored, evidence-based public health interventions to address localized declines and combat vaccine hesitancy. This analysis serves as a critical tool for guiding EU-wide and national policies aimed at harmonizing immunization strategies, optimizing vaccine delivery systems, and ensuring sustainable high coverage to prevent the re-emergence of infectious diseases. Future research should focus on the socio-economic and behavioral drivers behind these identified geographical disparities to further refine targeted communication and intervention strategies.

In recent years, however, vaccine hesitancy, defined as a delay in acceptance or outright refusal despite the availability of vaccination services,[7] has gained momentum, especially due to misinformation at both political and scientific levels. This phenomenon affects countries worldwide differently and unevenly, and depends on several social, political, educational, economic, behavioral, and health factors.[7] In this context, the increase in hesitancy, as well as the disruption caused by the COVID-19 pandemic,[8] has led to a reduction in vaccination coverage, with vaccine-preventable diseases re-emerging, even in high-income European Union (EU) countries.[9] To address this situation, many countries adopted several measures, with substantial variation across EU countries, with some recommending selected vaccines and others adopting vaccination mandates.[10] In particular, 13 EU countries (Belgium, Bulgaria, Croatia, Czechia, France, Germany, Hungary, Italy, Latvia, Malta, Poland, Slovakia and Slovenia) have established at least one mandatory vaccination for school entry, with differences in terms of modalities, timing, and the number of vaccines.[10] For example, while in Belgium, the only mandatory vaccination (against polio) has been in place since 1967, in Italy the number of mandatory vaccinations increased from four to ten in 2017, and in France, a law of 2018 established eleven mandatory vaccinations.[10] Other countries have maintained an approach emphasizing personal freedom, aiming at empower citizens to make informed decision. In Sweden, after experiencing small-scale and localized outbreaks of measles and rubella in 2013,[11] new vaccine policies were introduced, offering immunization programmes in at-risk groups and investigating underserved populations with low vaccination coverage.

Currently, information on population coverage against several preventable communicable diseases at country level is available from different sources, such as international organizations, Ministries of Health, national institutions, and independent research centers. However, to date, a systematic synthesis of EU vaccination coverage trends has not been developed. Even though these databases and dashboards allow for rapid evaluation of coverages, a structured comparative analysis of different EU countries is needed to put the data in the right perspective. Analysis of these data, indeed, is crucial for monitoring the evolution of infectious diseases and assessing the effectiveness of targeted policies adopted at national and international levels.[12,13] Evaluating trends in vaccination coverage provides scientific evidence for policymakers to implement effective and targeted prevention strategies. Importantly, even modest declines in vaccination coverage in countries with historically high uptake may represent early-warning signals of immunization system fragility, with potential implications for the reemergence of vaccine-preventable diseases.

In this context, our study aims to describe the trends of vaccination coverage for seven childhood vaccines from 1980 to 2024 across EU countries and to identify positive, negative, or stationary evolutions for both the single vaccination and the single country.

## Methods

This study is an observational ecological time-series analysis based on aggregated data and is reported in accordance with the STROBE guidelines.[14]

### Data source

We extracted data on vaccination coverage from the publicly available WHO/UNICEF Estimates of National Immunization Coverage (WUENIC) dataset, based on data officially reported to the organizations by Member States every year, as of September 2025.[15] The WUENIC dataset provides complete annual estimates for each country, even when original data are missing, through a standardized process combining administrative and survey data with expert review. We included all 27 current EU countries in our analysis and classified them according to the classification of EuroVoc, as shown in Supplementary Table S1. We considered the period from the first year available, 1980 (or more recently if data were unavailable) to 2024 (or the most updated data when no data were available for 2024). Based on the availability of data, we selected coverage indicators referring to seven vaccines scheduled during the first year of life to prevent nine vaccine-preventable diseases. In particular, we selected the vaccinations for diphtheria, tetanus toxoid, and pertussis (DTP-3), hepatitis B (HEPB-3), *Haemophilus influenzae* type B (HIB-3), measles (MCV-1), pneumococcus (PCV-3), polio (POL-3), and rubella (RCV-1). Further description of the vaccination schedule, according to the WHO, is available in Supplementary Table S2.

### Statistical analysis

We conducted descriptive statistics across vaccination coverage during the considered period in each country. To assess changes in vaccination coverage trends across EU countries, we used the Joinpoint regression model. Joinpoint regression is a tool for analyzing changes in trends over time and, for this reason, it is used in many scientific domains,[16,17] including vaccination.[18–20] Indeed, this model allows for identifying a point ("joinpoint") when a change in a parameter occurs within the time series. We used the Joinpoint Regression Program with default settings. The maximum number of joinpoints (n=7) was determined automatically by the software based on the length of the time series. The final model was selected using the permutation test procedure implemented in the program (overall two-sided $\alpha = 0.05$), choosing the most parsimonious model that provided a statistically significant improvement in fit. Analyses were performed using the standard log-linear model (ln transformation) implemented in the Joinpoint Regression Program, whereby the natural logarithm of the outcome is modeled over time. This approach is recommended by the software for the estimation of Annual Percent Changes (APCs) and Average Annual Percent Changes (AAPCs), which are derived directly from the slope of the log-linear model.

In our study, we conducted a trend analysis for each coverage indicator for all countries. In particular, we considered the year as the independent variable and the vaccination coverage indicator as the dependent variable, expressed as a percentage, while the results were sorted by country. Moreover, the Joinpoint model allows for estimating an APC in vaccination coverage, reflecting an increase or decrease over time. For each vaccination, the presence of joinpoint indicated changes in APC over the time. Finally, the model estimates the AAPC, a summary measure of the trend over the entire period. Given the number of models evaluated, a type I error Bonferroni correction was applied to adjust for multiple comparisons, resulting in a significance threshold for APC and AAPC of $p < 0.00027$ (0.05/183).[21] Each country–vaccine time series was analyzed independently using separate joinpoint regression models. The analysis was performed using Joinpoint Trend Analysis Software 5.3.0—Desktop Version, available from the Surveillance Research Program of the US National Cancer Institute.[22]

### APC and AAPC analysis

The last two trends of the APC that occurred in the time series were considered for each coverage indicator. For reasons of consistency, we called the second-last trend "trend A", accounting for the period between the second-last and the last joinpoint, and the last trend "trend B", accounting for the period after the last joinpoint. Trends A and B are marked for clarity in Supplementary Figure S1. Based on the significance of the APC, each trend was classified as significant increase, significant decrease, non-significant increase, and non-significant decrease. Changes between the last two segments (trend A and trend B) were used to assess recent variation in vaccination coverage.

The classification of trend evolution between trend A and trend B was based on predefined combinations of

APC changes. Trends were classified as positive when they showed sustained or emerging increases, and as negative when they showed sustained or emerging decreases. When changes occurred between non-significant trends, evolutions were classified as mildly positive or mildly negative. For series without joinpoints, classification was based on the overall APC.

Pairs of trends classified as positive or mildly positive were considered increasing, while those classified as negative or mildly negative were considered decreasing. Additional methods for classification are available in Supplementary Table S3.

Finally, to identify which EU countries and which antigen presented an overall improving or worsening trend in vaccination coverage, we considered the AAPC for each indicator, identifying both positive and negative evolution.

### Ethics approval
The study does not constitute human subjects research, nor does it use personal data of any kind. No Institutional Review Board approval was needed.

### Role of the funding source
The funding body had no role in the design of the study, analysis or interpretation of data, writing of the manuscript, or the decision to submit the article for publication.

## Results
### Overall results
Out of 189 possible vaccination–country trends (7 vaccines across 27 EU countries), 183 analyses were performed (Supplementary Figures S2–S5); data were unavailable in 6 cases. Among the anaysed trends, 55 showed a negative AAPC and 128 a positive AAPC, indicating decreasing or increasing vaccination coverage, respectively, over the available observed period. Among these, 31 negative AAPC were statistically significant, whereas 85 positive AAPC were significant. All AAPCs are shown in Table 1.

In the most recent year (2024), 71 country–antigen combinations achieved coverage ≥95%, while 62 were between 90% and 94% (Supplementary Table S4). Only Luxembourg and Portugal reached ≥95% coverage for all antigens. Hungary reached ≥95% coverage for all antigens with available data, as hepatitis B and pneumococcal vaccination data were unavailable. Belgium, France and Latvia reached ≥95% coverage for 6 of 7 antigens. On the other hand, Romania reported coverage <80% for all antigens, while Estonia showed coverage levels around 80%.

### AAPC results by country
Overall, 20 countries had multiple positive trends in the AAPC for 4 or more coverages (Table 1). Among these, eight countries showed positive AAPCs for all seven vaccination coverage, including Greece, Ireland, Latvia, France, Luxembourg, Malta, Portugal and Spain.

Moreover, five countries (Belgium, Cyprus, Germany, Hungary and Italy) had positive AAPC for six different coverages, while Denmark, Estonia and Lithuania showed positive AAPCs for five different coverages. Finally, four countries (Austria, Croatia, Slovenia and Sweden) showed positive AAPCs for four different coverages.

On the contrary, some countries showed negative trends in the AAPC for multiple coverages. Romania showed a negative trend for all 7 coverages. The Netherlands and Slovakia showed negative trends for 6 coverages. Bulgaria and Czechia both showed negative trends for 5 coverages while Poland presented negative AAPC for 4 coverages.

### AAPC by antigen
The analysis of the AAPC by antigen revealed heterogeneous trends (Table 2). For DTP-3, 9 of 27 countries showed a significant increase, whereas 7 exhibited a significant decrease. For HEPB-3, 14 of 24 countries showed a significant increase, and 3 showed a significant decrease. HIB-3 trends displayed a clear predominance of significant increases, observed in 17 of 27 countries, with 4 significant and 2 non-significant decreases. For MCV-1, 13 of 27 countries showed a significant increase, while 3 presented a significant decrease and 5 a non-significant decrease. PCV-3 showed mainly significant (n=8) or non-significant (n=11) increases among 24 available countries, with only 3 significant and 2 non-significant decrease. POL-3 trends demonstrated a more balanced distribution, with 8 significant increases and 6 significant decreases across 27 countries. Finally, RCV-1 trends showed mostly significant increases (16 of 27 countries).

### Variation in the APC of trend A and trend B
The results revealed in total 335 positive APC and 213 negative APC (Supplementary Table S5). The analysis of the latest trends reveals predominantly negative evolution (119 cases), compared to positive evolution (64 cases). Table 3 reports all the details about changes among trend A and B by country and antigen. Briefly, in 73 cases, trends shifted from positive to negative, and in 18 cases a positive trend lost significance. Two trends maintained a significant negative pattern, and 11 negative trends became significant. On the other hand, 18 trends shifted from negative to positive, while 3 trends maintained a significant positive pattern. Twenty-nine trends remained non-significantly positive, and 5 remained non-significantly negative.

Considering trends without joinpoint, an increase in 14 cases and a decrease in 10 cases is observed.

### Vaccination coverage trends by country
Considering the changes between trends A and B, 16 EU countries showed predominantly negative patterns,

| Country | DTP-3 | | | HEPB-3 | | | HIB-3 | | | MCV-1 | | | PCV-3 | | | POL-3 | | | RCV-1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Period | AAPC (95% CI) | p-value | Period | AAPC (95% CI) | p-value | Period | AAPC (95% CI) | p-value | First-last year | AAPC (95% CI) | p-value | Period | AAPC (95% CI) | p-value | Period | AAPC (95% CI) | p-value | Period | AAPC (95% CI) | p-value |
| AT | 1980–2024 | −0.12 (−0.18; −0.05) | 0.0016 | 2000–2024 | 4.19 (3.75; 4.72) | **<0.0001** | 1999–2024 | 0.74 (0.57; 0.95) | **<0.0001** | 1981–2024 | 3.30 (2.78; 3.85) | **<0.0001** | Data NA | | | 1980–2024 | −0.10 (−0.18; −0.02) | 0.0256 | 1981–2024 | 3.30 (2.78; 3.85) | **<0.0001** |
| BE | 1980–2024 | 0.03 (−0.11; 0.20) | 0.769 | 1997–2024 | 14.35 (11.79; 16.70) | **<0.0001** | 1993–2024 | 5.33 (4.28; 6.33) | **<0.0001** | 1981–2024 | 1.62 (0.45; 2.44) | 0.0192 | 2012–2024 | 0.11 (0.07; 0.15) | **<0.0001** | 1980–2024 | −0.06 (−0.12; −0.01) | 0.0308 | 1985–2024 | 0.87 (0.55; 1.20) | **<0.0001** |
| BG | 1980–2024 | −0.20 (−0.25; −0.16) | **<0.0001** | 1992–2024 | 0.61 (−0.09; 1.16) | 0.0572 | 2010–2024 | −0.02 (−0.55; 0.53) | 0.9598 | 1980–2024 | −0.13 (−0.20; −0.05) | 0.0004 | 2010–2024 | 1.12 (0.15; 1.70) | 0.0288 | 1980–2024 | −0.18 (−0.29; −0.07) | 0.0012 | 1993–2024 | −0.03 (−0.18; 0.12) | 0.6071 |
| HR | 1992–2024 | 0.32 (0.27; 0.38) | **<0.0001** | 2007–2024 | −0.30 (−0.62; −0.08) | 0.0052 | 2002–2024 | 0.53 (0.30; 0.71) | **<0.0001** | 1992–2024 | −0.01 (−0.07; 0.04) | 0.6027 | 2021–2024 | 5.27 (−5.08; 16.79) | 0.3011 | 1992–2024 | 0.26 (0.21; 0.31) | **<0.0001** | 1992–2024 | −0.01 (−0.07; 0.04) | 0.6027 |
| CY | 1980–2024 | 1.95 (1.43; 2.50) | **<0.0001** | 1991–2024 | 4.88 (4.79; 5.02) | **<0.0001** | 2000–2024 | 5.11 (4.43; 5.83) | **<0.0001** | 1980–2024 | 2.50 (2.29; 2.72) | **<0.0001** | 2015–2024 | −0.32 (−1.16; 0.53) | 0.4219 | 1980–2024 | 2.14 (1.74; 2.65) | **<0.0001** | 1980–2024 | 2.50 (2.29; 2.72) | **<0.0001** |
| CZ | 1993–2024 | −0.40 (−0.47; −0.35) | **<0.0001** | 2002–2024 | 0.00 (−0.12; 0.13) | 0.9666 | 2002–2024 | −0.50 (−0.62; −0.38) | **<0.0001** | 1993–2024 | −0.32 (−0.44; −0.17) | **<0.0001** | Data NA | | | 1993–2024 | −0.43 (−0.52; −0.38) | **<0.0001** | 1993–2024 | −0.32 (−0.44; −0.17) | **<0.0001** |
| DK | 1980–2024 | 0.29 (0.20; 0.40) | **<0.0001** | Data NA | | | 1993–2024 | 0.64 (0.45; 0.96) | 0.0004 | 1987–2024 | 0.60 (0.48; 0.73) | **<0.0001** | 2009–2024 | 0.84 (0.62; 1.08) | **<0.0001** | 1980–2024 | −0.02 (−0.10; 0.03) | 0.4555 | 1987–2024 | 0.60 (0.48; 0.73) | **<0.0001** |
| EE | 1993–2024 | 0.39 (0.33; 0.45) | **<0.0001** | 2004–2024 | −0.63 (−0.80; −0.47) | **<0.0001** | 2004–2024 | 6.72 (5.81; 8.06) | **<0.0001** | 1993–2024 | 0.46 (0.36; 0.58) | **<0.0001** | 2010–2024 | −0.61 (−0.93; −0.29) | **<0.0001** | 1993–2024 | 0.56 (0.47; 0.64) | **<0.0001** | 1993–2024 | 0.46 (0.36; 0.58) | **<0.0001** |
| FI | 1980–2024 | −0.02 (−0.07; 0.04) | 0.5811 | Data NA | | | 1992–2024 | −0.22 (−0.28; −0.11) | **<0.0001** | 1981–2024 | 0.67 (0.62; 0.72) | **<0.0001** | 2010–2024 | 0.61 (0.52; 0.74) | **<0.0001** | 1980–2024 | −0.01 (−0.12; 0.13) | 0.9846 | 1981–2024 | 0.67 (0.62; 0.72) | **<0.0001** |
| FR | 1980–2024 | 0.48 (0.38; 0.61) | **<0.0001** | 1998–2024 | 5.34 (4.98; 5.72) | **<0.0001** | 1998–2024 | 0.65 (0.47; 0.89) | 0.0004 | 1983–2024 | 4.48 (4.32; 4.61) | **<0.0001** | 2008–2024 | 0.44 (−0.14; 1.13) | 0.1212 | 1980–2024 | 0.48 (0.41; 0.58) | **<0.0001** | 1983–2024 | 4.48 (4.32; 4.61) | **<0.0001** |
| DE | 1981–2024 | −0.17 (−0.33; −0.02) | 0.0284 | 1993–2024 | 5.61 (5.26; 5.86) | **<0.0001** | 1991–2024 | 1.15 (0.97; 1.26) | **<0.0001** | 1980–2024 | 2.84 (2.44; 3.17) | **<0.0001** | 2012–2024 | 11.36 (7.74; 16.09) | **<0.0001** | 1980–2024 | 0.19 (0.06; 0.31) | 0.004 | 1991–2024 | 0.82 (0.69; 0.96) | **<0.0001** |
| EL | 1980–2024 | 0.52 (0.15; 0.83) | 0.0104 | 1991–2024 | 6.38 (4.59; 8.40) | **<0.0001** | 1994–2024 | 12.95 (11.32; 14.11) | **<0.0001** | 1984–2024 | 0.91 (−0.37; 2.33) | 0.07 | 2011–2024 | 1.20 (1.02; 1.34) | **<0.0001** | 1980–2024 | 0.13 (0.00; 0.26) | 0.0468 | 1995–2024 | 0.80 (0.50; 0.99) | **<0.0001** |
| HU | 1980–2024 | 0.00 (0.00; 0.00) | 0.0028 | Data NA | | | 1999–2024 | 0.00 (0.00; 0.00) | 0.078 | 1980–2024 | 0.00 (0.00; 0.00) | 0.0028 | Data NA | | | 1980–2024 | 0.02 (0.01; 0.04) | 0.0368 | 1989–2024 | 0.00 (0.00; 0.00) | 0.2679 |
| IE | 1980–2024 | 2.30 (2.09; 2.56) | **<0.0001** | 2010–2024 | 3.97 (1.90; 5.27) | 0.0012 | 1997–2024 | 0.67 (0.59; 0.74) | **<0.0001** | 1983–2024 | 6.09 (5.23; 7.15) | **<0.0001** | 2010–2024 | 3.73 (1.79; 4.96) | 0.0012 | 1980–2024 | 0.55 (0.39; 0.75) | **<0.0001** | 1983–2024 | 6.09 (5.23; 7.15) | **<0.0001** |
| IT | 1990–2024 | 0.31 (0.12; 0.54) | 0.03 | 1991–2024 | 0.00 (−0.03; 0.04) | 0.7143 | 2000–2024 | 2.22 (2.12; 2.36) | **<0.0001** | 1990–2024 | 2.18 (2.02; 2.33) | **<0.0001** | 2008–2024 | 2.53 (2.32; 2.73) | **<0.0001** | 1983–2024 | 0.03 (−0.13; 0.17) | 0.7818 | 1990–2024 | 2.18 (2.02; 2.33) | **<0.0001** |
| LV | 1992–2024 | 0.43 (0.17; 0.71) | 0.0248 | 1997–2024 | 1.25 (1.08; 1.55) | **<0.0001** | 1994–2024 | 6.56 (4.73; 8.23) | **<0.0001** | 1992–2024 | 0.21 (0.05; 0.44) | 0.0148 | 2011–2024 | 2.10 (0.18; 4.10) | 0.0292 | 1992–2024 | 0.09 (−0.07; 0.25) | 0.2779 | 1993–2024 | 0.69 (0.53; 0.88) | **<0.0001** |
| LT | 1992–2024 | 0.41 (0.33; 0.50) | **<0.0001** | 1998–2024 | 0.61 (0.28; 0.84) | **<0.0001** | 1999–2024 | 16.85 (15.87; 17.79) | **<0.0001** | 1992–2024 | −0.16 (−0.20; −0.11) | **<0.0001** | 2016–2024 | 0.50 (−0.04; 0.86) | 0.0716 | 1992–2024 | 0.05 (−0.06; 0.16) | 0.3103 | 1992–2024 | −0.16 (−0.20; −0.11) | **<0.0001** |
| LU | 1983–2024 | 0.86 (0.72; 1.03) | **<0.0001** | 1997–2024 | 2.57 (2.27; 2.80) | **<0.0001** | 1997–2024 | 0.52 (0.51; 0.53) | **<0.0001** | 1983–2024 | 2.30 (2.21; 2.40) | **<0.0001** | 2008–2024 | 0.74 (0.53; 1.02) | **<0.0001** | 1983–2024 | 0.23 (0.21; 0.25) | **<0.0001** | 1995–2024 | 0.38 (0.27; 0.47) | **<0.0001** |
| MT | 1984–2024 | 2.29 (1.46; 3.38) | 0.012 | 2003–2024 | 0.53 (0.17; 0.81) | 0.0044 | 1996–2024 | 3.31 (3.03; 3.58) | **<0.0001** | 1984–2024 | 6.59 (5.67; 7.74) | **<0.0001** | 2021–2024 | 18.57 (−8.30; 53.43) | 0.2492 | 1981–2024 | 0.48 (0.32; 0.62) | **<0.0001** | 1985–2024 | 5.69 (4.76; 6.86) | **<0.0001** |
| NL | 1980–2024 | −0.12 (−0.15; −0.10) | **<0.0001** | 2011–2024 | 14.26 (11.38; 18.09) | **<0.0001** | 1997–2024 | −0.30 (−0.34; −0.26) | **<0.0001** | 1980–2024 | −0.08 (−0.11; −0.04) | 0.0004 | 2009–2024 | −0.68 (−0.85; −0.55) | **<0.0001** | 1980–2024 | −0.12 (−0.15; −0.10) | **<0.0001** | 1980–2024 | −0.08 (−0.11; −0.04) | 0.0004 |
| PL | 1980–2024 | −0.04 (−0.06; −0.02) | 0.0016 | 1991–2024 | 14.60 (13.81; 15.51) | **<0.0001** | 2005–2024 | 8.95 (7.68; 10.78) | **<0.0001** | 1980–2024 | −0.01 (−0.05; 0.02) | 0.6335 | 2018–2024 | 5.25 (1.43; 8.38) | 0.0048 | 1980–2024 | −0.22 (−0.26; −0.19) | **<0.0001** | 1988–2024 | −0.07 (−0.10; −0.05) | **<0.0001** |
| PT | 1980–2024 | 0.72 (0.62; 0.81) | **<0.0001** | 1995–2024 | 9.23 (7.80; 10.08) | **<0.0001** | 1998–2024 | 0.17 (0.07; 0.31) | 0.0008 | 1980–2024 | 1.44 (1.25; 1.64) | **<0.0001** | 2016–2024 | 3.04 (1.44; 4.09) | **<0.0001** | 1980–2024 | 4.17 (3.79; 4.44) | **<0.0001** | 1984–2024 | 1.69 (1.46; 1.89) | **<0.0001** |
| RO | 1985–2024 | −0.36 (−0.44; −0.27) | **<0.0001** | 1996–2024 | −0.81 (−0.92; −0.71) | **<0.0001** | 2011–2024 | −0.93 (−1.42; −0.45) | **<0.0001** | 1983–2024 | −0.04 (−0.15; 0.07) | 0.4559 | 2019–2024 | −2.43 (−3.94; −0.91) | 0.002 | 1985–2024 | −0.25 (−0.33; −0.17) | **<0.0001** | 2002–2024 | −1.06 (−1.16; −0.97) | **<0.0001** |
| SK | 1994–2024 | −0.11 (−0.12; −0.10) | **<0.0001** | 2000–2024 | −0.10 (−0.12; −0.08) | **<0.0001** | 1996–2024 | 11.67 (9.16; 13.22) | **<0.0001** | 1994–2024 | −0.15 (−0.19; −0.11) | **<0.0001** | 2009–2024 | −0.19 (−0.25; −0.13) | **<0.0001** | 1994–2024 | −0.07 (−0.10; −0.05) | 0.0004 | 1994–2024 | −0.15 (−0.19; −0.11) | **<0.0001** |
| SL | 1992–2024 | −0.33 (−0.45; −0.23) | **<0.0001** | 2021–2024 | 1.37 (0.25; 2.48) | 0.01 | 2001–2024 | −0.15 (−0.34; 0.08) | 0.122 | 1992–2024 | 0.13 (−0.02; 0.27) | 0.0872 | 2015–2024 | 1.33 (−0.01; 2.68) | 0.0512 | 1992–2024 | −0.35 (−0.48; −0.23) | **<0.0001** | 1992–2024 | 0.13 (−0.02; 0.27) | 0.0872 |
| ES | 1984–2024 | 0.28 (0.12; 0.44) | 0.0104 | 1996–2024 | 0.48 (0.33; 0.62) | **<0.0001** | 1998–2024 | 0.66 (0.55; 0.80) | **<0.0001** | 1981–2024 | 5.73 (5.34; 6.20) | **<0.0001** | 2017–2024 | 0.30 (−0.36; 0.83) | 0.4135 | 1984–2024 | 0.20 (0.08; 0.40) | 0.0044 | 1981–2024 | 5.73 (5.34; 6.20) | **<0.0001** |
| SE | 1980–2024 | −0.11 (−0.15; −0.09) | **<0.0001** | 2011–2024 | 9.75 (9.18; 10.53) | **<0.0001** | 1991–2024 | 1.46 (1.10; 1.68) | **<0.0001** | 1980–2024 | 0.09 (0.05; 0.13) | 0.0012 | 2008–2024 | 2.24 (1.09; 2.97) | 0.0008 | 1980–2024 | −0.08 (−0.12; −0.06) | **<0.0001** | 1982–2024 | 0.00 (−0.04; 0.03) | 0.963 |

In bold $p < 0.00027$; NA, not applicable; Data NA, data not available; DTP-3, Diphtheria, Tetanus, and Pertussis (third dose); HEPB-3, Hepatitis B (third dose); HIB-3, *Haemophilus influenzae* type b (third dose); MCV-1, Measles-containing vaccine (first dose); PCV-3, Pneumococcal conjugate vaccine (third dose); POL-3, Poliovirus vaccine (third dose); RCV-1, Rubella-containing vaccine (first dose).

***Table 1:*** **AAPC by antigen and country.**

| Antigen | Significant increase | Non-Significant increase | Significant decrease | Non-Significant decrease | No variation | Total |
|---|---|---|---|---|---|---|
| DTP-3 | 9 (33.33%) | 6 (22.22%) | 7 (25.93%) | 4 (14.81%) | 1 (3.70%) | 27 |
| HEPB-3 | 14 (58.33%) | 5 (16.67%) | 3 (12.50%) | 1 (4.17%) | 2 (8.33%) | 24 |
| HIB-3 | 17 (62.96%) | 3 (11.11%) | 4 (14.81%) | 2 (7.41%) | 1 (3.70%) | 27 |
| MCV-1 | 13 (48.15%) | 5 (18.52%) | 3 (11.11%) | 5 (18.52%) | 1 (3.70%) | 27 |
| PCV-3 | 8 (33.33%) | 11 (45.83%) | 3 (12.50%) | 2 (8.33%) | 0 (0.00%) | 24 |
| POL-3 | 8 (29.63%) | 7 (25.93%) | 6 (22.22%) | 6 (22.22%) | 0 (0.00%) | 27 |
| RCV-1 | 16 (59.26%) | 1 (3.70%) | 5 (18.52%) | 3 (11.11%) | 2 (7.41%) | 27 |

DTP-3, Diphtheria, Tetanus, and Pertussis (third dose); HEPB-3, Hepatitis B (third dose); HIB-3, *Haemophilus influenzae* type b (third dose); MCV-1, Measles-containing vaccine (first dose); PCV-3, Pneumococcal conjugate vaccine (third dose); POL-3, Poliovirus vaccine (third dose); RCV-1, Rubella-containing vaccine (first dose).

*Table 2:* **AAPC by antigen.**

| Country | Metric | DTP-3 | HEPB-3 | HIB-3 | MCV-1 | PCV-3 | POL-3 | RCV-1 |
|---|---|---|---|---|---|---|---|---|
| AT | Trend A | −3.74 | **1.33** | −3.3 | 35.95 | Data NA | −3.77 | 35.95 |
| | Trend B | −0.27 | −1.08 | 0.16 | 1.44 | Data NA | −0.27 | 1.44 |
| | Final coverage | 85% | 85% | 85% | 90% | | 85% | 90% |
| BE | Trend A | 5.92 | **380.87** | **120.89** | 12.4 | **0.32** | **0.49** | **0.87** |
| | Trend B | 0.07 | 1.94 | 0.09 | 0.85 | 0 | −0.04 | NA |
| | Final coverage | 97% | 97% | 97% | 96% | 94% | 98% | 96% |
| BG | Trend A | **−0.2** | 11.69 | −0.02 | −0.13 | 13.41 | −0.18 | 0.31 |
| | Trend B | NA | −0.09 | NA | NA | −0.8 | NA | −0.35 |
| | Final coverage | 94% | 94% | 94% | 94% | 91% | 94% | 94% |
| HR | Trend A | **0.5** | 1.37 | **9.34** | **0.49** | 5.27 | 0.46 | **0.49** |
| | Trend B | **−0.31** | −0.52 | −0.31 | **−0.46** | NA | −0.3 | **−0.46** |
| | Final coverage | 92% | 91% | 92% | 90% | 89% | 92% | 90% |
| CY | Trend A | **50.27** | 1.56 | **18.71** | **44.52** | −0.32 | **48.97** | **44.52** |
| | Trend B | 0.15 | −0.18 | −0.02 | 0.23 | NA | 0.14 | **0.23** |
| | Final coverage | 94% | 94% | 94% | 99% | 82% | 94% | 99% |
| CZ | Trend A | **−0.38** | −0.49 | −0.47 | −0.55 | Data NA | −0.45 | −0.55 |
| | Trend B | **−4.76** | **−4.38** | **−4.41** | **−3.75** | Data NA | **−4.46** | **−3.75** |
| | Final coverage | 86% | 86% | 86% | 89% | Data NA | 86% | 89% |
| DK | Trend A | −1.55 | Data NA | −0.85 | −3.13 | **2.67** | 1.07 | −3.13 |
| | Trend B | 0.58 | Data NA | 0.59 | 0.79 | 0.38 | 0 | 0.79 |
| | Final coverage | 96% | Data NA | 96% | 94% | 96% | 96% | 94% |
| EE | Trend A | −0.36 | −0.27 | **97.93** | −0.23 | Data NA | **−0.28** | −0.23 |
| | Trend B | **−3.77** | −2.29 | −0.36 | −1.13 | Data NA | **−2.96** | −1.13 |
| | Final coverage | 81% | 81% | 81% | 83% | 87% | 81% | 83% |
| FI | Trend A | −2.97 | Data NA | −3.32 | 0.19 | **−0.61** | −2.93 | 0.19 |
| | Trend B | 0.17 | Data NA | 0.19 | −0.3 | NA | 0.16 | −0.3 |
| | Final coverage | 91% | Data NA | 91% | 94% | 96% | 91% | 94% |
| FR | Trend A | 4.82 | **11.47** | **2.62** | 2.02 | 0.08 | −2.24 | 2.02 |
| | Trend B | −0.04 | 1.34 | −0.06 | 0.47 | 0.76 | 0.37 | 0.47 |
| | Final coverage | 96% | 96% | 96% | 95% | 75% | 96% | 95% |
| DE | Trend A | **4.97** | 21.48 | 2.21 | 5.19 | 11.4 | 8.11 | 0.91 |
| | Trend B | −0.24 | 0.08 | **−0.24** | 0.22 | **−1.03** | −0.26 | −0.04 |
| | Final coverage | 89% | 85% | 88% | 96% | 90% | 88% | 96% |

(Table 3 continues on next page)

with four or more decreasing vaccination coverage (Table 4). The most severe worsening in vaccination trends was observed in Bulgaria, Cyprus, Ireland, The Netherlands, Romania, and Sweden, each showing seven decreasing trends, while Croatia, Czechia, Estonia, Lithuania, and Slovakia, each recorded six decreasing trends.

Five countries exhibited moderately negative patterns, with four to five decreasing coverages: Belgium, Greece, and Slovenia (four decreases each), and Germany and Spain (five decreases each).

In contrast, Hungary (six increasing trends) and Luxemburg (six increasing, one decreasing) emerged as the best performers, followed by Denmark (five increasing trends, one decreasing), and Portugal (five increasing, two decreasing). France, Italy, Latvia, Malta, and Poland displayed a relatively balanced pattern, with four increasing and three decreasing trends. Finally, Austria and Finland each had three positive and three negative trends.

### Vaccination coverage trends by antigen

Considering the changes between trends A and B for each antigen, most vaccines showed predominantly decreasing patterns across EU countries, with MCV-1 and RCV-1 showing the most favorable evolution (Fig. 1, Table 4).

The most marked decline was observed for HIB-3 and POL-3, each with 20 countries showing decreasing trends, followed by HEPB-3 (18 countries), and DTP-3 (17 countries). PCV-3 also exhibited a mainly decreasing pattern, with 16 countries showing declines, and RCV-1 (15 countries) while MCV-1 showed a more balanced situation, with 13 decreasing and 14 increasing trends. Positive evolutions were less frequent overall. The highest number of increasing trends was observed for MCV-1 (n=14), followed by RCV-1 (n=12), DTP-3 (n=10), PCV-3 (n=8), POL-3 (n=7), HIB-3 (n=7), and HEPB-3 (n=6).

### Countries with the most pronounced recent declines

The magnitude of decrease was heterogeneous by country and antigen in the latest APC segment (Trend B), as shown in Supplementary Table S5.

Czechia showed the highest level of decrease for almost all antigens, all within the same period between 2022 and 2024, indicating a high level of deterioration in coverage (DTP-3, HEPB-3, HIB-3, MCV-1, POL-3, RCV-1). The Netherlands followed a similar path, with APC showing marked reductions for almost all antigens between 2021 and 2024 (DTP-3, HIB-3, PCV-3, POL-3) and between 2020 and 2024 for MCV-1. Other countries with marked decreases included Estonia, where a drop in coverage was observed for DTP-3, between 2021 and 2024, for HEPB-3 between 2018 and 2024, and for POL-3 between 2020 and 2024.

Other marked decreases were observed in Romania between 2019 and 2024 for HEPB-3 and RCV-1, as well as Lithuania from 2017 to 2024, for MCV-1 and RCV-1. Finally, Slovenia showed the largest decrease in PCV-3 coverage in the 2020–2024 period, as well as Ireland in the 2012–2024 period.

### Trends during COVID-19 pandemic

Most of the latest APC segments identified by the Joinpoint model started between 2019 and 2022, corresponding to the COVID-19 pandemic and its immediate aftermath. Within these segments, declining trends predominated across countries and antigens, with 28 country–antigen combinations showing decreasing trends and only 8 showing increasing trends. Specifically, eight decreasing trends were observed among segments starting in 2019, six decreases and one increase among those starting in 2020, eight decreases and five increases among those starting in 2021, and seven decreases and one increase among those starting in 2022. The most marked declines were identified in Czechia (from 2022 onwards), while decreases involving multiple antigens were also observed in the Netherlands, Estonia, Romania, Slovakia, and Sweden. Complete APC estimates and the corresponding time periods are reported in Supplementary Table S6.

## Discussion

This study provides a comprehensive overview of vaccination coverage trends across the 27 EU Member States over more than four decades, highlighting the heterogeneity of temporal dynamics and recent reversals in long-term positive trajectories. Overall, while most countries have achieved and maintained high coverage for several antigens, recent years have been characterized by a slowdown or decline in vaccination rates.

Our analysis revealed that although most countries displayed an increase over the full period, the most recent segmental analyses (trends A and B) indicated a predominance of negative evolutions, with only a few countries showing increasing trends in more than half of the antigens, notably Hungary, Luxembourg, Denmark, Portugal, France, Italy, Latvia, Malta, and Poland.

Moreover, heterogeneous patterns across vaccines were observed, with some (such as HIB-3, POL-3, and DTP-3) displaying widespread and alarming decreases. Changes in vaccination schedules over time, including the transition from separate measles and rubella vaccines to combined MMR vaccines, may partly explain differences observed between MCV-1 and RCV-1 coverage across countries and periods, particularly in earlier years. These findings should be interpreted alongside absolute coverage levels. Countries with high baseline coverage may still appear to perform well despite recent declines, while those with persistently low coverage may face substantial public health risks even in the presence of stable or improving trends. Importantly, in countries with historically high coverage, even modest reductions should be interpreted as early-warning signals of potential immunization

| Country | Metric | DTP-3 | HEPB-3 | HIB-3 | MCV-1 | PCV-3 | POL-3 | RCV-1 |
|---|---|---|---|---|---|---|---|---|
| (Continued from previous page) | | | | | | | | |
| EL | Trend A | 12.68 | **146.64** | 21.03 | 1.9 | **87.54** | 0.13 | 0.91 |
| | Trend B | 0.3 | 0.22 | 0.82 | −0.43 | 0.34 | NA | −0.53 |
| | Final coverage | 95% | 92% | 99% | 91% | 99% | 95% | 91% |
| HU | Trend A | 0 | Data NA | 0 | 0 | 1.84 | 0.15 | 0 |
| | Trend B | NA | Data NA | NA | NA | 0.02 | 0 | NA |
| | Final coverage | 99% | Data NA | 99% | 99% | 99% | 99% | 99% |
| IE | Trend A | 2.09 | **37.15** | 0.69 | **105.12** | **40.28** | 1.42 | **105.12** |
| | Trend B | −0.07 | −0.72 | −0.33 | 0.71 | −1.36 | −0.22 | 0.71 |
| | Final coverage | 92% | 92% | 92% | 90% | 84% | 92% | 90% |
| IT | Trend A | 5.47 | −0.91 | **4.06** | 10 | 0.87 | 5.9 | 10.0 |
| | Trend B | 0 | 0.13 | −0.11 | 0.45 | −0.23 | −0.15 | 0.45 |
| | Final coverage | 94% | 94% | 95% | 95% | 90% | 94% | 95% |
| LV | Trend A | 4.32 | **365.79** | **71.33** | −0.37 | 2.1 | 0.09 | **5.6** |
| | Trend B | 0.03 | 0.39 | 1.08 | 0.43 | NA | NA | −0.02 |
| | Final coverage | 97% | 99% | 97% | 98% | 92% | 97% | 98% |
| LT | Trend A | 0.35 | **12.65** | 10.23 | 0.2 | −0.28 | **0.52** | 0.2 |
| | Trend B | **−0.42** | −0.34 | −0.62 | −1.35 | 2.9 | −0.41 | −1.35 |
| | Final coverage | 89% | 87% | 89% | 86% | 87% | 89% | 86% |
| LU | Trend A | 0.88 | −0.8 | 0.39 | **2.43** | 3.6 | **1.01** | 0.43 |
| | Trend B | 0.02 | 0.32 | 0 | **0.3** | 0.17 | −0.01 | 0.01 |
| | Final coverage | 99% | 98% | 99% | 99% | 97% | 99% | 99% |
| MT | Trend A | **37.42** | 5.17 | **11.02** | **101.67** | 18.57 | 9.56 | **138.47** |
| | Trend B | 0.71 | 0.53 | −0.17 | **1.22** | NA | −0.09 | **1.14** |
| | Final coverage | 97% | 97% | 97% | 88% | 97% | 97% | 88% |
| NL | Trend A | 0.53 | **79.47** | 0.09 | −0.38 | −0.38 | 0.53 | −0.38 |
| | Trend B | **−1.38** | −0.21 | **−1.87** | **−1.34** | **−1.85** | **−1.38** | **−1.34** |
| | Final coverage | 91% | 89% | 89% | 89% | 88% | 91% | 89% |
| PL | Trend A | −0.78 | 11.23 | **124.01** | −0.91 | 19.22 | **−1.75** | **−0.91** |
| | Trend B | 0.09 | −0.53 | 0.09 | 0.39 | −1.11 | 1.05 | 0.4 |
| | Final coverage | 94% | 87% | 94% | 92% | 89% | 86% | 92% |
| PT | Trend A | 3.87 | 6.85 | 3.5 | 6.67 | **14.44** | **64.02** | 5.96 |
| | Trend B | 0.16 | 0.14 | 0.16 | 0.2 | −0.5 | 0.25 | 0.2 |
| | Final coverage | 99% | 99% | 99% | 99% | 98% | 99% | 99% |
| RO | Trend A | 0.29 | −0.72 | **−0.93** | **0.98** | −2.43 | **0.55** | 1.29 |
| | Trend B | **−0.97** | −2.72 | NA | **−0.92** | NA | **−0.93** | **−3.03** |
| | Final coverage | 79% | 79% | 79% | 78% | 78% | 79% | 78% |
| SK | Trend A | **0.22** | 0.22 | 16.77 | 0.03 | −0.97 | 0.23 | 0.03 |
| | Trend B | **−0.47** | **−0.47** | −0.16 | **−0.31** | 0.02 | −0.47 | **−0.31** |
| | Final coverage | 96% | 96% | 96% | 94% | 96% | 96% | 94% |
| SL | Trend A | 0.87 | 1.37 | 0.75 | 0.13 | **6.54** | 0.46 | 0.13 |
| | Trend B | −0.56 | NA | **−0.55** | NA | −4.83 | −0.62 | NA |
| | Final coverage | 90% | 90% | 90% | 95% | 56% | 90% | 95% |
| ES | Trend A | 0.74 | **6.83** | **6.76** | 21.6 | 2.63 | 1.36 | 21.6 |
| | Trend B | −0.17 | −0.2 | −0.11 | 0.27 | −0.62 | −0.2 | 0.27 |
| | Final coverage | 94% | 94% | 94% | 97% | 92% | 94% | 97% |
| SE | Trend A | −0.04 | 22.49 | **29.99** | 0.13 | **23.87** | −0.07 | 0.13 |
| | Trend B | **−0.66** | −0.11 | −0.15 | −1.1 | −0.52 | **−0.9** | **−1.1** |
| | Final coverage | 96% | 95% | 95% | 93% | 94% | 95% | 93% |

In bold significant trends ($p < 0.00027$); NA, not applicable; Data NA, data not available; DTP-3, Diphtheria, Tetanus, and Pertussis (third dose); HEPB-3, Hepatitis B (third dose); HIB-3, *Haemophilus influenzae* type b (third dose); MCV-1, Measles-containing vaccine (first dose); PCV-3, Pneumococcal conjugate vaccine (third dose); POL-3, Poliovirus vaccine (third dose); RCV-1, Rubella-containing vaccine (first dose).

***Table 3:*** **APC for trend A and trend B, by country and antigen.**

| Country | DTP-3 | HEPB-3 | HIB-3 | MCV-1 | PCV-3 | POL-3 | RCV-1 | Increasing | Decreasing | Data NA |
|---|---|---|---|---|---|---|---|---|---|---|
| AT | mildly negative | negative | mildly positive | mildly positive | Data NA | mildly negative | mildly positive | 3 | 3 | 1 |
| BE | mildly positive | negative | negative | mildly positive | negative | negative | positive | 3 | 4 | 0 |
| BG | negative | mildly negative | mildly negative | mildly negative | mildly negative | mildly negative | mildly negative | 0 | 7 | 0 |
| CY | negative | mildly negative | negative | negative | mildly negative | negative | negative | 0 | 7 | 0 |
| CZ | negative | negative | negative | negative | Data NA | negative | negative | 0 | 6 | 1 |
| DE | negative | mildly positive | negative | mildly positive | negative | mildly negative | mildly negative | 2 | 5 | 0 |
| DK | mildly positive | Data NA | mildly positive | mildly positive | negative | mildly positive | mildly positive | 5 | 1 | 1 |
| EE | negative | mildly negative | negative | mildly negative | Data NA | negative | mildly negative | 0 | 6 | 1 |
| EL | mildly positive | negative | mildly positive | mildly negative | negative | mildly positive | mildly negative | 3 | 4 | 0 |
| ES | mildly negative | negative | negative | mildly positive | mildly negative | mildly negative | mildly positive | 2 | 5 | 0 |
| FI | mildly positive | Data NA | mildly positive | mildly negative | negative | mildly positive | mildly negative | 3 | 3 | 1 |
| FR | mildly negative | negative | negative | mildly positive | mildly positive | mildly positive | mildly positive | 4 | 3 | 0 |
| HR | negative | mildly negative | negative | negative | mildly positive | mildly negative | negative | 1 | 6 | 0 |
| HU | mildly positive | Data NA | mildly positive | mildly positive | mildly positive | mildly positive | mildly positive | 6 | 0 | 1 |
| IE | mildly negative | negative | mildly negative | negative | negative | mildly negative | negative | 0 | 7 | 0 |
| IT | mildly positive | mildly positive | negative | mildly positive | mildly negative | mildly negative | mildly positive | 4 | 3 | 0 |
| LT | negative | negative | mildly negative | mildly negative | mildly positive | negative | mildly negative | 1 | 6 | 0 |
| LU | mildly positive | mildly positive | mildly positive | positive | mildly positive | negative | mildly positive | 6 | 1 | 0 |
| LV | mildly positive | negative | negative | mildly positive | mildly positive | mildly positive | negative | 4 | 3 | 0 |
| MT | negative | mildly positive | negative | positive | mildly positive | mildly negative | positive | 4 | 3 | 0 |
| NL | negative | negative | negative | negative | negative | negative | negative | 0 | 7 | 0 |
| PL | mildly positive | mildly negative | negative | mildly positive | mildly negative | positive | positive | 4 | 3 | 0 |
| PT | mildly positive | mildly positive | mildly positive | mildly positive | negative | negative | mildly positive | 5 | 2 | 0 |
| RO | negative | mildly negative | negative | negative | mildly negative | negative | negative | 0 | 7 | 0 |
| SE | negative | mildly negative | negative | mildly negative | negative | negative | negative | 0 | 7 | 0 |
| SK | negative | negative | mildly negative | negative | mildly positive | mildly negative | negative | 1 | 6 | 0 |
| SL | mildly negative | mildly positive | negative | mildly positive | negative | mildly negative | mildly positive | 3 | 4 | 0 |
| Decreasing | 17 | 18 | 20 | 13 | 16 | 20 | 15 | | | |
| Increasing | 10 | 6 | 7 | 14 | 8 | 7 | 12 | | | |

Data NA, data not available; DTP-3, Diphtheria, Tetanus, and Pertussis (third dose); HEPB-3, Hepatitis B (third dose); HIB-3, *Haemophilus influenzae* type b (third dose); MCV-1, Measles-containing vaccine (first dose); PCV-3, Pneumococcal conjugate vaccine (third dose); POL-3, Poliovirus vaccine (third dose); RCV-1, Rubella-containing vaccine (first dose).

***Table 4:*** **Increasing and decreasing trends considering changes from trend A and trend B, by country and antigen.**

system fragility. By providing a formal and comparable assessment of trend changes, this analysis enables the identification of recent reversals that may not be apparent from visual inspection alone.

After decades of progressive improvement, vaccination coverage has recently stagnated or declined in a substantial number of EU countries. This finding aligns with previous reports from WHO and ECDC, which have documented a plateauing of routine immunization rates in Europe since the late 2010s. Consistent with these reports, several of the most recent declining trends identified in our analysis occurred during or immediately after the COVID-19 pandemic. However, although this temporal overlap suggests a possible contribution of disruptions associated with the pandemic, our analysis was not designed to quantify the specific impact of the pandemic on vaccination coverage.

The general decrease in vaccination coverage poses a substantial threat to public health,[23] mainly by weakening herd immunity and thereby exposing an increasing share of the population to vaccine-preventable diseases, particularly those at higher risk, such as infants, the elderly, and immunocompromised individuals.[24] In addition to reducing herd protection, declining vaccination coverage also compromises individual immunity, increasing the risk of infection at both population and individual levels. The potential consequences include the resurgence of controlled diseases and renewed outbreaks,[25] leading to increased hospital admissions, higher healthcare costs, and additional strain on an already overstretched workforce.[26] Notably, several countries maintaining coverage levels close to or above 90% still exhibited recent declining trends. While these levels may appear reassuring in absolute terms, our findings suggest that such patterns may represent early signals of weakening system performance. Detecting these dynamics is crucial, as even small reductions in coverage can rapidly translate into increased susceptibility to outbreaks, particularly for highly transmissible diseases.

The decline observed in recent years is likely multifactorial, reflecting a complex interplay of

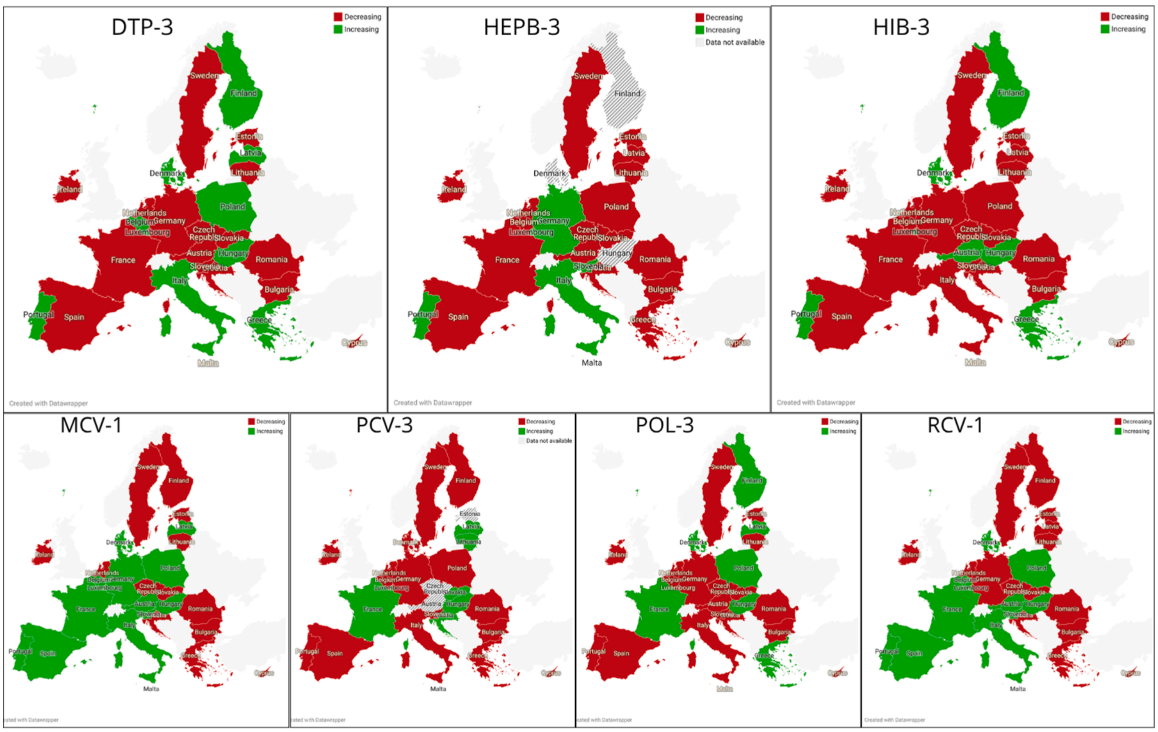


*Fig. 1:* Recent vaccination coverage trends across European Union countries by antigen. Countries are classified as showing increasing (in green) or decreasing (in red) trends according to changes between trend A and trend B.

political, scientific, social, and cultural dynamics that have fueled vaccine hesitancy, even in high-income settings.[7,27] The rise of populist movements has further complicated this landscape, as political polarization has undermined trust in vaccination policies and institutions.[28,29]

Moreover, inequities in access to vaccination remain a persistent challenge. Disadvantaged populations are disproportionately affected by structural, geographic, and financial barriers to vaccination.[30] Ensuring that vaccines are universally available and free of charge is therefore a fundamental equity measure, one that has consistently proven effective in improving coverage rates, as financial barriers remain a major determinant of low vaccination coverage.[31]

Educational level is another well-documented determinant of vaccine acceptance[32,33]. Addressing misinformation and knowledge gaps regarding vaccine safety and efficacy should be a policy priority. Introducing structured educational programs at both national and community levels, beginning in schools and involving children, parents, and teachers, can foster early awareness, promote health literacy, and build lasting confidence in immunization.[34]

Making scientific evidence transparent, accessible, and understandable to the general population is also a crucial responsibility for public health professionals.[35,36] As recommended by the WHO Europe,[31] insights into the barriers and enablers of vaccination should be translated into targeted, evidence-based interventions aimed at improving vaccine uptake. Healthcare professionals play a pivotal role in this process, as their knowledge, attitudes, and confidence are among the strongest determinants of their patients' willingness to vaccinate.[37–39]

Geographical patterns in vaccination coverage within the EU reflect differences in vaccination policies and practices, including the role of mandatory vaccination. Notably, countries such as Belgium, Hungary, France, Germany, Italy, and Malta, which have implemented some form of compulsory childhood vaccination, generally display more favorable long-term trends in coverage.[8,40–42] While mandatory vaccination appears to be an effective countermeasure to declining coverage, these results should be interpreted with caution, given the influence of contextual, cultural, and political factors that are difficult to disentangle. Changes in vaccination schedules over time, including the transition to combined vaccines, may partly explain differences observed between MCV and RCV coverage. In the 1970s, rubella vaccination was primarily targeted at adolescent girls, with the aim of preventing congenital rubella syndrome rather than reducing transmission at the population level. Subsequently, between the late 1980s and mid-1990s, European Union countries progressively introduced combined measles–mumps–rubella (MMR) vaccines, substantially modifying vaccination schedules and strategies for these antigens.[43]

As widely recognized, prevention remains the only truly effective strategy to contain highly contagious diseases.[44] Strengthening vaccination coverage must therefore be regarded as a public health priority. However, timely corrective action depends on the presence of active monitoring and robust surveillance systems capable of detecting and interpreting early warning signals.[45] In this regard, the continuous analysis of vaccination coverage trends represents an essential component of infectious disease surveillance, providing the evidence base needed to guide policymakers, identify areas of concern, and investigate underlying causes.[13]

This study has some limitations that should be acknowledged. First, we considered only the last two trends identified by the Joinpoint model to classify vaccination trajectories and countries. While this approach may overlook earlier variations in long-term patterns, we believe that the most recent segments provide the most meaningful representation of the current situation and policy-relevant dynamics. Second, this study focused on temporal trend analysis and did not incorporate additional sociodemographic or health system variables. The Joinpoint regression relies solely on aggregated annual vaccination coverage data at the population level and does not allow for the identification of underlying causes or contextual factors driving observed changes in trends. Consequently, the associations between observed changes and specific explanatory variables could not be assessed, and future studies integrating contextual and system-level factors are needed to better understand the drivers of these patterns. Moreover, although several countries experienced changes in vaccination coverage during or after the COVID-19 pandemic, the present analysis was not intended to quantify the specific effect of the pandemic. The Joinpoint approach identifies changes in trends empirically rather than testing predefined events. Future studies using interrupted time-series analyses or models with pre-specified breakpoints could provide a more direct assessment of the pandemic's contribution to changes in vaccination coverage.

Third, our analysis focused primarily on temporal trends rather than absolute coverage levels. This means that countries such as Greece and Sweden, which displayed predominantly negative trends, still maintained high coverage levels, around or above than 90%. Nonetheless, even within countries with high baseline coverage, declining trends warrant careful attention, as they may indicate emerging vulnerabilities.

Moreover, WUENIC estimates are based on administrative and survey data, which may be affected by reporting biases, including potential overestimation of coverage and retrospective data revisions. Similarly, differences in data availability across countries may affect comparability of trends and should be considered when interpreting results. This study focused on first-year vaccinations, excluding other antigens and schedules. While this approach ensures consistency in our analysis, further studies should evaluate additional vaccinations (e.g., MCV2, which is essential for measles elimination). Finally, countries maintaining coverage ≥95% and showing overall positive evolutions further validate the consistency and robustness of our analytical approach, confirming that trend-based analyses can complement absolute coverage indicators in identifying areas requiring public health attention.

Finally, vaccination coverage represents a bounded proportion. Although alternative modeling approaches (e.g., logit-based models) may be considered for proportion data, the present study adopted the standard log-linear Joinpoint methodology, which is specifically designed to estimate APCs and AAPCs and represents the established approach for trend analysis using the Joinpoint Regression Program.

## Conclusion

In recent years, vaccination coverage in most EU countries has declined, reversing the positive trend seen over the past forty years. This evidence calls for systemic countermeasures at international, national, and community levels, requiring a substantial coordinated effort in which public health must play a leading role by providing scientific support to policymakers, communicating effectively, ensuring adequate education, and increasing the knowledge and skills of healthcare professionals on vaccines.

#### Contributors

Conceptualization: LV; Methodology: LV, LR, FAC, CS; Software: LV, LR, CS, FAC; Validation: LV, WR, CDW, SB; Formal analysis: LR, FAC, CS; Data Curation: LV, LR, FAC, CS; Writing–Original Draft: LV, LR, FAC, CS; Writing–Review & Editing: LV, RP, WR, CDW, SB; Visualization: LV; Supervision: LV, SB; Project administration: LV, SB. All authors have accessed and verified the data and were responsible for the decision to submit the manuscript. All authors read and approved the final version of the manuscript.

#### Data sharing statement

All data and material are available from the Corresponding Author upon reasonable request. The original dataset used in the study are publicly available on the WHO/UNICEF Estimates of National Immunization Coverage (WUENIC) website at https://immunizationdata.who.int.

#### Acknowledgement of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used a generative AI tool to facilitate the writing process. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

#### Editor note

The Lancet Group takes a neutral position with respect to territorial claims in published maps and institutional affiliations.

#### Declaration of interests

The Authors declare no competing interests.

#### Acknowledgements
This work received financial support from the D3.1 funding line of Università Cattolica del Sacro Cuore, an institutional program aimed at supporting publication and printing costs for scientific research work.

#### Appendix A. Supplementary data
Supplementary data related to this article can be found at https://doi.org/10.1016/j.lanepe.2026.101834.

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