Assessing residual seasonality in published outputs

How the ONS uses detailed statistical methods and analytical tools to assess the impact of residual seasonality on published time series.

Contact:
Gross Domestic Product team
gdp@ons.gov.uk

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1 . Overview

Ensuring that main economic indicators are free of residual seasonality is a critical part of seasonal adjustment and statistical production. We have outlined how the Office for National Statistics (ONS) uses detailed statistical methods and analytical tools to assess for the impact of residual seasonality on published time series.

Our case studies, based on currently available data, demonstrate that there is no residual seasonality in the main aggregate outputs for quarterly and monthly gross domestic product (GDP) estimates. The ONS regularly assesses and monitors high-profile aggregate data for residual seasonality. Detailed statistical checks are performed as part of the monthly and quarterly production compilation tasks for high-profile published aggregate time series and interventions by time series experts for parameter changes are made when necessary.

2 . What is seasonal adjustment

Seasonal adjustment is the process of estimating and removing systematic calendar-related fluctuations that occur at the same time and in a similar magnitude each year from a time series. Seasonality can be caused by events such as holidays, weather patterns, or fiscal year endings, and can obscure the underlying economic trends policymakers and analysts seek to understand.

Standard and internationally endorsed procedures for seasonal adjustment include filter-based approaches, which use moving averages to estimate and remove seasonal fluctuations (X-13-ARIMA-SEATS) and model-based approaches, which use statistical models to estimate and remove seasonal components from the data (such as TRAMO-SEATS). The Office for National Statistics (ONS) uses X-13-ARIMA-SEATS for the seasonal adjustment of its economic data.

3 . What is residual seasonality

Seasonal adjustment is an important but complex analytical process. However, even after applying standard seasonal adjustment techniques, seasonally adjusted time series can sometimes exhibit signs of residual seasonality, for example, systematic seasonal effects that remain in the "seasonally adjusted" series.

Residual seasonality can be caused by non-optimal seasonal adjustment of directly seasonally adjusted time series. For example, not using the right type of calendar adjustment or not accounting for structural changes in the time series. Residual seasonality can also arise when subcomponents of a time series are directly seasonally adjusted, but the higher-level aggregate is indirectly seasonally adjusted by aggregating the directly seasonally adjusted subcomponents.

Ensuring that main economic indicators are free of residual seasonality is a critical part of seasonal adjustment and statistical production. This is because undetected seasonal patterns can impact economic interpretations and policy decisions.

4 . How the ONS makes an assessment for residual seasonality

In the Office for National Statistics (ONS) we follow international best practice for seasonal adjustment, as described by the United Nations Economic Commission for Europe (UNECE) in the Fundamental Principles of Official Statistics.

Time series experts conduct annual reviews of the detailed specifications that determine how time series are seasonally adjusted. During each production round, time series are also quality assured and time series experts may intervene between these annual reviews if a problem is identified with the quality of the seasonally adjusted estimates.

To assess a seasonally adjusted time series for evidence of residual seasonality, the following methods can be used.

Seasonality tests

There are different statistical tests for seasonality that can be used. To ensure that these tests are robust it is important to test different spans of a time series and account for potential trends and outliers that could adversely impact the test results.

Testing for calendar effects

Systematic movements related to the arrangement of the calendar that are not regular seasonal effects (for example, the impact of Easter that can fall in Quarter 1 or Quarter 2) should be removed as part of seasonal adjustment. Time series models can be fitted to test for the presence of such effects.

Graphical checks

These can include plots of the levels of the data, growth rates, spectral plots and special seasonal plots that show a detrended series plotted over time and grouped by month or quarter (known as seasonal x irregular (SI) ratio plots).

Testing for residual seasonality

To test for residual seasonality in a time series we can use some of the time series modelling capabilities in software such as X-13ARIMA-SEATS and JDemetra+. This allows us to ensure that a robust set of tests are applied by accounting for trends and outliers that could distort the results of statistical tests. Additionally, these models can be used to test for the presence of calendar effects and the software also provide a range of useful graphs to support the analysis.

There are various tests for seasonality, but the main one within the X-13-ARIMA-SEATS package is the combined test, which includes information from the following three statistical tests.

Friedman test

This is an F-test for seasonality assuming stability. It checks for significant differences in ranks across multiple groups, indicating stable seasonal patterns.

Kruskall-Wallis test

This is a non-parametric test for seasonality assuming stability. It compares the ranks of data across multiple groups to identify significant differences, useful for detecting stable seasonal patterns.

Evolutive test (or moving seasonality test)

This test checks for changes in seasonality over time. It uses a two-way analysis of variance model to detect significant annual variations, indicating moving seasonality.

Section 8: Detailed tests used as part of seasonal adjustment processing provides a list of statistical tests used in this methodology and available in seasonal adjustment software for official statistics (X-13ARIMA-SEATS and JDemetra+).

The analysis span is important because seasonality can evolve over time and the most recent time periods are often of interest. In the assessment of residual seasonality reported in Sections 5 and 6 we have used both the full span of data and the most recent five years.

5 . Case study: quarterly GDP

The compilation of both monthly and quarterly gross domestic product (GDP) requires the use of a large number of data sources, often at a detailed level.

Seasonal adjustment is applied for the component parts of GDP on a disaggregated basis, and then the aggregated seasonally adjusted estimate for GDP is calculated from those estimates and is known as an indirectly seasonally adjusted time series.

To illustrate how seasonality impacts the quarterly GDP series, we can create an illustrative seasonally adjusted estimate for GDP, by taking the non-seasonally adjusted aggregate dataset and seasonally adjusting these data directly. Importantly, this will not give exactly the same results as the official indirect seasonal adjustment. However, this can be used to demonstrate how seasonality can evolve over time, and it can also separately be used as a graphical indicator for monitoring residual seasonality.

When the seasonal and irregular components are extracted from a seasonal adjustment and are grouped by periodicity and ordered by year (Figure 1), this is known as a seasonal x irregular chart. The purpose of this is to demonstrate that seasonality is not static over time and can evolve. It also highlights one-off, or irregular, events.

From Figure 1, UK GDP volume in Quarter 1 (Jan to Mar) has historically had periods of low activity in comparison with other quarters. This has evolved over time to now be similar to Quarter 2 (Apr to June) activity. The important point to note is that the seasonal factor (darker red line) has also adapted to capture the evolving nature of seasonal activity. When the seasonal factor cannot adapt quickly enough to abrupt seasonal pattern changes, this can lead to residual seasonality.

Figure 1: Example of an estimated seasonal x irregular chart derived from the aggregate non-seasonally adjusted UK GDP volume, illustrating how seasonality can evolve over time for different quarters

Notes:

1. The darker (red) line is the estimated seasonal factor, and the grey dots represent the irregular related to the seasonal component.

Download the data

Downloac

For the formal statistical tests, published seasonally adjusted data have been used for quarterly GDP volume, up to and including Quarter 4 (Oct to Dec) 2024, to enable a statistical assessment of residual seasonality. A summary of the main test results follows. Results of statistical tests are shown in Table 1, where a p-value greater than 0.05 indicates that there is no residual seasonality based on that test.

Summary results from different tests relating to residual seasonality in the published aggregate UK seasonally adjusted quarterly GDP volume

Trading days

- Result for full span : not tested
- Note: tests for trading days in quarterly data are not reliable as the trading day cycles coincide with the seasonal cycles

Easter

- Result for full span: no residual effect found in the published seasonally adjusted quarterly GDP data
- Note: no evidence of residual seasonality over full span

Test for the presence of seasonality assuming stability

- Result for full span: no evidence of stable seasonality at the 0.1% level in the published seasonally adjusted quarterly GDP data
- Note: no evidence of residual seasonality over full span

Non-parametric test for the presence of seasonality assuming stability

- Result for full span: no evidence of seasonality at the 1% level in the published seasonally adjusted quarterly GDP data
- Note: no evidence of residual seasonality over full span

Combined test for the presence of identifiable seasonality

- Result for full span: identifiable seasonality is not present in the published seasonally adjusted quarterly GDP data

- Note: no evidence of residual seasonality over full span

Table 1: Statistical test results showing that there is no evidence of residual seasonality in the published aggregate UK seasonally adjusted quarterly GDP volume

	Full span		Last 5 years	
Type of test	**Test statistic**	**p-value**	**Test statistic**	**p-value**
Kruskall-Wallis	0.709	0.871	2.627	0.453
F-test	0.199	0.897	0.844	0.492
QS (correlation test)	3.858	0.145	0.000	1.000
Friedman	1.729	0.631	3.600	0.308
Periodogram	0.074	0.974	0.713	0.563

Source: ONS calculations

Notes

1. These tests are calculated using the linearised time series from TRAMO-SEATS (using the RSAFull setting in the software JDememtra+) . A p-value greater than 0.05 indicates there is no significant effect.

6 . Case study: monthly GDP

Similar to the quarterly gross domestic product (GDP) example, the same analysis and statistical tests can be applied to the monthly GDP dataset.

Published seasonally adjusted data have been used for monthly GDP, up to and including February 2025, for this statistical assessment of residual seasonality. A summary of the main tests follows. Results of statistical tests are shown in Table 2, where a p-value greater than 0.05 indicates that there is no residual seasonality based on that test.

Summary results from different tests relating to residual seasonality in the published aggregate UK seasonally adjusted monthly GDP volume

Trading days

- Result for full span: no residual effect found in the published seasonally adjusted monthly GDP data

- Note: non-significant trading day effect found via corrected Akaike Information Criteria; no evidence of residual seasonality over the full span

Easter

- Result for full span: no residual effect found in the published seasonally adjusted monthly GDP data

- Note: non-significant Easter effect found via corrected Akaike Information Criteria; no evidence of residual seasonality over the full span

Test for the presence of seasonality assuming stability

- Result for full span: no evidence of stable seasonality at the 0.1% level in the published seasonally adjusted monthly GDP data
- Note: no evidence of residual seasonality over full span

Non-parametric test for the presence of seasonality assuming stability

- Result for full span: no evidence of seasonality at the 1% level in the published seasonally adjusted monthly GDP data
- Note: no evidence of residual seasonality over full span

Combined test for the presence of identifiable seasonality

- Result for full span: identifiable seasonality is not present in the published seasonally adjusted monthly GDP data
- Note: no evidence of residual seasonality over full span

Table 2: Statistical test results showing that there is no evidence of residual seasonality in the published aggregate UK seasonally adjusted monthly GDP volume

	Full span		**Last 5 years**	
Type of test	**Test statistic**	**p-value**	**Test statistic**	**p-value**
Kruskall-Wallis	2.889	0.922	7.164	0.786
F-test	0.252	0.993	0.499	0.894
QS (correlation test)	0.831	0.660	0.000	1.000
Friedman	2.515	0.996	6.969	0.802
Periodogram	0.234	0.995	0.584	0.832

Source: ONS calculations

Notes

1. These tests are calculated using the linearised time series from TRAMO-SEATS (using the RSAFull setting in the software JDememtra+). A p-value greater than 0.05 indicates there is no significant effect.

7 . How the ONS regularly monitors residual seasonality

From a practical perspective, the Office for National Statistics (ONS) regularly assesses and monitors high-profile aggregate data for residual seasonality. The detailed statistical checks are performed as part of the monthly and quarterly production compilation tasks for high profile published aggregate time series and interventions by time series experts for parameter changes are made when necessary.

As would be expected, effects like residual seasonality can be subtle and evolve over time, and may even occur by statistical chance when large numbers of time series are assessed. In any case, for aggregate time series, seasonal adjustment parameters at a detailed level are regularly reviewed as part of a systematic programme of work and updated to ensure that the quality of both the individual and the published seasonally adjusted aggregates is maintained.

8 . Detailed tests used as part of seasonal adjustment processing

Explanations of the following tests can be found in the official document to the freeware seasonal adjustment JDemetra+.

Trading days

These are tested using a regARIMA model, which automatically identifies and adjusts for variations in economic data because of the number of trading days in a month.

Easter effects

These are also tested using a regARIMA model. Easter effects account for variations in economic activity around Easter holidays, which can shift depending on the calendar.

M7

This is one of the "Monitoring and Quality" statistics from the X-11 algorithm. It reformulates the combined test for seasonality on Table D8, reporting on a scale from 0 to 3. Values greater than 1 indicate no evidence of seasonality.

QS statistics

These tests check for positive autocorrelation at seasonal lags to determine seasonality.

Friedman test

A non-parametric test for the presence of seasonality assuming stability. It is applied to Table D8 in the X-11 algorithm, which analyses the series with an estimated trend removed.

Kruskall-Wallis test

Another non-parametric test for seasonality assuming stability, applied to Table D8 in the X-11 algorithm. It compares the ranks of data across multiple groups to identify significant differences.

Moving seasonality test

This test checks for changes in seasonality over time. If there is evidence of moving seasonality, it can alter the result of the "combined test" from "Identifiable seasonality not present" to "Identifiable seasonality probably not present". However, a significant result from this test is not evidence of seasonality. For instance, if a series has independent noise that increases over time, this variation could be detected as significant annual variation, but it would not be true seasonality.

Combined test for seasonality

This test is a combination of the tests assuming stability (Friedman and the Kruskall-Wallis tests) and the test for moving seasonality. This simply returns a result of either "Identifiable seasonality present", "Identifiable seasonality probably not present", or "Identifiable seasonality not present".

9 . Cite this methodology

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