

# **Elementary seasonal adjustment of economic data with JDemetra+**

Jan Gerhardt, Thomas Witthohn, Karsten Webel / DG Data & Statistics  
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## I Disclaimer

The **JDemetra+** development team is responsible for the maintenance and improvement of **the JDemetra+ time series software** for official statistics **that can be downloaded** free of charge **from** the following website:

 [https://github.com/jdemetra.](https://github.com/jdemetra)

The team is not responsible for the implementation of JDemetra+ methods in other statistical software packages, unless explicitly stated otherwise.

## I Preface

This presentation has been prepared using the following R packages:

- ☞ `{dplyr}, {ggplot2}, {ggthemes}, {tidyverse}`
- ☞ `{kableExtra}, {knitr}`
- ☞ `{RJDemetra}`

Additional course material will be made available on the following website:

 <https://github.com/bbkrd/CIC-seminar>

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JDemetra+

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# Aims

## Theory

- Basic understanding → Ideas, concepts
- Pretreatment → RegARIMA models
- Seasonal adjustment → X-11 & ARIMA model-based (AMB) approaches

## Application

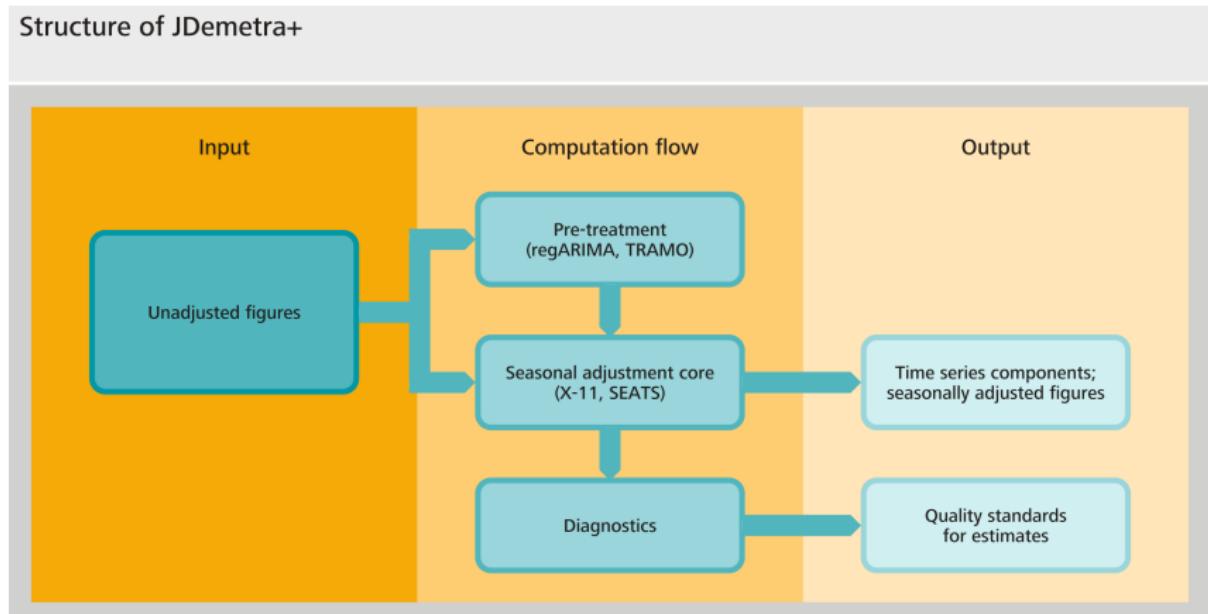
- Software → JDemetra+ (JD+)
- Specification → Key options
- Results → Interpretation, quality assessment

## Discussion

- Your questions → Best practices, implementation (business processes), theory

# Road map

## Structure of JDmetra+



# Agenda

Motivation

Introduction to JD+

RegARIMA pretreatment

- Regression equation
- TransReg plug-in
- ARIMA equation

X-11 approach

- Basic principle
- Further issues

ARIMA model-based approach

Quality assessment

Revision policies

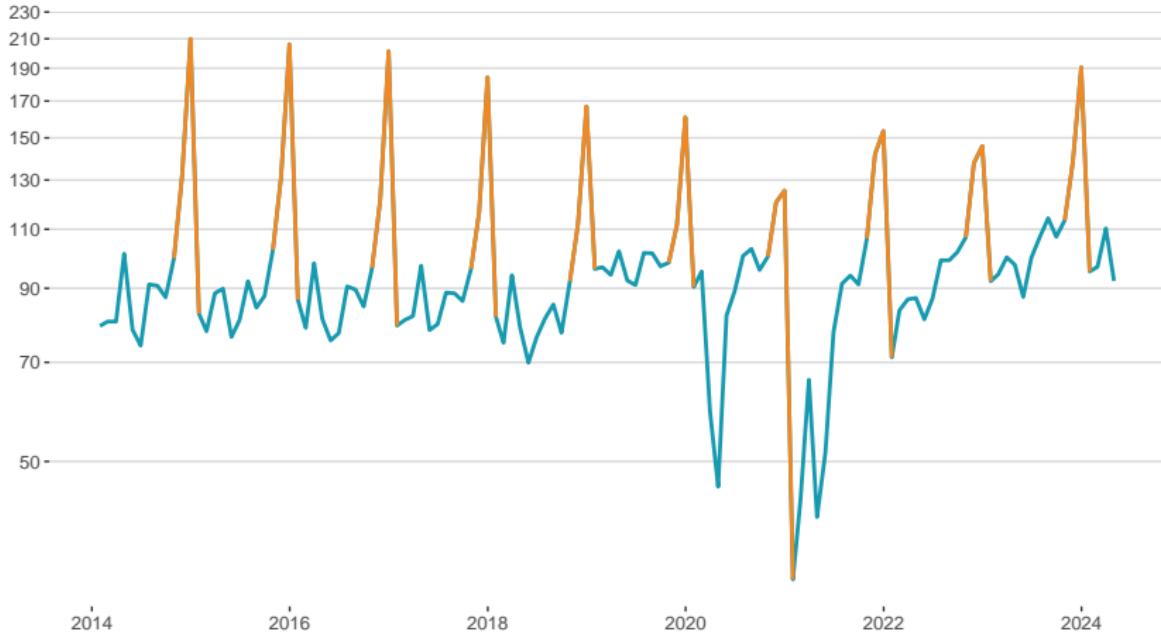
Composite time series

Summary

## Motivation

- Introduction to JD+
- RegARIMA pretreatment
  - Regression equation
  - TransReg plug-in
  - ARIMA equation
- X-11 approach
  - Basic principle
  - Further issues
- ARIMA model-based approach
- Quality assessment
- Revision policies
- Composite time series
- Summary

# What is seasonality? (I/II)



Retail trade turnover: games & toys (value, 2015 = 100) & usual seasonal fluctuations

## I What is seasonality? (II/II)

Deutsche Bundesbank, Statistical Series  
“Seasonally adjusted business statistics”

“Usual seasonal fluctuations” means those movements which

- ☞ recur with similar intensity
- ☞ in the same season each year

and which, on the basis of past movements of the time series in question,

- ☞ can, under normal circumstances, be expected to recur.

## I Other verbal definitions

### Hylleberg (1992)

**Seasonality is the systematic**, although not necessarily regular, **intra-year movement caused by the changes of the weather, the calendar, and timing of decisions**, directly or indirectly through the production and consumption decisions made by the agents of the economy. These decisions are **influenced by endowments, the expectations and preferences of the agents, and the production techniques** available in the economy.

### Nerlove (1964)

In the more general case, then, we may **define seasonality as that characteristic** of a time series **that gives rise to spectral peaks at seasonal frequencies**.

# Why does seasonality show up?

## Repetitive events

- Natural → Climatic seasons
- Secular → Public holidays
- Clerical → Religious festivals

## Seasonal economic models

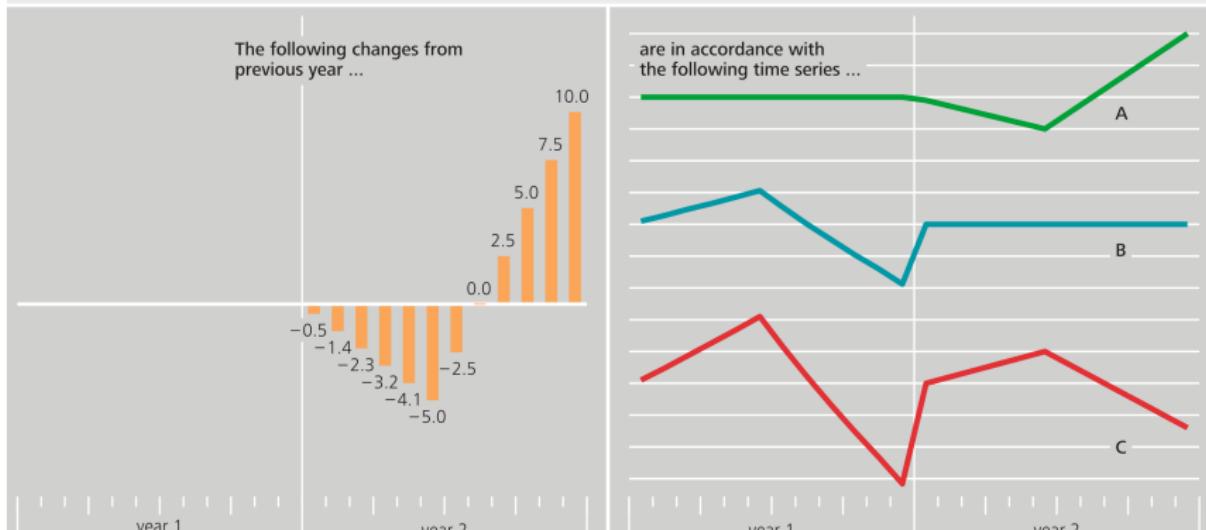
- Agents → Optimising behaviour, rational expectations
  - Endowments, preferences, profit, utility
- Institutions → Conventional business practices, technological changes

## Data compilation

- Sub-components (potentially non-seasonal) → Cross-sectional aggregation

# Why not year-on-year changes? (I/III)

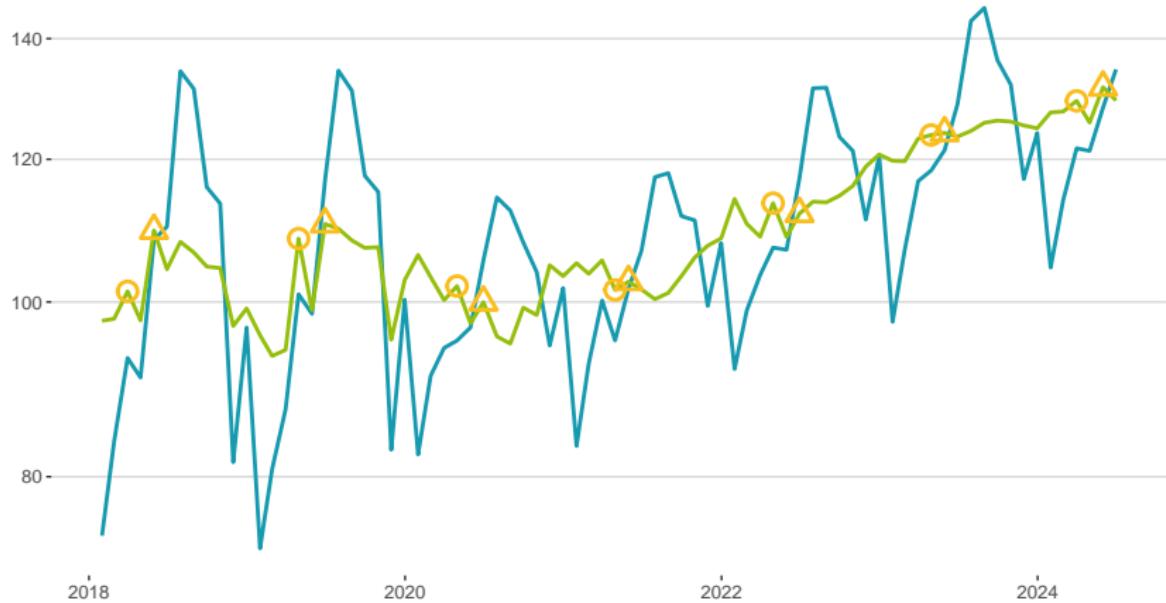
## Meaningfulness of changes from previous year



Deutsche Bundesbank

S3PR0008.Chart

## Why not year-on-year changes? (II/III)



CPI: package holidays (2020 = 100) & only seasonally adjusted figures with Easter (circles) & Whitsun (triangles) identifiers

## I Why not year-on-year changes? (III/III)

### Economic developments

- Current direction → Unclear
- Turning points → Delayed detection

### Leakage

- Moving seasonality
- Calendar variation → Moving holidays (e.g. Easter), number of working days

### Irregular movements

- Inadequate reflection → Possible

## I Why seasonal adjustment? (I/II)

Deutsche Bundesbank, Statistical Series  
"Seasonally adjusted business statistics"

The [...] purpose in seasonally adjusting time series **is to filter out the usual seasonal fluctuations** within the movements of the time series under review.

Lovell (1963)

Seasonal adjustment is [...] filtering out the seasonal factor without seriously distorting the other elements generating the observed data.

Bell & Hillmer (1984)

Seasonal adjustment is done to simplify data so that they may be more easily interpreted by statistically unsophisticated users **without a significant loss of information**.

## I Why seasonal adjustment? (II/II)

Deutsche Bundesbank, Statistical Series  
“Seasonally adjusted business statistics”

Seasonal adjustment also includes the

- ☞ elimination of working-day variations insofar as influences deriving from
- ☞ differences in the number of working days or the dates of particular days

(e.g. public holidays, weekday on the last day of the month in the case of stock series) can be demonstrated and quantified.

## Visibility in seasonally adjusted data

Deutsche Bundesbank, Statistical Series  
"Seasonally adjusted business statistics"

Thus, **fluctuations due to**

- ☞ **exceptionally strong or weak seasonal influences**  
[...] **will continue to be visible in the seasonally adjusted series** to the extent that they
  - ☞ exceed, or fall short of, the normal seasonal average.

In general, **other**

- ☞ **random disruptions and unusual movements** that are readily understandable in economic terms  
[...] **are also not eliminated.**

# Quiz: seasonal or not?

## Seasonal or non-seasonal movement?

Time	Event	Movement
Every winter	Lower output in construction	
Every February	Lower turnover compared to January & March	
Leap year February	Higher retail trade turnover	
Easter	Sales peak	
August	Higher orders received due to a biennial exhibition	
Christmas	Sales peak	

## I Tiebreakers: fill in the blank!

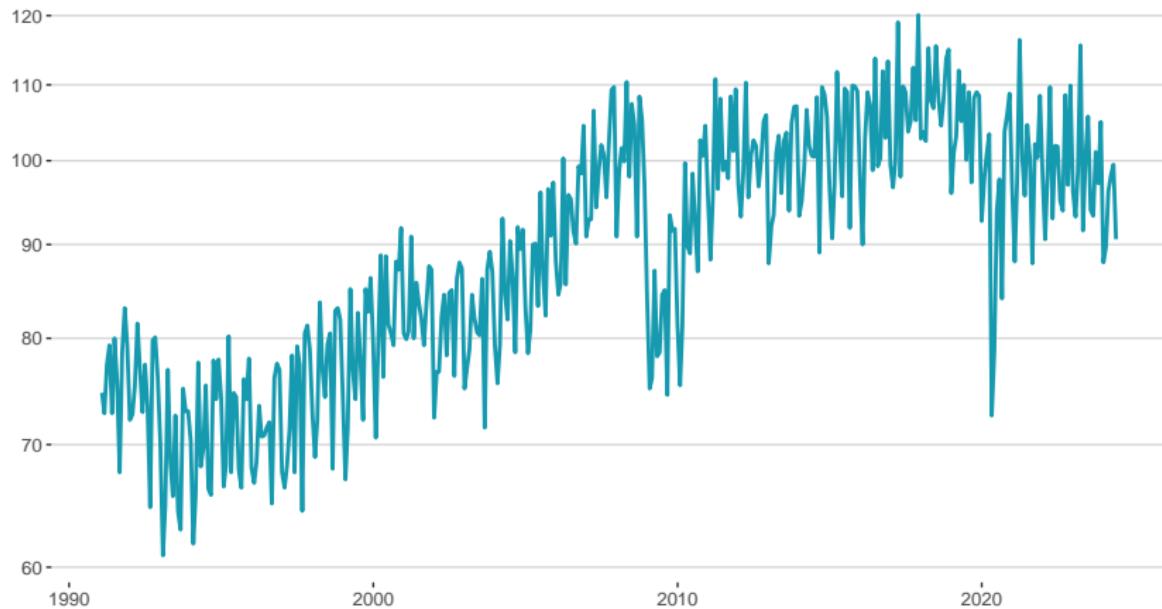
Shiskin & Eisenpress (1957), Seasonal Adjustments by Electronic Computer Methods, JASA 52 (280), 415–449.

The computations of Method II take about [...] \_\_\_\_\_ for a ten-year monthly series [...].

OECD (1960), Seasonal Adjustment on Electronic Computers.

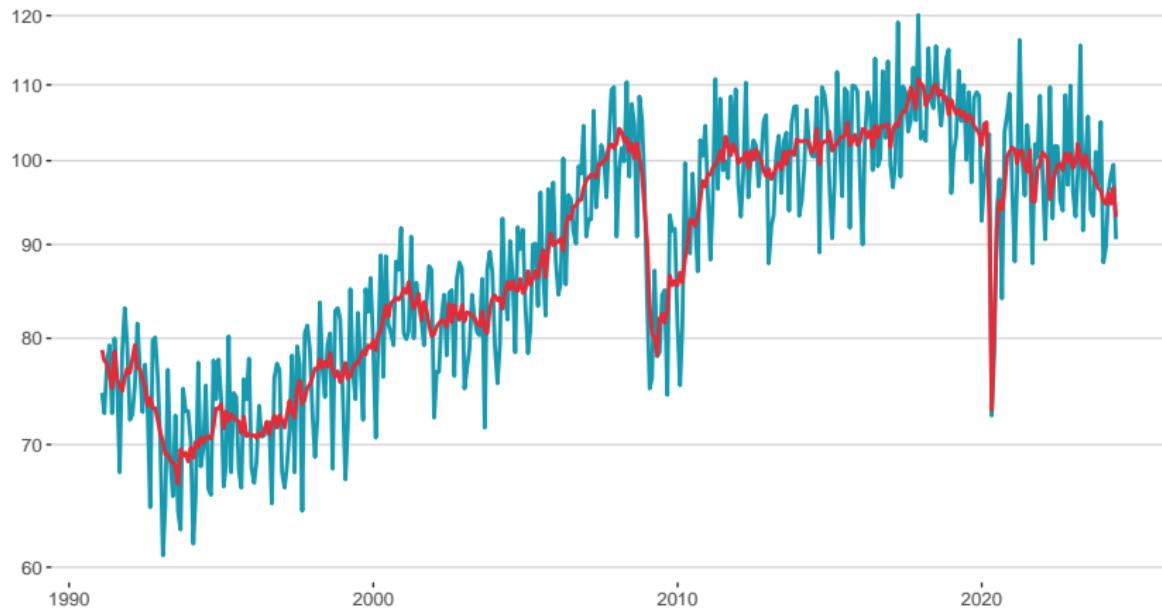
A Method II adjustment done by the Bureau of the Census on its computer costs from \$ \_\_\_ to \$ \_\_\_ for a ten year series, [...].

# Input



**Industrial production** (volume, 2021 = 100, Jan 1991 – May 2024)

# Output



**Industrial production** (volume, 2021 = 100, Jan 1991 – May 2024) &  
seasonally adjusted figures

# Obstacles



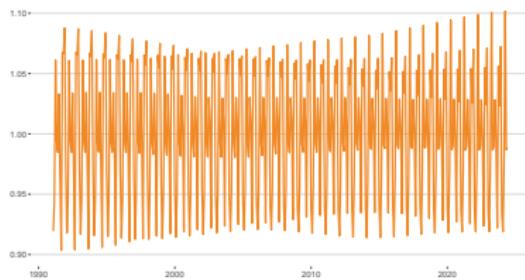
Temporary outliers



Persistent outliers



Calendar variation



Seasonal variation

# I Seasonal adjustment approaches

## Empirical-based (non-parametric)

- Seasonal dynamics → Ad hoc extraction methods
- Weighted moving averages → STL, X-11

## Model-based (parametric)

- Seasonal & non-seasonal dynamics → Joint framework
- Top-down strategy → ARIMA model decomposition
- Bottom-up strategy → Structural time series models

## Syntheses

- Model-based pretreatment & ad hoc filters → X-12-ARIMA
- Model-based & HP filters → Atomic seasonal models

# Key messages

## Seasonality

- ☞ Usual seasonal fluctuations → Persistent intra-year swings (same period, similar amplitude)

## Year-on-year changes

- ☞ Removal → Deterministic seasonality (same amplitude)
- ☞ Leakage → Moving seasonality, calendar variation

## Seasonal adjustment

- ☞ Unadjusted data → Extraction of unpredictable patterns ("news")
- ☞ Removal → Deterministic & moving seasonality, calendar variation

# References (I/VIII)

## Time series analysis

- G E P Box & G M Jenkins (1970), Time Series Analysis – Forecasting and Control, Holden-Day, San Francisco.
- P J Brockwell & R A Davis (1991), Time Series: Theory and Methods (2nd ed.), Springer, New York.
- U Grenander & M Rosenblatt (1957), Statistical Analysis of Stationary Time Series, Wiley, New York.
- J D Hamilton (1994), Time Series Analysis, Princeton University Press, Princeton.
- M Nerlove, D M Grether & J L Carvalho (1979), Analysis of Economic Time Series – A Synthesis, Academic Press, New York.
- D Peña, G C Tiao & R S Tsay (eds) (2001), A Course in Time Series Analysis, Wiley, New York.

## References (II/VIII)

### Seasonal time series

- ¶ W R Bell & S C Hillmer (1984), [Issues Involved With the Seasonal Adjustment of Economic Time Series](#), Journal of Business & Economic Statistics 2 (4), 291–320.
- ¶ W R Bell, S H Holan & T S McElroy (eds) (2012), Economic Time Series – Modeling and Seasonality, CRC Press, Boca Raton.
- ¶ E B Dagum & S Bianconcini (2016), Seasonal Adjustment Methods and Real Time Trend-Cycle Estimation, Springer, Berlin.
- ¶ E B Dagum, G Huot & M Morry (1988), [Seasonal Adjustment in the Eighties: Some Problems and Solutions](#), Canadian Journal of Statistics 16 (S1), 109–126.

## References (III/VIII)

### Seasonal time series

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- M C Lovell (1963), Seasonal Adjustment of Economic Time Series and Multiple Regression Analysis, Journal of the American Statistical Association 58 (304), 993–1010.
- M Nerlove (1964), Spectral Analysis of Seasonal Adjustment Procedures, Econometrica 32 (3), 241–286.
- T Proietti (2000), Comparing Seasonal Components for Structural Time Series Models, International Journal of Forecasting 16 (2), 247–260.

## References (IV/VIII)

Reviews of seasonal adjustment methods

-  D F Findley (2005), [Some Recent Developments and Directions in Seasonal Adjustment](#), Journal of Official Statistics 21 (2), 343–365.
-  P H Franses (1996), [Recent Advances in Modelling Seasonality](#), Journal of Economic Surveys 10 (3), 299–345.
-  S N Marris (1960), A Technical Survey of Problems and Methods of Seasonal Adjustment in Europe and North America with Special Reference to United States Bureau of the Census Method II, in: Seasonal Adjustment on Electronic Computers, OECD, Paris, 33–78.

## References (V/VIII)

Reviews of seasonal adjustment methods

-  H Mendershausen (1937), [Methods of Computing and Eliminating Changing Seasonal Fluctuations](#), Econometrica 5 (3), 234–262.
-  D A Pierce (1980), [A Survey of Recent Developments in Seasonal Adjustment](#), The American Statistician 34 (3), 125–134.
-  K Webel (2022), [A review of some recent developments in the modelling and seasonal adjustment of infra-monthly time series](#), Discussion Paper No 31/2022, Deutsche Bundesbank.

# References (VI/VIII)

## Seasonal economic models

- ¶ E Ghysels (1987), [Seasonal Extraction in the Presence of Feedback](#), Journal of Business & Economic Statistics 5 (2), 191–194.
- ¶ E Ghysels (1988), [A Study Toward a Dynamic Theory of Seasonality for Economic Time Series](#), Journal of the American Statistical Association 83 (401), 168–172.
- ¶ D R Osborn (1988), [Seasonality and Habit Persistence in a Life Cycle Model of Consumption](#), Journal of Applied Econometrics 3 (4), 255–266.
- ¶ C I Plosser (1979), [The Analysis of Seasonal Economic Models](#), Journal of Econometrics 10 (2), 147–163.
- ¶ D van Dijk, B Strikholm & T Teräsvirta (2003), [The Effects of Institutional and Technological Change and Business Cycle Fluctuations on Seasonal Patterns in Quarterly Industrial Production Series](#), Econometrics Journal 6 (1), 79–98.

# References (VII/VIII)

Official statistics in Europe

- Eurostat (2024), [ESS Guidelines on Seasonal Adjustment](#), Publications Office of the European Union, Luxembourg, ISBN 978-92-68-15943-9.
- Eurostat (2018), [Handbook on Seasonal Adjustment](#), Publications Office of the European Union, Luxembourg, ISBN 978-92-79-80170-3.

# References (VIII/VIII)

Related topics

-  P A Cholette (1984), [Adjusting Sub-Annual Series to Yearly Benchmarks](#), Survey Methodology 10 (1), 35–49.
-  E B Dagum & P A Cholette (2006), Benchmarking, Temporal Distribution, and Reconciliation Methods for Time Series, Springer, New York.
-  T Di Fonzo & M Marini (2011), [Simultaneous and Two-Step Reconciliation of Systems of Time Series: Methodological and Practical Issues](#), Journal of the Royal Statistical Society C 60 (2), 143–161.
-  B Quenneville, F Picard & S Fortier (2013), [Calendarization with Interpolating Splines and State Space Models](#), Journal of the Royal Statistical Society C 62 (3), 371–399.

Motivation

## Introduction to JD+

RegARIMA pretreatment

- Regression equation
- TransReg plug-in
- ARIMA equation

X-11 approach

- Basic principle
- Further issues

ARIMA model-based approach

Quality assessment

Revision policies

Composite time series

Summary

Since the early 19th century seasonal adjustment is a component of the statistics business process. This business has developed over the years and different methods have been implemented in different applications.

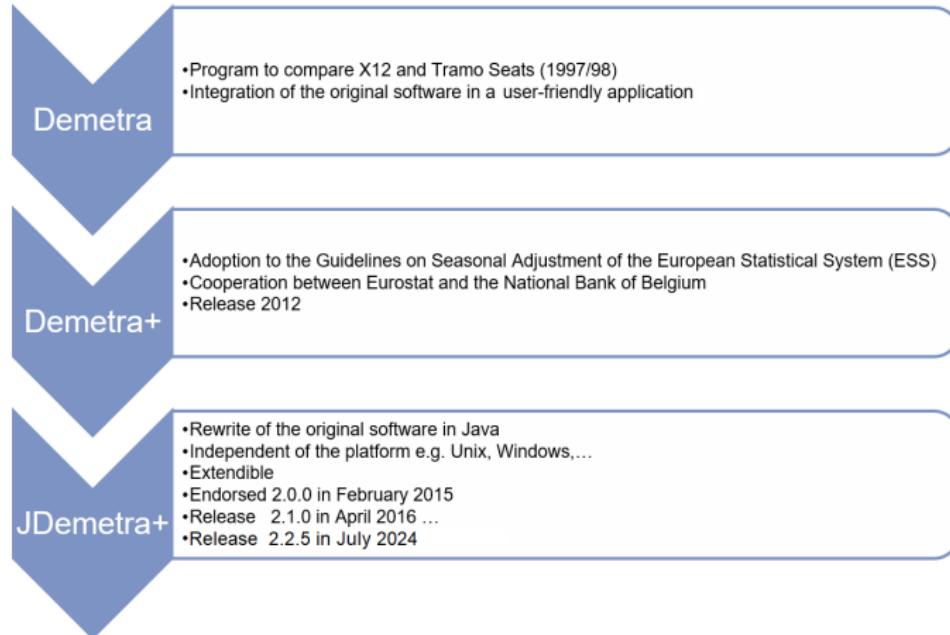
Since the early 19th century seasonal adjustment is a component of the statistics business process. This business has developed over the years and different methods have been implemented in different applications.

### Widely-used methods for seasonal adjustment

- X-11 (U.S. Census Bureau, iterative application of linear filters)
- TRAMO/SEATS (Maravall and Gómez, Signal Extraction in ARIMA Time Series to obtain simultaneously the different components of a time series)
- Structural Models (e.g. Harvey)

# JDemetra+

## History (II/II)

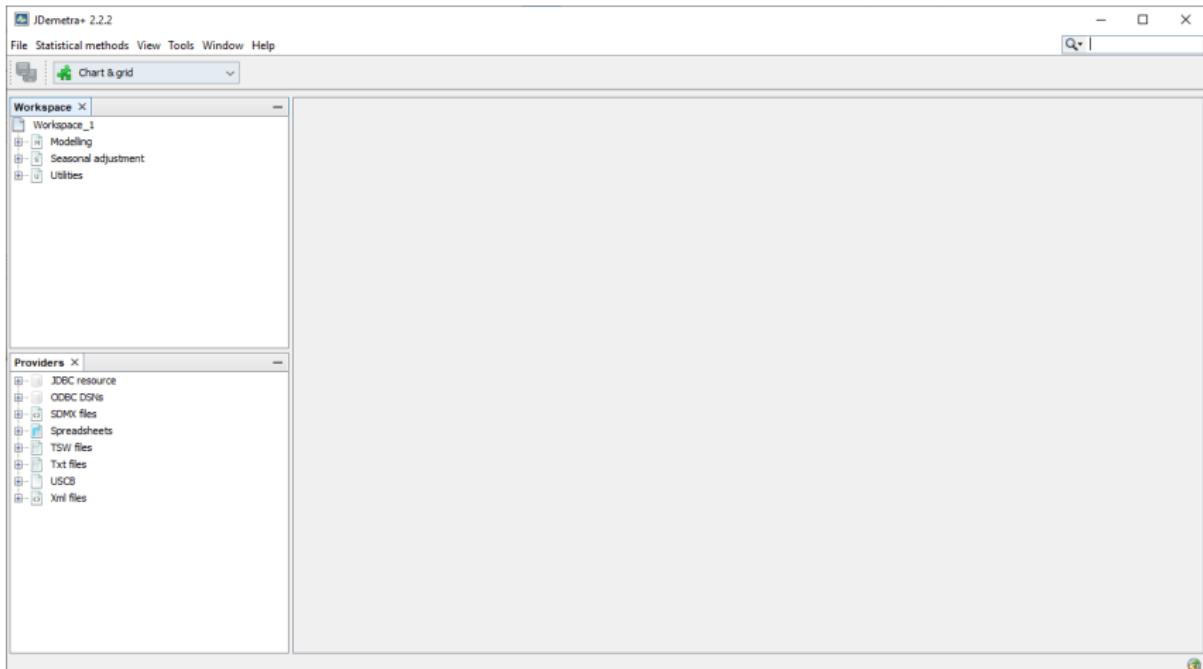


- One extendible main application
- Open source application (Java, Maven, NetBeans Framework)
- Officially adopted for the ESS since February 2015
- Recommended software in the ESS Guidelines
- Development is done by the National Bank of Belgium,  
supported by the Deutsche Bundesbank for the X-11 part

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supported by the Deutsche Bundesbank for the X-11 part
- The release version 2.2.5 (jdemetra-2.2.5.zip) is available for  
download on GitHub  
<https://github.com/jdemetra/jdemetra-app/releases>
- Installation guide  
<https://github.com/jdemetra/jdemetra-app/wiki/Quick-install-guide>

# Basic functionalities

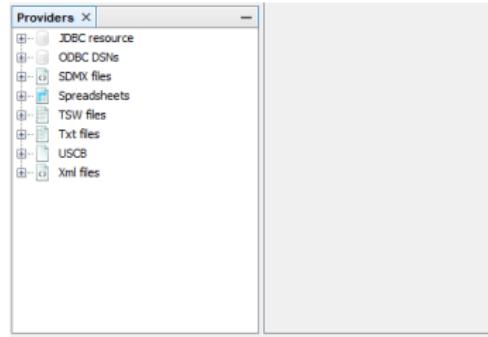
## Starting the application for the first time



# Basic functionalities

## Data import (I/II)

### Providers Node structure of supported data sources



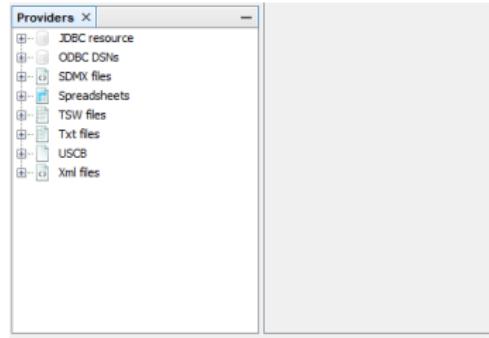
# Basic functionalities

## Data import (I/II)

**Providers** Node structure of supported data sources

Data can be imported among other providers via

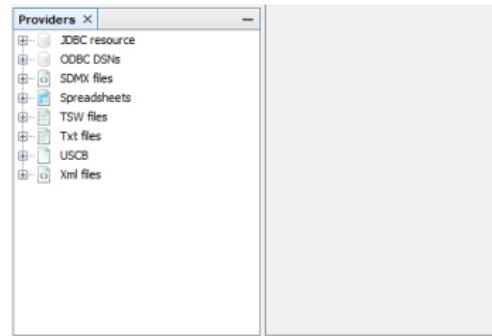
- “**Spreadsheets**” from Excel files (\*.xls, \*.xlsx)
- “**Txt files**” from Text files (\*.txt, \*.csv, \*.tsv)
- “**SDMX**” from SDMX files (\*.xml)
- “**ODBC DSNs**”, “**JDBC resource**” from standard databases (Oracle, SQLServer, DB2, etc.)
- plug-ins from further providers



# Basic functionalities

## Data import (II/II)

How to import data:

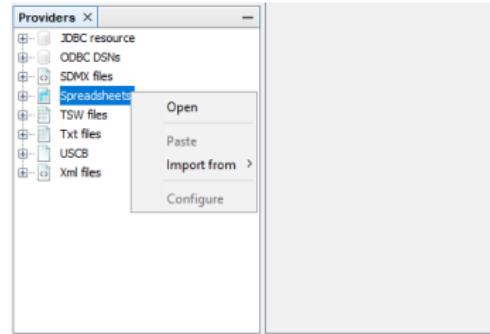


# Basic functionalities

## Data import (II/II)

### How to import data:

- Right-click on the selected provider
- Select **Open** in the context menu

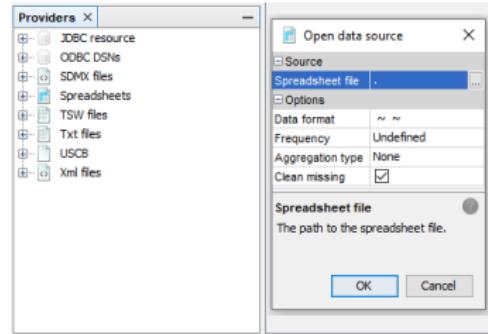


# Basic functionalities

## Data import (II/II)

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- A new dialogue window pops up

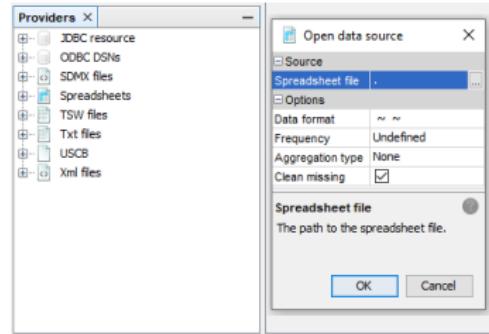


# Basic functionalities

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- **Necessary:** Insert the path to the spreadsheet file.
- **Optional:** Set data formats (locale, date pattern, number pattern), frequency of the time series in **JD+**, handling of missing values

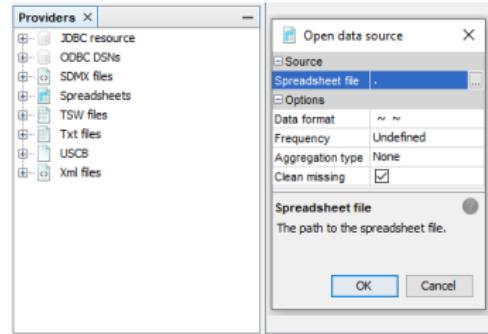


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- **Optional:** Set data formats (locale, date pattern, number pattern), frequency of the time series in **JD+**, handling of missing values
- If the original time series have a higher frequency, you decide how these will be aggregated to the imported ones'



# Basic functionalities

Some nice features

- Add Star: Load time series automatically
- Drag and drop for time series
- Customize the window to your own needs
- Key R shows data points in a chart
- Zoom in charts: move mouse right down and other direction to reset

# Basic functionalities

## Seasonal Adjustment (I/II)

JDemetra+ offers two possibilities to conduct a seasonal adjustment:

### Single Analysis:

- One time series
- One specification
- Single document

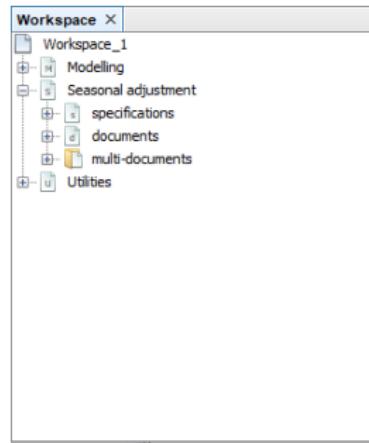
### Multi-processing:

- Several time series with individual specifications
- Multi document

# Basic functionalities

## Seasonal Adjustment (II/II)

**Workspace** Node structure containing settings for seasonal adjustment

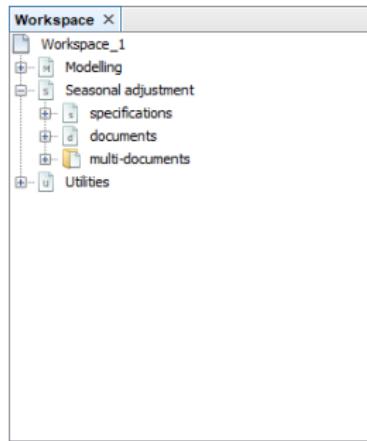


# Basic functionalities

## Seasonal Adjustment (II/II)

**Workspace** Node structure containing settings for seasonal adjustment

- **Modelling** find an ARIMA model for a time series
- **Seasonal adjustment: specifications** both pre-defined and individually customized
- **Seasonal adjustment: documents** run seasonal adjustment for one time series with one specification
- **Seasonal adjustment: multi-documents** run seasonal adjustment for several time series with individual specifications
- **Utilities** calendars, user-defined variables



# Basic functionalities

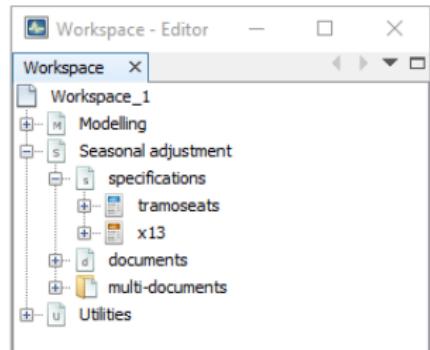
## SA specifications (I/III)

### tramoseats

- methods of TS

x13

- methods of X-13



# Basic functionalities

## SA specifications (II/III)

### Pre-defined TRAMO-SEATS specification

Specification	RSA0	RSA1	RSA2	RSA3	RSA4	RSA5	RSAfull
Transformation	no	test	test	test	test	test	test
Pre-adjustment for leap-year	no	no	no	no	no	no	no
Working days	no	no	test	no	test	no	no
Trading days	no	no	no	no	no	yes	test
Easter effect	no	no	test	no	test	test	test
Outliers	no	test	test	test	test	test	test
ARIMA model	Airline	Airline	Airline	automatic	automatic	automatic	automatic

# Basic functionalities

## SA specifications (III/III)

### Pre-defined X-13 specifications

Specification	X11	RSA1	RSA2c	RSA3	RSA4c	RSA5c
Transformation	no	test	test	test	test	test
Pre-adjustment for leap-year	no	no	test	no	test	test
Working days	no	no	test	no	test	no
Trading days	no	no	no	no	no	test
Easter effect	no	no	test	no	test	test
Outliers	no	no	test	test	test	test

# Basic functionalities

Saving the current work (I/III)

**Workspace** Concept for gathering the current workload and making it reusable at a later time and for others.

# Basic functionalities

## Saving the current work (I/III)

**Workspace** Concept for gathering the current workload and making it reusable at a later time and for others.

- Only a single workspace can be opened.

# Basic functionalities

## Saving the current work (I/III)

**Workspace** Concept for gathering the current workload and making it reusable at a later time and for others.

- Only a single workspace can be opened.
- A **JD+** workspace contains all specifications, multi-documents, variables and time series.

# Basic functionalities

## Saving the current work (I/III)

**Workspace** Concept for gathering the current workload and making it reusable at a later time and for others.

- Only a single workspace can be opened.
- A **JD+** workspace contains all specifications, multi-documents, variables and time series.
- It consists of a superior xml file and a directory of the same name with subdirectories containing xml files.

# Basic functionalities

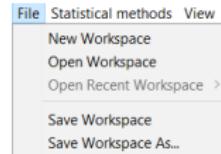
## Saving the current work (I/III)

**Workspace** Concept for gathering the current workload and making it reusable at a later time and for others.

- Only a single workspace can be opened.
- A **JD+** workspace contains all specifications, multi-documents, variables and time series.
- It consists of a superior xml file and a directory of the same name with subdirectories containing xml files.
- Therefore a **JD+** workspace is exchangeable between different users.

# Basic functionalities

## Saving the current work (II/III)

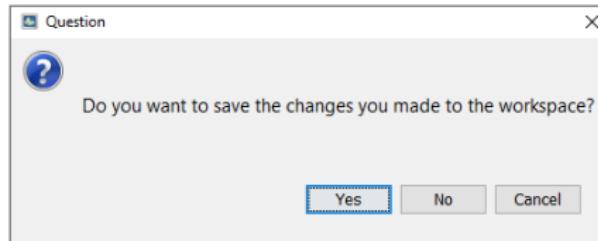


- New Workspace      Opens a new empty workspace
- Open Workspace      Opens an existing workspace by selecting its superior xml file
- Open Recent Workspace      Displays a list of previously opened workspaces to be opened
- Save Workspace      Saves the current workspace (create/overwrite)
- Save Workspace As...      Saves the current workspace under a selectable name in a selectable location

# Basic functionalities

## Saving the current work (III/III)

If you change to another workspace or the current workspace or the application is closed, JD+ will let you save the workspace.



# Enhanced functionalities via plug-ins

What is a plug-in?

JDemetra+ is a plug-in supporting application.

# Enhanced functionalities via plug-ins

What is a plug-in?

JDemetra+ is a plug-in supporting application.

A plug-in ...

- is a software component which adds a specific feature to an existing software application

# Enhanced functionalities via plug-ins

What is a plug-in?

JDemetra+ is a plug-in supporting application.

A plug-in ...

- is a software component which adds a specific feature to an existing software application
- is independent from the software version
- enhances the application without changing its original code

# Enhanced functionalities via plug-ins

What is a plug-in?

JDemetra+ is a plug-in supporting application.

A plug-in ...

- is a software component which adds a specific feature to an existing software application
- is independent from the software version
- enhances the application without changing its original code
- can be shared and installed individually
- allows an easy distribution of new functionalities among community members

# Enhanced functionalities via plug-ins

How to install a plug-in?

## How to install the plug-in TransReg

1. Download the plug-in as an  
nbm-file from

<https://github.com/bbkrd/TransReg/releases>

# Enhanced functionalities via plug-ins

How to install a plug-in?

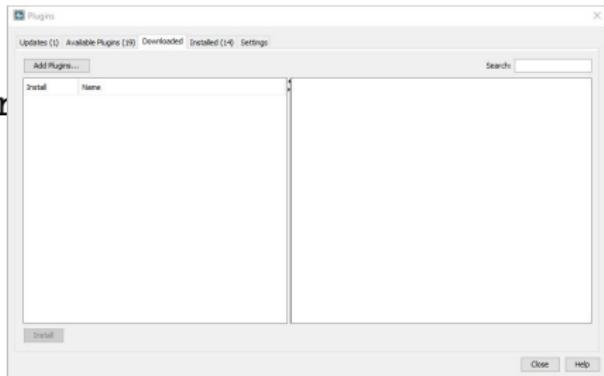
## How to install the plug-in TransReg

1. Download the plug-in as an nbm-file from

<https://github.com/bbkrd/Tr>

2. Open the plug-in window in the menu bar *Tools* →

*Plugins*

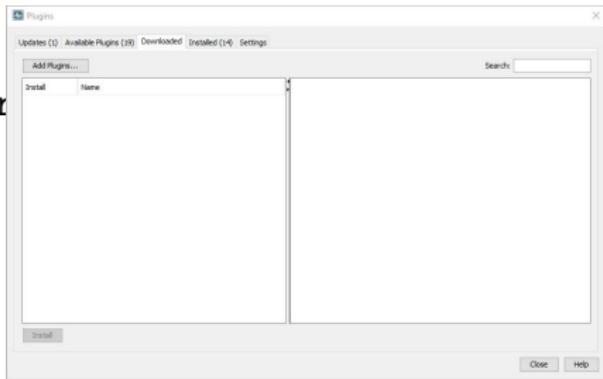


# Enhanced functionalities via plug-ins

How to install a plug-in?

## How to install the plug-in TransReg

1. Download the plug-in as an nbm-file from  
<https://github.com/bbkrd/TransReg>
2. Open the plug-in window in the menu bar *Tools* → *Plugins*
3. Drag'n'drop the nbm-file in the window on the "Downloaded" tabpage OR select the file by clicking "Add Plugins..."

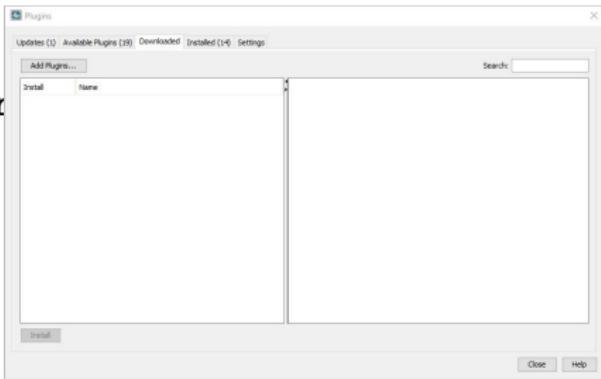


# Enhanced functionalities via plug-ins

How to install a plug-in?

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3. Drag'n'drop the nbm-file in the window on the "Downloaded" tabpage OR select the file by clicking "Add Plugins..."
4. Click on the button "Install" and follow the instructions (license agreement, restart)



# Useful links (I/II)

## Release 2.2.4

- ⌚ <https://github.com/jdemetra/jdemetra-app/releases/tag/v2.2.4>  
→ Application
- ⌚ <https://github.com/jdemetra/jwsacruncher/releases> → Cruncher

## Documentation (Eurostat CROS-Portal)

- ⌚ <https://jdemetradocumentation.github.io/JDemetra-documentation/>
- ⌚ [http://ec.europa.eu/eurostat/cros/content/documentation\\_en](http://ec.europa.eu/eurostat/cros/content/documentation_en)
- ⌚ [https://.../jdemetra-cruncher-mass-production\\_en](https://.../jdemetra-cruncher-mass-production_en)

## Helpdesk (Eurostat CROS-Portal)

- ⌚ [https://.../ess-seasonal-adjustment-helpdesk\\_en](https://.../ess-seasonal-adjustment-helpdesk_en)

# Useful links (II/II)

Deutsche Bundesbank

## Plug-ins (Development)

- ⌚ <https://github.com/bbkrd/TransReg>
- ⌚ <https://github.com/bbkrd/CompRes>
- ⌚ <https://github.com/bbkrd/KIX-UI>, <https://github.com/bbkrd/KIX2.0>

## Documentation

- ⌚ <https://bbkrd.github.io/>

## Source Code (Open Source)

- ⌚ <https://github.com/jdemetra/jdemetra-app>
- ⌚ <https://github.com/jdemetra/jdemetra-core>

Motivation

Introduction to JD+

RegARIMA pretreatment

- Regression equation
- TransReg plug-in
- ARIMA equation

X-11 approach

- Basic principle
- Further issues

ARIMA model-based approach

Quality assessment

Revision policies

Composite time series

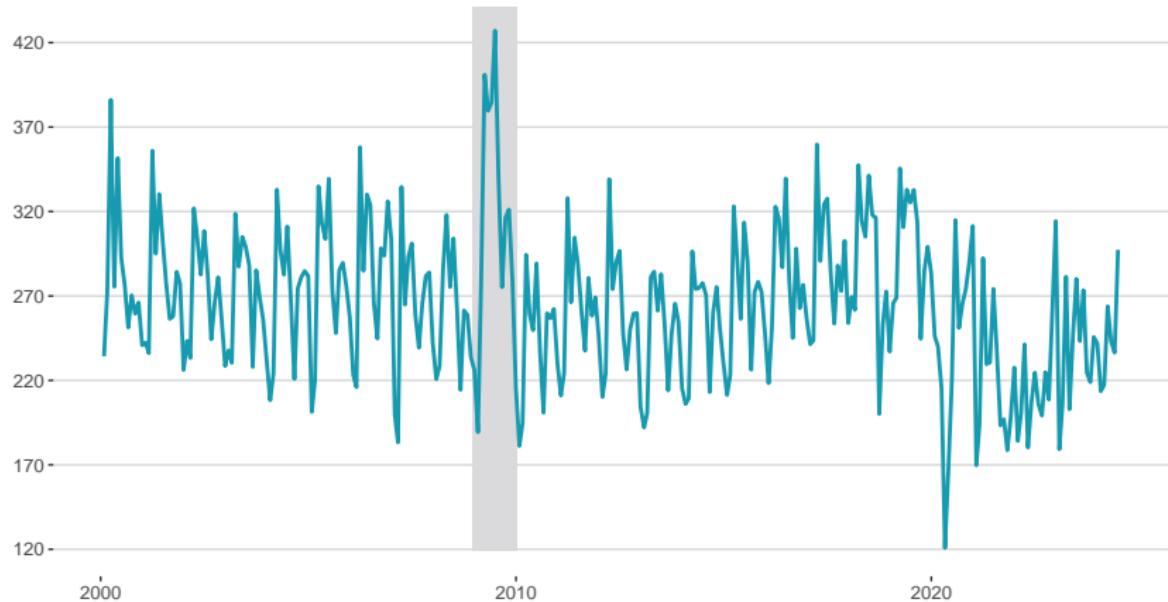
Summary

## Quiz: guess the year!

In almost every true series of observations, some are found, which differ so much from the others as to indicate some abnormal source of error not contemplated in the theoretical discussions, and the introduction of which into the investigations can only serve, in the present state of science, to perplex and mislead the inquirer.

# Messy data (I/V)

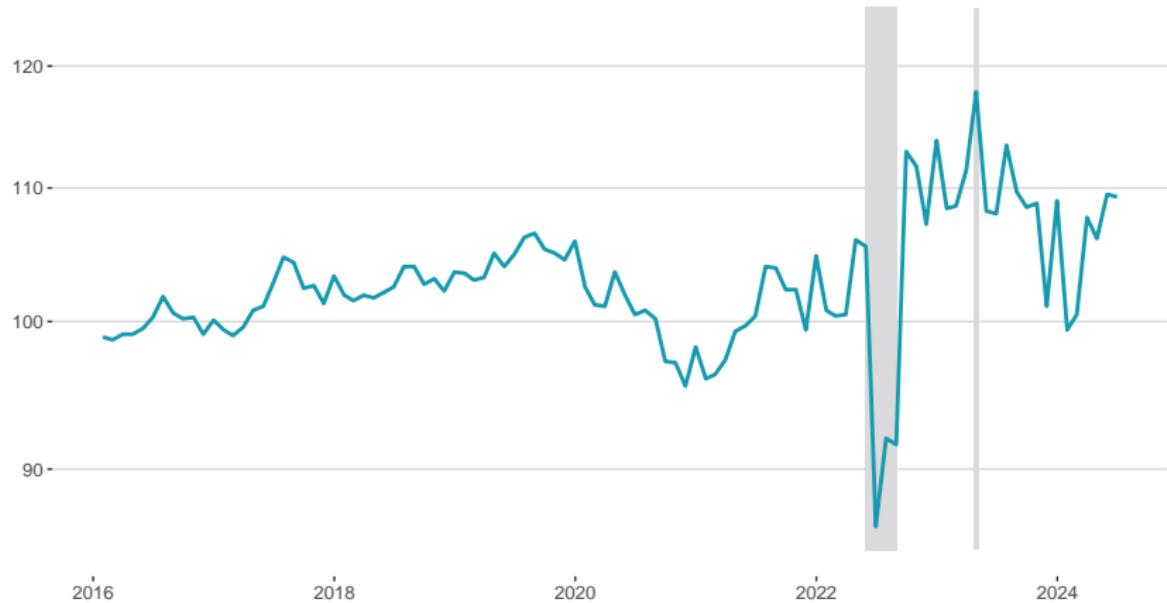
Temporary outliers: monetary incentive



Registered passenger cars in Germany (thousands) with governmental fund identifier (shaded area)

# Messy data (II/V)

Temporary outliers: monetary incentive



**CPI: transport services** (2020 = 100) with **€9 ticket** (*shaded area*) & **€49 ticket** (*vertical*) identifiers

## Messy data (III/V)

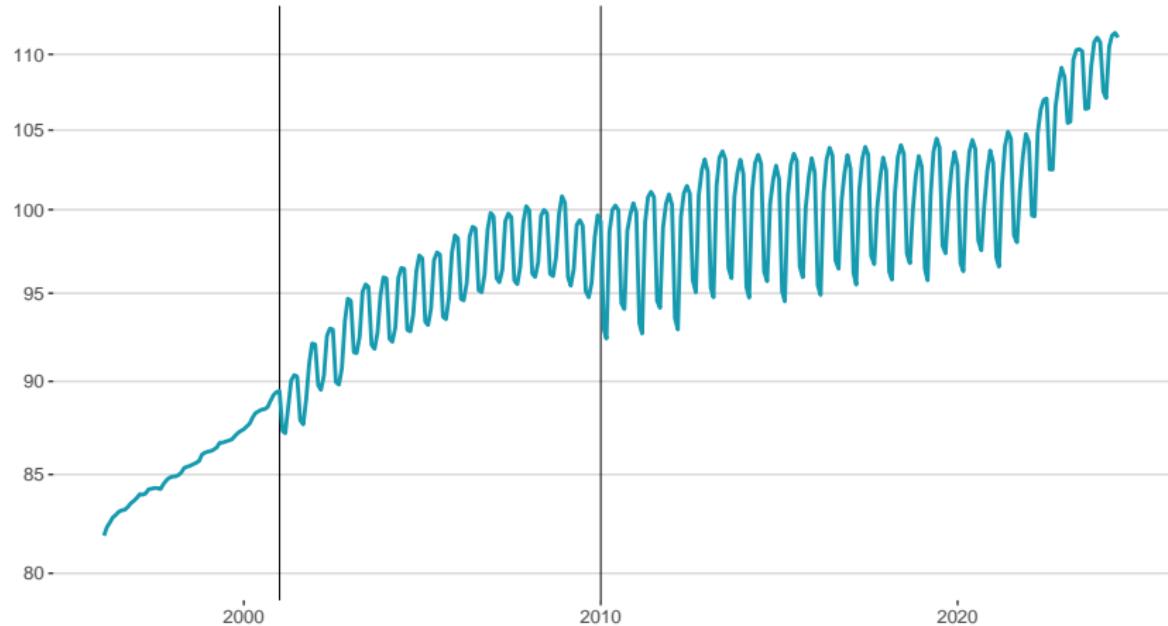
Persistent outliers: change in classification



**Employed persons** (thousands) **in the manufacture of wearing apparel**  
**(solid) & of leather & related products** (dashed)

# Messy data (IV/V)

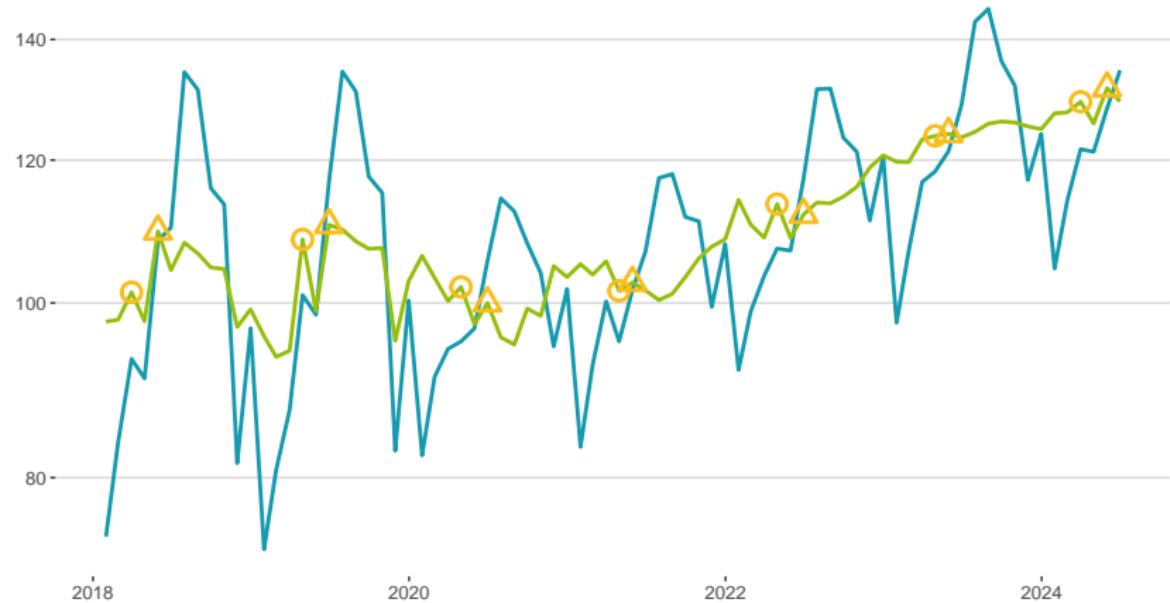
Structural breaks: change in data compilation



HICP for Spain: industrial goods excluding energy (2015 = 100) with implementation date identifiers (verticals)

# Messy data (V/V)

Calendar variation: moving holidays



CPI: package holidays (2020 = 100) & only seasonally adjusted figures  
with Easter (circles) & Whitsun (triangles) identifiers

# Reasons (I/II)

## Outliers

### Temporary unusual circumstances

- Atypical holiday constellations
- Extreme weather conditions
- Large-scale orders
- Major sport events
- Pandemics
- Strikes

### Persistent changes

- Classification
- Policy → Economic, political
- Legislation, regulation

## I Reasons (II/II)

### Calendar variation

#### Stock data

- Reporting → Day of the week
- Currency in circulation, overnight deposits, etc.

#### Flow data

- Each weekday → Varying number over months
- Orders received, output, turnover, etc.

#### Moving holidays

- Easter, Whitsun, etc.

# Pretreatment regression model

## Goals

- Outliers → Temporary removal
- Calendar effects → Permanent removal
- Data → Log transformation, “optimal” forecasts

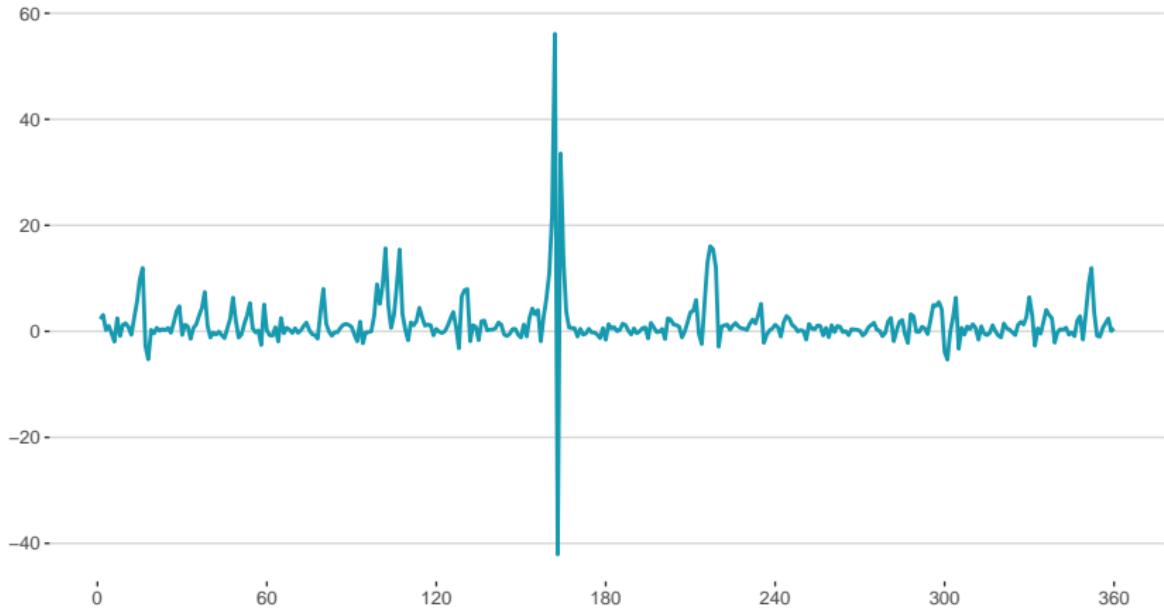
## Regression equation

- Linear regression model → Exogenous effects
- Independent variables → Outlier & calendar regressors
- Disturbances → ARIMA process

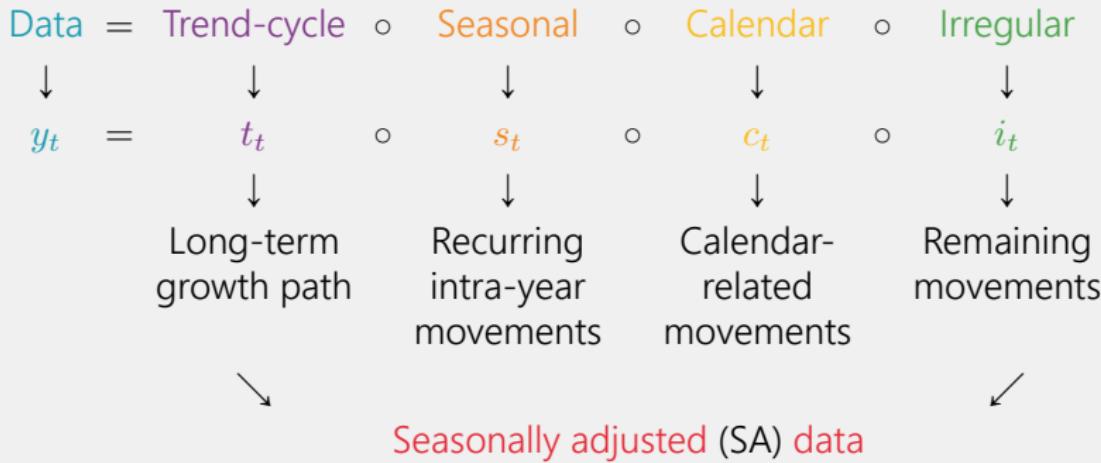
## ARIMA equation

- Seasonal ARIMA model → Dependence structure

## Reminder: outlier concept is a relative one



# Unobserved component (UC) model



## Assumptions

- Data  $\rightarrow$  Monthly
- Decomposition  $\rightarrow$  Additive ( $\circ = +$ ), multiplicative ( $\circ = \times$ )

Motivation

Introduction to JD+

RegARIMA pretreatment

- Regression equation
- TransReg plug-in
- ARIMA equation

X-11 approach

- Basic principle
- Further issues

ARIMA model-based approach

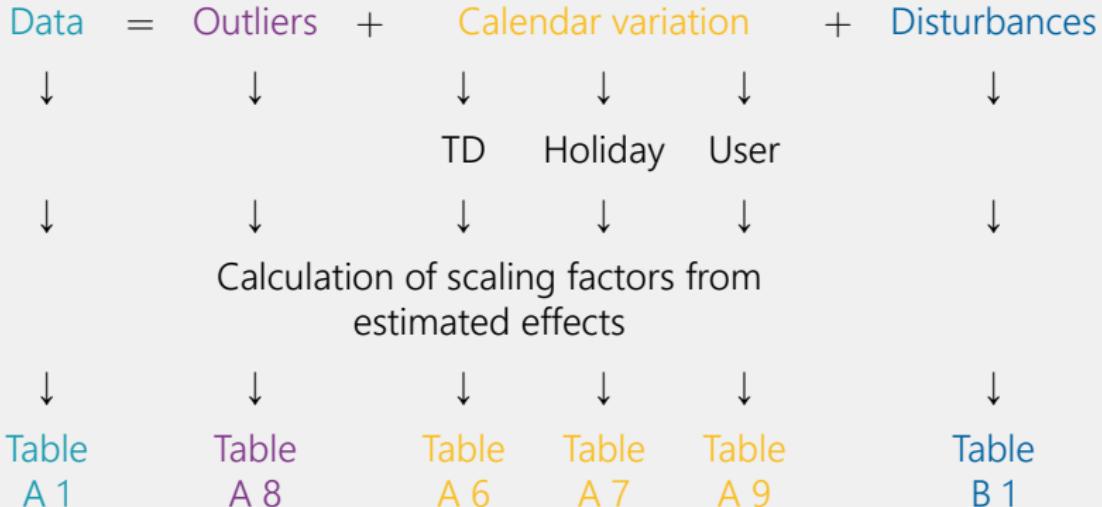
Quality assessment

Revision policies

Composite time series

Summary

# Non-technical setup



# Technical setup

$$f(\textcolor{teal}{y}_t) = \sum_k \beta_k \times k\text{-th regressor}_t + z_t$$

## Notations

- $f$  → Transformation
  - Additive decomposition → Identity
  - Multiplicative decomposition → Log
  - Automatic selection → Log-level test
- $\beta_k$  → Unknown outlier & calendar effects
- $z_t$  → ARIMA disturbances

# Outliers (I/VI)

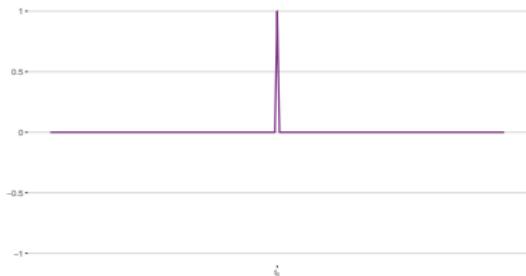
## Types

Effect	Type	UC	Correction	Visibility in SA figures	Frequency of use (BBk)
Temporary	Additive outlier	Irregular	Present	Yes	Common
	Transitory change	Irregular	Present	Yes	Occasional
	Transitory level shift <sup>1)</sup>	Trend-cycle	Present	Yes	N/A
Persistent	Level shift	Trend-cycle	Past	Yes	Common
	Linear ramp	Trend-cycle	Past	Yes	Rare
	Quadratic ramp <sup>1)</sup>	Trend-cycle	Past	Yes	N/A
	Seasonal outlier	Seasonal	Past	No	Rare

<sup>1)</sup> This type is currently not implemented in JD+.

# Outliers (II/VI)

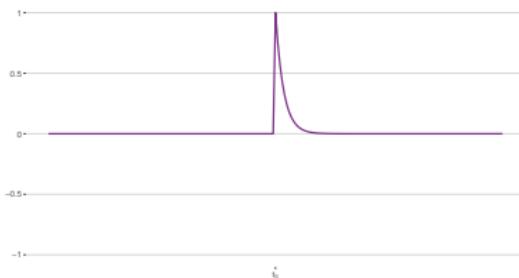
## Regression variables



Additive outlier (AO)



Level shift (LS)



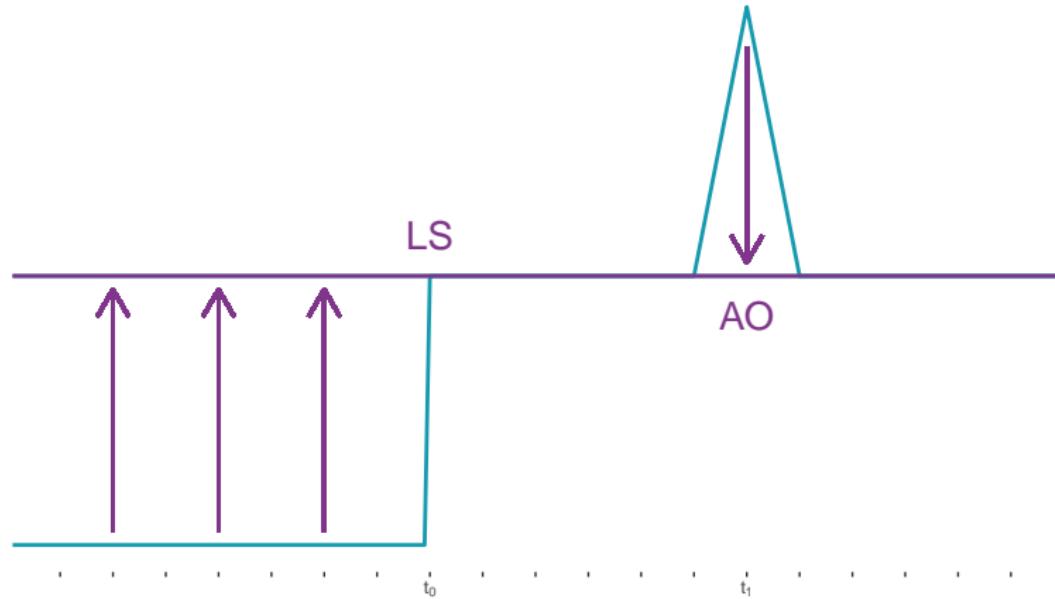
Transitory change (TC)



Seasonal outlier (SO)

# Outliers (III/VI)

Correction principle



Unadjusted figures & outlier adjusted figures

# Outliers (IV/VI)

Estimated effects

## Industrial production

Volume, 2021 = 100

LS	Estimate	Std. err.	t-value	AO	Estimate	Std. err.	t-value
10-2008	-0.0306	0.01516	-2.02	03-2020	-0.0863	0.01395	-6.19
11-2008	-0.0470	0.01599	-2.94	04-2020	-0.3209	0.01512	-21.22
12-2008	-0.0428	0.01598	-2.68	05-2020	-0.1880	0.01514	-12.42
01-2009	-0.0847	0.01597	-5.30	06-2020	-0.0578	0.01395	-4.14
02-2009	-0.0388	0.01522	-2.55				
04-2009	-0.0301	0.01522	-1.98				
05-2009	0.0453	0.01530	2.96				
09-2009	0.0363	0.01431	2.53				
05-2010	0.0354	0.01445	2.45				
10-2020	0.0463	0.01441	3.21				
03-2022	-0.0379	0.01463	-2.59				

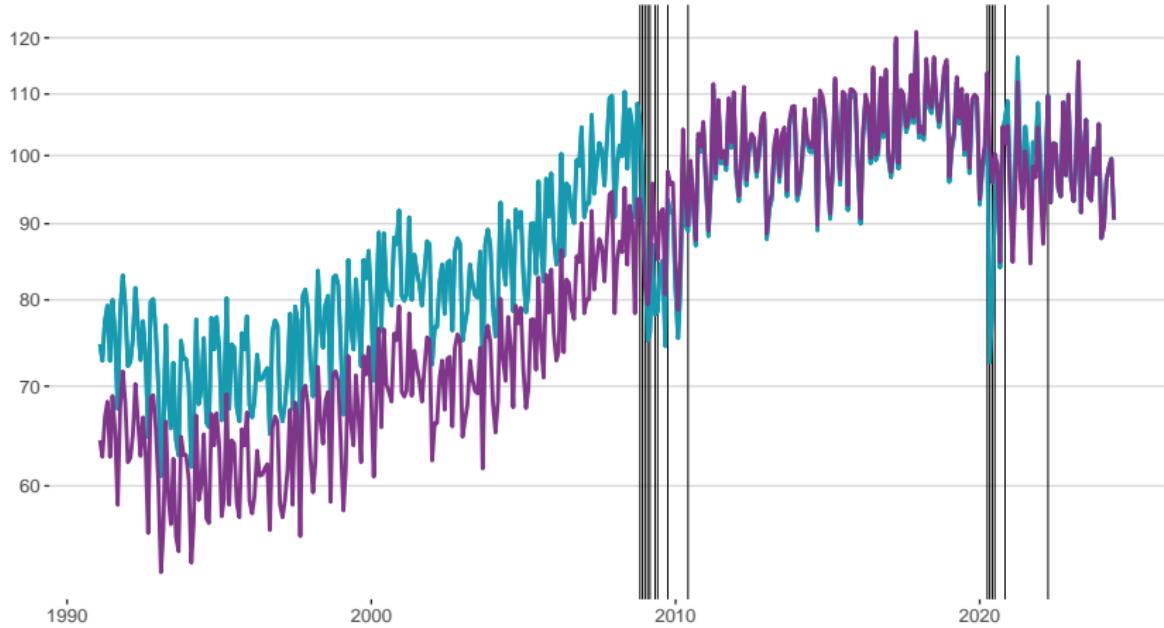
# Outliers (V/VI) Estimated component



**Combined outlier component (A 8) for industrial production**

# Outliers (VI/VI)

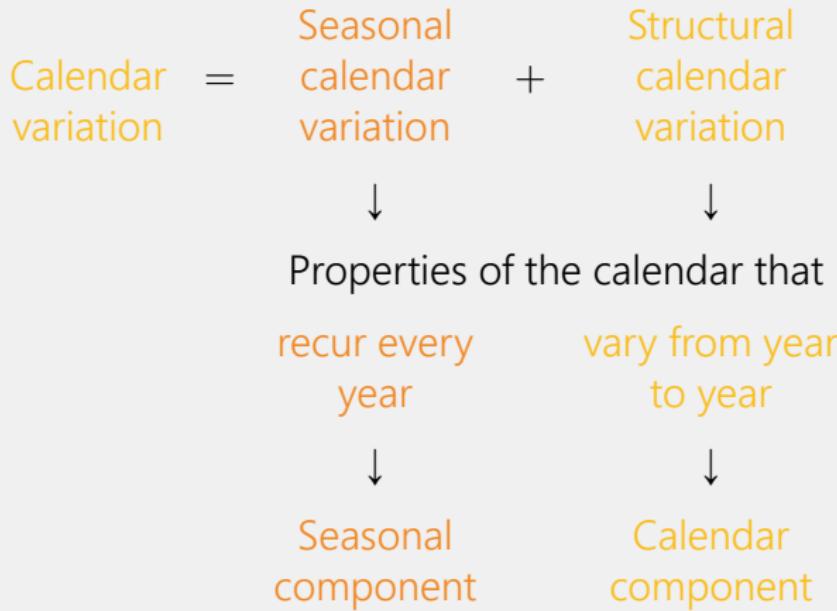
Temporary removal



Industrial production (volume, 2021 = 100) & outlier adjusted figures  
with AO & LS identifiers (verticals)

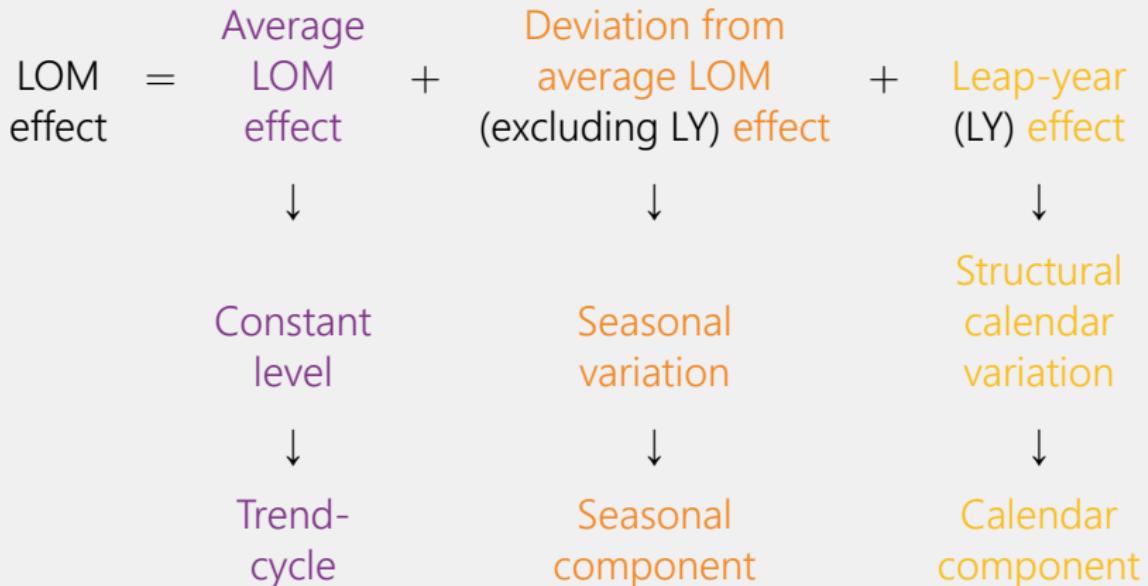
# Calendar variation (I/X)

## Types



# Calendar variation (II/X)

Example: length-of-month (LOM) effect in flows (Bell, 1984)



# Calendar variation (III/X)

## Predefined regression variables

### Selected variables

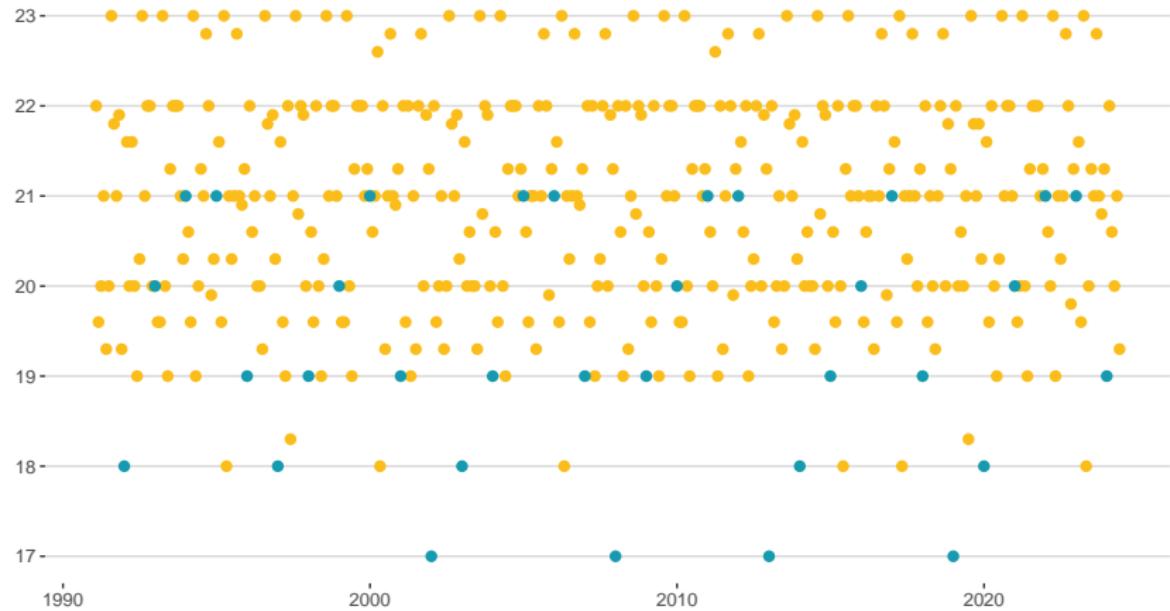
- Trading day contrasts → Individual & common day-of-the-week effects
- Leap year → February dummy
- Easter → February/March/April share of pre-Easter period of interest (in days)

### Pros & cons

- Advantage → Easy use, instant results, indication
- Disadvantage → No customisation, possible mismatch with national calendar

# Calendar variation (IV/X)

User-defined regression variables



**Working days in Germany** (including partial working days, non-centred)  
for **January through November & December**

# Calendar variation (V/X)

Estimated working-day effects

## Industrial production

Volume, 2021 = 100

Working days in ...	Estimate	Std. err.	t-value
January, ..., November	0.0359	0.00064	56.25
December	0.0231	0.00152	15.18

## Working-day (WD) regression variables

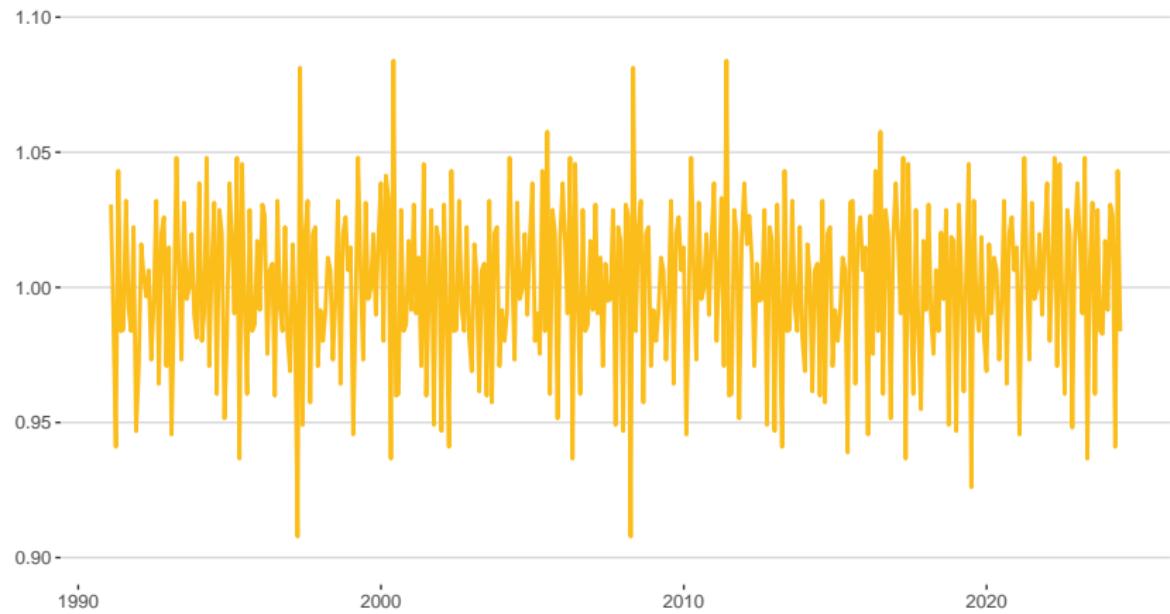
- Centred → Month-specific means

## Interpretation

- One additional WD → Average rise in production
  - January, ..., November → 3.6 %
  - December → 2.3 %

# Calendar variation (VI/X)

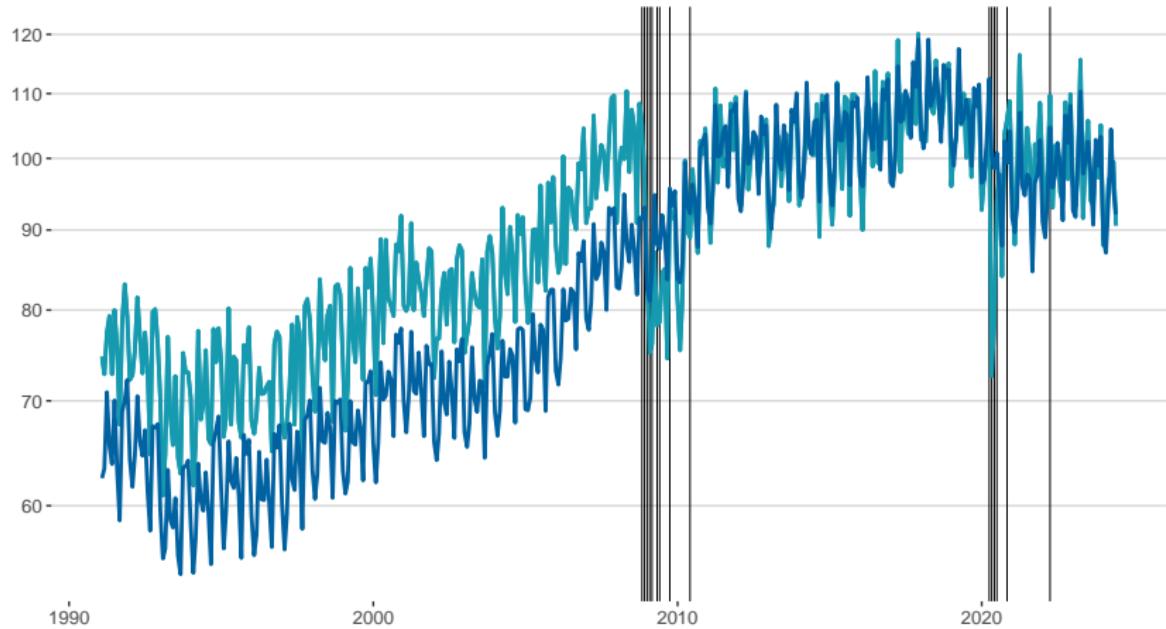
Estimated working-day component



User-defined TD component (A 6) for industrial production

# Calendar variation (VII/X)

Permanent removal



Industrial production (volume, 2021 = 100) & outlier & calendar adjusted  
(linearised) figures with AO & LS identifiers (verticals)

# Calendar variation (VIII/X)

Estimated moving-holiday effects

## CPI: package holidays

2020 = 100

Location of ...	Estimate	Std. err.	t-value
Easter Sunday in March	0.0440	0.01409	3.12
Easter Sunday in April	0.0671	0.01502	4.47
Whit Sunday in May/June	0.0341	0.00772	4.41

## Moving-holiday (MH) regression variables

- Easter → March & April dummies
- Whitsun → Joint May/June dummy

## Interpretation

- Location of MH → Average rise in consumer prices
  - Easter Sunday → 4.4 % (March) & 6.7 % (April)
  - Whit Sunday → 3.4 % (May & June)

# Calendar variation (IX/X)

Permanent removal



CPI: package holidays (2020 = 100), only seasonally adjusted figures & seasonally adjusted figures

# Calendar variation (X/X)

Further aspects

## Calendar adjustment in official statistics

Criterion <sup>1)</sup>	Working days	Bridge days	School holidays	Average impact of Weather
Estimated effect ... significant plausible	Yes Yes	Yes Yes	Yes No	Yes Yes
Majority of adjusted figures plausible	Yes	Yes	Yes	No
Systematic over-/under-adjustment irrelevant	Yes	No	No	No
Catch-up effects quantifiable	Yes	No	No	No

1 As described in Section 4.5 of the [ESS Guidelines on Seasonal Adjustment](#) (2024 edition).

Motivation

Introduction to JD+

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- Regression equation
- TransReg plug-in
- ARIMA equation

X-11 approach

- Basic principle
- Further issues

ARIMA model-based approach

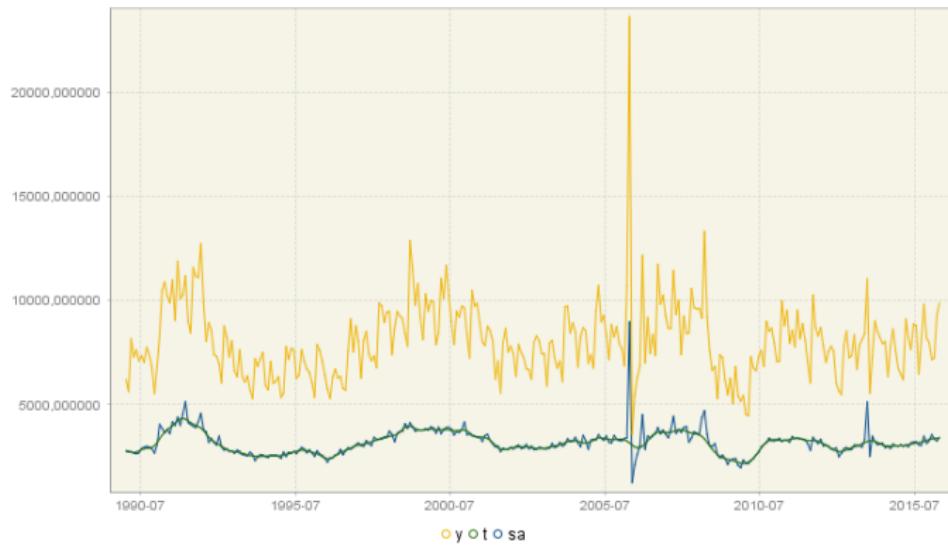
Quality assessment

Revision policies

Composite time series

Summary

# Question?



Adjusting German car registrations using a non-centred  
working-day regressor

# I Problem

## JD+

- No automatic centring of user-defined variables
- Non-centred regressors lead to a level mismatch
- No built-in centring option
- Centring outside JD+ and then loading centred regressors necessary

# I Solution (I/II)

## Idea

- Centring user-defined regressors
- Deviation from long-term average
- $\text{centeruser} = \text{mean}$
- $\text{centeruser} = \text{seasonal}$

## Implementation

- Transformation of regressors
- A plug-in to create, generate, transform and work with regressors

## I Solution (II/II)

Install

TransReg-1.2.9.nbm

Create a TransReg document

Workspace → TransReg → documents → New

Create a new variable

Utilities → Variables → New

Use the transformed variable

Open with Chart & Grid → Drag & Drop to variable

# I Useful links

## Plug-ins

⌚ <https://github.com/bbkrd/TransReg>

## Documentation

⌚ <https://bbkrd.github.io/pages/transreg/>

Motivation

Introduction to JD+

RegARIMA pretreatment

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Summary

# I Reminder: regression equation

## Goals

- Data → Log transformation, “optimal” forecasts
- Outliers → Temporary removal
- Calendar variation → Permanent removal

## Disturbances

- Trend & seasonal dynamics → Non-zero autocorrelations at multiple lags
- White-noise assumption → Invalid
- Valid alternative → ARIMA models

# Why ARIMA models?

## STATCAN requirements (Dagum, 1978)

- Models → Parsimony (number of parameters), stability (across time), simplicity
- Forecasts → Mean squared error (MSE) optimality, reflectivity (infra-year dynamics), short-term effectiveness

## Key concept

- Data (general structure) → Past observations & lagged random shocks

# I Ingredients

## Non-seasonal/**seasonal** operators

- Stationary autoregressive → AR/SAR
- Differencing → D/SD
- Invertible moving average → MA/SMA

## White noise (WN)

- Mean → Zero
- Variance → Finite, constant
- Dependence structure → Zero (all lags)

# I Non-technical setup

Disturbances of regression equation



AR  $\circ$  SAR  $\circ$  D  $\circ$  SD  $\circ$  B1 = MA  $\circ$  SMA  $\circ$  WN



Order identification & parameter estimation

# I Technical setup

AR	SAR	D	SD	B 1	MA	SMA	WN
↓	↓	↓	↓	↓	↓	↓	↓

$$\phi_p(B) \Phi_P(B^{12}) (1 - B)^d (1 - B^{12})^D z_t = \theta_q(B) \Theta_Q(B^{12}) \varepsilon_t$$

## Notations

- $B$  → Backshift operator, i.e.  $B^k z_t = z_{t-k}$
- Short →  $f(pdq)(PDQ)$

# Details (I/VI)

Non-seasonal AR operator

$$\phi_p(B) = 1 - \phi_1 B - \phi_2 B^2 - \cdots - \phi_p B^p$$

Example ( $p = 2$ )

$$\begin{aligned}\phi_2(B)z_t &= (1 - \phi_1 B - \phi_2 B^2) z_t \\ &= z_t - \phi_1 z_{t-1} - \phi_2 z_{t-2}\end{aligned}$$

## Details (II/VI) Seasonal AR operator

$$\Phi_P(B^{12}) = 1 - \Phi_1 B^{12} - \Phi_2 B^{24} - \cdots - \Phi_P B^{12P}$$

Example ( $P = 2$ )

$$\begin{aligned}\Phi_2(B^{12}) z_t &= (1 - \Phi_1 B^{12} - \Phi_2 B^{24}) z_t \\ &= z_t - \Phi_1 z_{t-12} - \Phi_2 z_{t-24}\end{aligned}$$

## Details (III/VI)

Non-seasonal differencing operator

$$(1 - B)^d$$

Example ( $d = 1$ )

$$(1 - B)z_t = z_t - z_{t-1}$$

## Details (IV/VI)

Seasonal differencing operator

$$(1 - B^{12})^D$$

Example ( $D = 1$ )

$$(1 - B^{12}) z_t = z_t - z_{t-12}$$

## Details (V/VI)

Non-seasonal MA operator

$$\theta_q(B) = 1 - \theta_1 B - \theta_2 B^2 - \cdots - \theta_q B^q$$

Example ( $q = 2$ )

$$\begin{aligned}\theta_2(B)\varepsilon_t &= (1 - \theta_1 B - \theta_2 B^2) \varepsilon_t \\ &= \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2}\end{aligned}$$

## Details (VI/VI)

Seasonal MA operator

$$\Theta_Q(B^{12}) = 1 - \Theta_1 B^{12} - \Theta_2 B^{24} - \dots - \Theta_Q B^{12Q}$$

Example ( $Q = 1$ )

$$\begin{aligned}\Theta_1(B^{12}) \varepsilon_t &= (1 - \Theta_1 B^{12}) \varepsilon_t \\ &= \varepsilon_t - \Theta_1 \varepsilon_{t-12}\end{aligned}$$

# Airline model (I/III)

## Definition

$$(1 - B) (1 - B^{12}) z_t = (1 - \theta_1 B) (1 - \Theta_1 B^{12}) \varepsilon_t$$

### Notations

- $-1 \leq \theta_1, \Theta_1 \leq 1$
- Short  $\rightarrow (pdq)(PDQ) = (011)(011)$

### Interpretation

- $\Theta_1$  close to one/zero  $\rightarrow$  Stable/unstable seasonality
- $\theta_1$  close to one/zero (given  $\Theta_1$ )  $\rightarrow$  Stable/unstable trend

# Airline model (II/III)

Explanation: model for input series

$$z_t = a + bt + st + \text{residual}_t$$

Deterministic components

- Trend
- Seasonal factors

Consequence

$$(1 - B)(1 - B^{12}) \text{residual}_t = (1 - \theta_1 B)(1 - \Theta_1 B^{12}) \varepsilon_t$$

# Airline model (III/III)

## Application

### Choice of Henderson & seasonal filters in X-11

$\theta_1$	0.95		0.80		$\Theta_1$		0.70		0.60	
0.95	s3x15	H23	s3x15	H23	s3x9	H23	s3x5	H23	s3x5	H23
0.80	s3x15	H23	s3x15	H23	s3x9	H23	s3x5	H23	s3x5	H23
0.70	s3x15	H23	s3x15	H23	s3x9	H23	s3x5	H23	s3x5	H23
0.60	s3x15	H17	s3x15	H17	s3x9	H17	s3x5	H17	s3x5	H17
0.50	s3x15	H13	s3x15	H13	s3x9	H13	s3x5	H13	s3x5	H13
0.40	s3x15	H13	s3x15	H13	s3x9	H13	s3x5	H13	s3x5	H13
0.20	s3x15	H9	s3x15	H9	s3x9	H9	s3x5	H9	s3x5	H9
0.00	s3x15	H9	s3x15	H9	s3x9	H9	s3x5	H9	s3x5	H9
$\theta_1$	0.50		0.40		$\Theta_1$		0.20		0.00	
0.95	s3x3	H23	s3x3	H23	s3x3	H23	s3x3	H23	s3x3	H23
0.80	s3x3	H23	s3x3	H23	s3x3	H23	s3x3	H23	s3x3	H23
0.70	s3x3	H23	s3x3	H23	s3x3	H23	s3x3	H23	s3x3	H23
0.60	s3x5	H23	s3x3	H23	s3x3	H23	s3x3	H23	s3x3	H23
0.50	s3x5	H13	s3x3	H17	s3x3	H23	s3x3	H23	s3x3	H23
0.40	s3x5	H13	s3x3	H13	s3x3	H17	s3x3	H23	s3x3	H23
0.20	s3x3	H9	s3x3	H9	s3x3	H13	s3x3	H13	s3x3	H23
0.00	s3x3	H9	s3x3	H9	s3x3	H9	s3x3	H9	s3x3	H23

Source: R Depoutot & C Planas (1998), Comparing Seasonal Adjustment and Trend Extraction Filters with Application to a Model-Based Selection of X11 Linear Filters, Discussion Paper No 9/1998/A/9, Eurostat.

# Keys messages

## Pretreatment

- ☞ Temporary & persistent outliers → Temporary removal
- ☞ Structural calendar variation → Permanent removal

## RegARIMA model

- ☞ Regression equation → Exogenous effects
  - Outliers → Predefined JD+ variables
  - Calendar variation → Predefined JD+ variables & customisation
- ☞ ARIMA equation → Disturbances
  - Dependence structure → Seasonal ARIMA model

## User-defined calendar regression variables

- ☞ JD+ assumption → Centred form

# References (I/IV)

## Transformations & outliers

- ¶ G E P Box & D R Cox (1964), [An Analysis of Transformations](#), Journal of the Royal Statistical Society B 26 (2), 211–252.
- ¶ G E P Box & G C Tiao (1975), [Intervention Analysis with Applications to Economic and Environmental Problems](#), Journal of the American Statistical Association 70 (349), 70–79.
- ¶ A J Fox (1972), [Outliers in Time Series](#), Journal of the Royal Statistical Society B 34 (3), 350–363.
- ¶ G M Ljung (1993), [On Outlier Detection in Time Series](#), Journal of the Royal Statistical Society B 55 (2), 559–567.

## References (II/IV)

### Calendar variation

- ¶ W R Bell (1984), [Seasonal Decomposition of Deterministic Effects](#), Research Report 84/01, U.S. Bureau of the Census.
- ¶ W R Bell & S C Hillmer (1983), [Modeling Time Series With Calendar Variation](#), Journal of the American Statistical Association 78 (383), 526–534.
- ¶ W S Cleveland & S J Devlin (1980), [Calendar Effects in Monthly Time Series: Detection by Spectrum Analysis and Graphical Methods](#), Journal of the American Statistical Association 75 (371), 487–496.
- ¶ W S Cleveland & S J Devlin (1982), [Calendar Effects in Monthly Time Series: Modeling and Adjustment](#), Journal of the American Statistical Association 77 (379), 520–528.

# References (III/IV)

## Calendar variation

-  Deutsche Bundesbank (2012), [Calendar effects on economic activity](#), Monthly Report 64 (12), 51–60.
-  O C Pang, W R Bell & B C Monsell (2022), [Accommodating Weather Effects in Seasonal Adjustment: A Look into Adding Weather Regressors for Regional Construction Series](#), Research Report No. 2022-01, Center for Statistical Research & Methodology, US Census Bureau, Washington, DC.
-  M F Tüzen, G M Gökçin & Ö Yiğit (2023), [The Calculation of Composite Calendar Regressors Including Moving Holidays in Türkiye](#), Journal of Statistical Research 13 (2), 13–27.

## References (IV/IV)

### ARIMA models

-  O D Anderson (1977), [The Interpretation of Box-Jenkins Time Series Models](#), Journal of the Royal Statistical Society D 26 (2), 127–145.
-  K Chiu, J Higginson & G Huot (1985), [Performance of ARIMA Models in Time Series](#), Survey Methodology 11 (1), 51–64.
-  E B Dagum (1978), [Modelling, Forecasting and Seasonally Adjusting Economic Time Series with the X-11-ARIMA Method](#), Journal of the Royal Statistical Society D 27 (3–4), 203–216.
-  P Newbold & C W J Granger (1974), [Experience with Forecasting Univariate Time Series and the Combination of Forecasts](#), Journal of the Royal Statistical Society A 137 (2), 131–146.

| Motivation

| Introduction to JD+

| RegARIMA pretreatment

- Regression equation
- TransReg plug-in
- ARIMA equation

| X-11 approach

- Basic principle
- Further issues

| ARIMA model-based approach

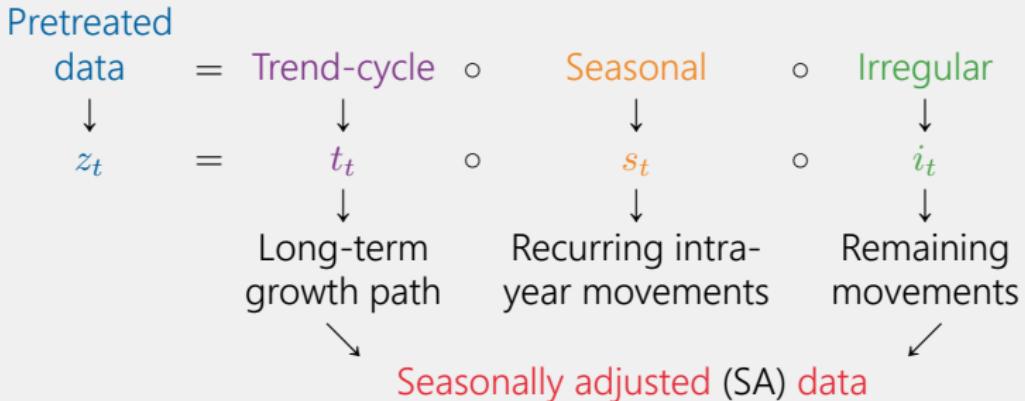
| Quality assessment

| Revision policies

| Composite time series

| Summary

# I UC model after linearisation



## Decomposition ( $\circ$ )

- Multiplicative  $\rightarrow$  Seasonal proportional to trend-cycle
- Additive  $\rightarrow$  Seasonal independent of level of trend-cycle

# I Reminder & outlook

## Pretreated data

- Outliers → Temporary removal
- Calendar variation → Permanent removal
- Data → Log transformation (multiplicative decomposition), “optimal” forecasts

## X-11 approach

- Assumptions
  - Data → Monthly
  - Decomposition → Multiplicative ( $\circ = \times$ )
- Illustration → Section D (see slides on X-11 strategy)

| Motivation

| Introduction to JD+

| RegARIMA pretreatment

- Regression equation
- TransReg plug-in
- ARIMA equation

| X-11 approach

- Basic principle
- Further issues

| ARIMA model-based approach

| Quality assessment

| Revision policies

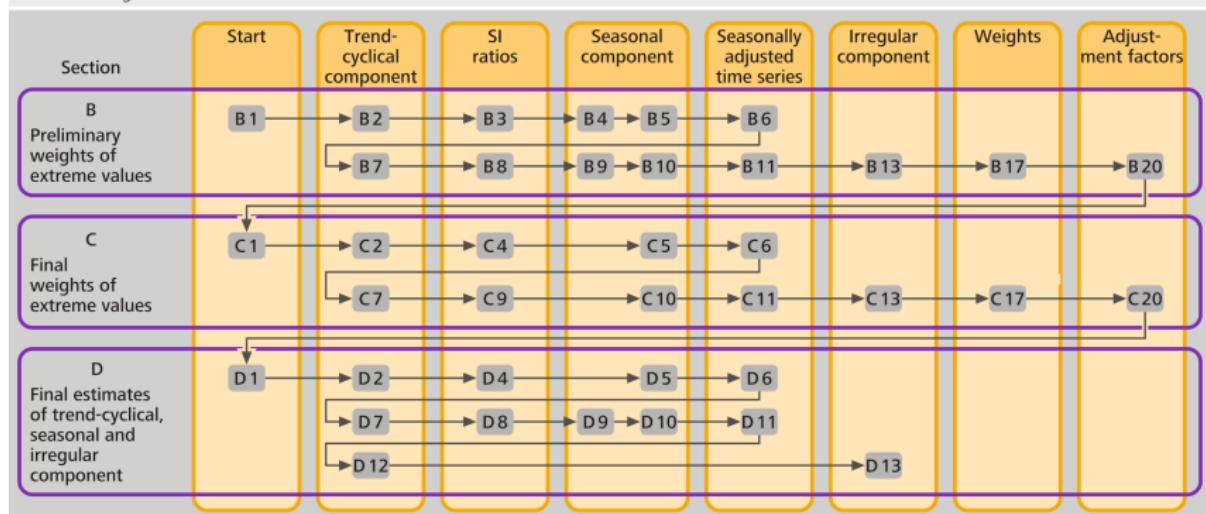
| Composite time series

| Summary

# Strategy (I/II)

## Basic principle of the X-11 seasonal adjustment algorithm in JDemetra+\*

Workflow diagram



\* In X-13 terminology, Section A is solely devoted to the treatment of outliers and calendar effects within a regARIMA modelling framework which is done prior to the application of the X-11 core.

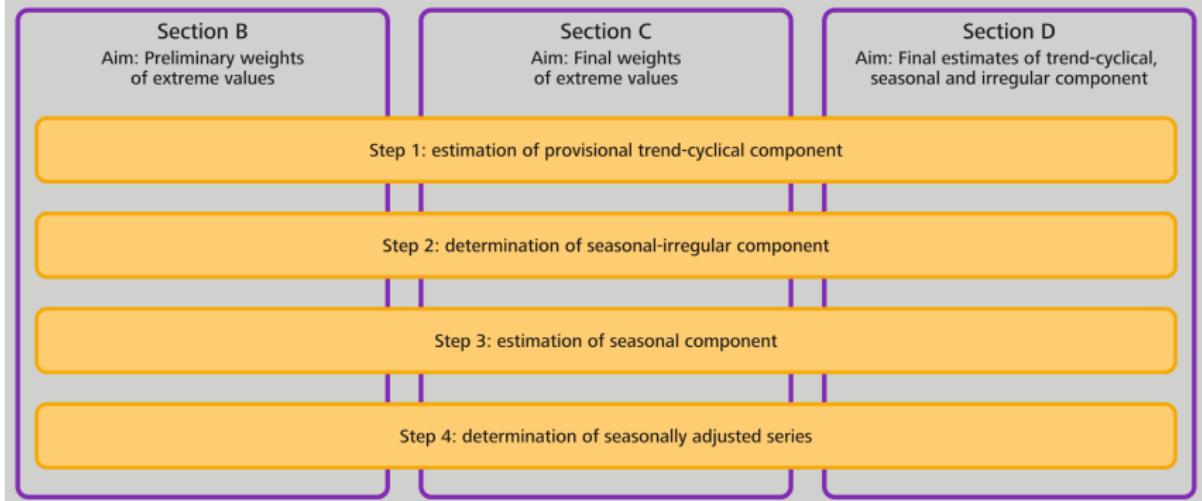
Deutsche Bundesbank

S3PR0037D.Chart

# Strategy (II/II)

## Basic principle of the X-11 seasonal adjustment algorithm\*

Workflow diagram, simplified version



\* In X-13 terminology, Section A is solely devoted to the treatment of outliers and calendar effects within a regARIMA modelling framework which is done prior to the application of the X-11 core.

## I Step 1: provisional trend-cycle (I/II)

Preliminary trend-cycle

$$\hat{t}_t = \frac{1}{24} z_{t-6} + \frac{1}{12} z_{t-5} + \cdots + \frac{1}{12} z_t + \cdots + \frac{1}{12} z_{t+5} + \frac{1}{24} z_{t+6}$$

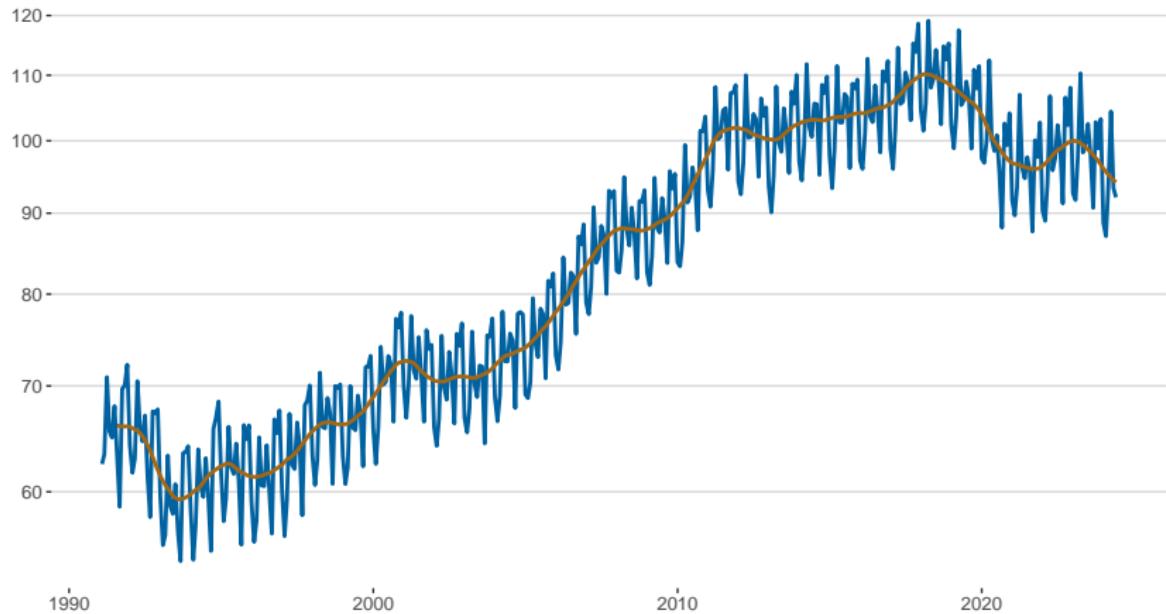
Interpretation

- Linearised data → Smoothed by centred moving average (MA) over 13 months

Boundary issue

- MA application → 6 missing values (at either end)

## I Step 1: provisional trend-cycle (II/II)



**Modified industrial production (D 1) & preliminary trend-cycle (D 2)**

## | Step 2: seasonal-irregular component

Preliminary seasonal-irregular (SI)

$$(\hat{si})_t = \frac{z_t}{\hat{t}_t}$$

Interpretation

- Linearised data → Removal of preliminary trend-cycle

## I Step 3: seasonal component (I/III)

Preliminary **seasonal**

$$\hat{s}_t = \frac{1}{9} (\hat{si})_{t-24} + \frac{2}{9} (\hat{si})_{t-12} + \frac{3}{9} (\hat{si})_t + \frac{2}{9} (\hat{si})_{t+12} + \frac{1}{9} (\hat{si})_{t+24}$$

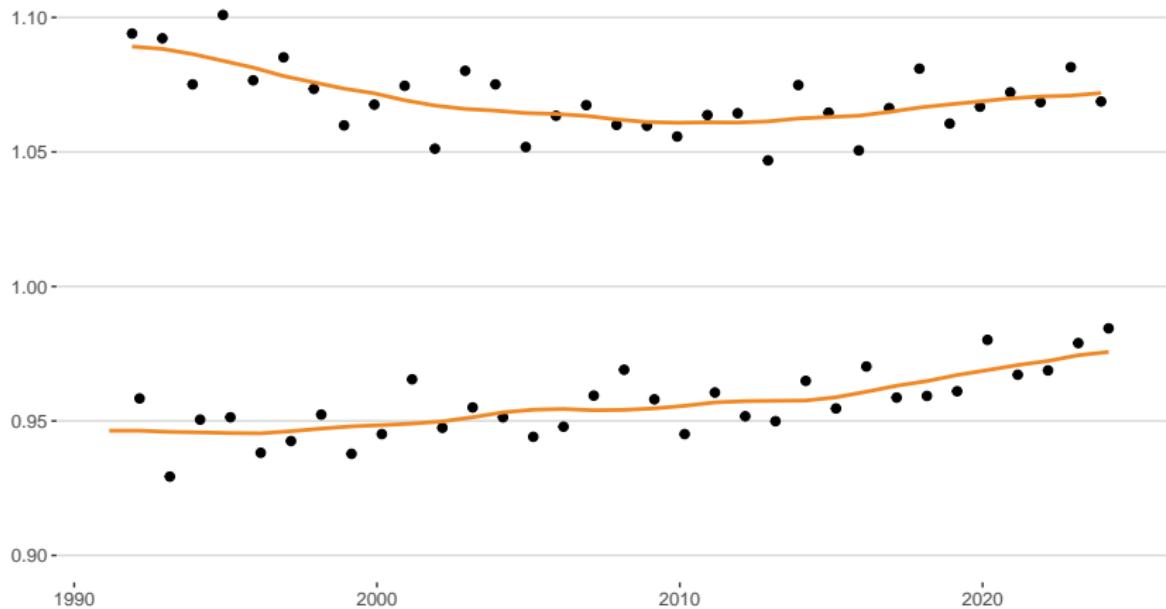
Interpretation

- Preliminary **SI ratios** → Smoothed by  $3 \times 3$  seasonal filter within each month
- Normalisation → Centred MA over 13 months

Boundary issue

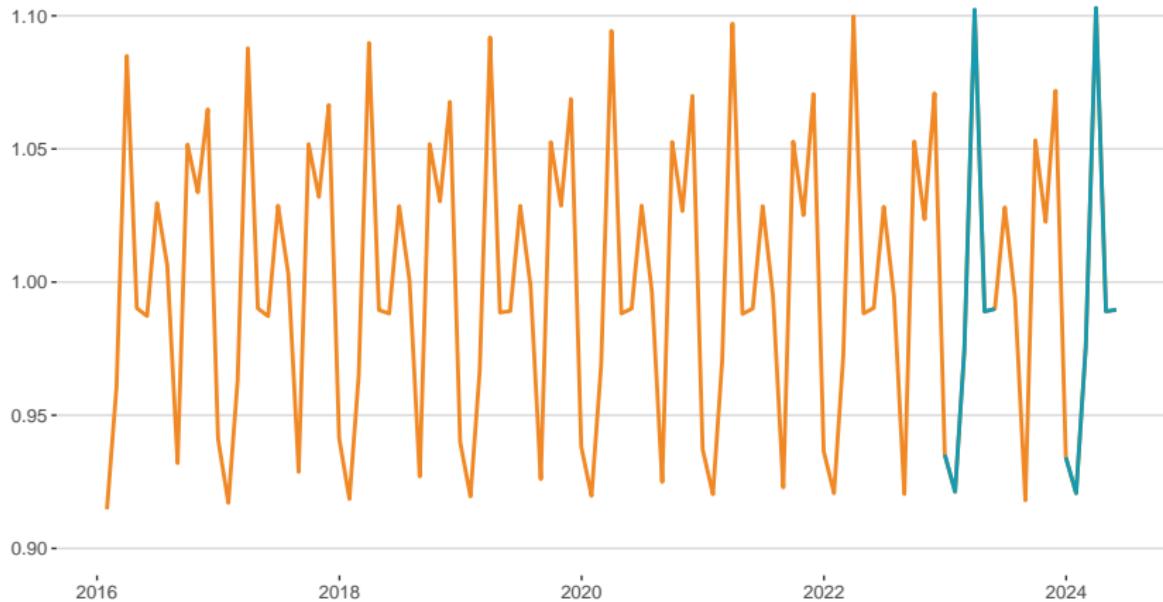
- Missing values → Imputation (copy-paste in case of no regARIMA forecasts)

## I Step 3: seasonal component (II/III)



**Preliminary SI ratios** (D 4) & normalised **preliminary seasonal** (D 5) for industrial production in **February** (bottom) & **November** (top)

## I Step 3: seasonal component (III/III)



Normalised **preliminary seasonal** (D 5) for industrial production with **imputed values** (*final six values*)

## I Step 4: seasonally adjusted series (I/II)

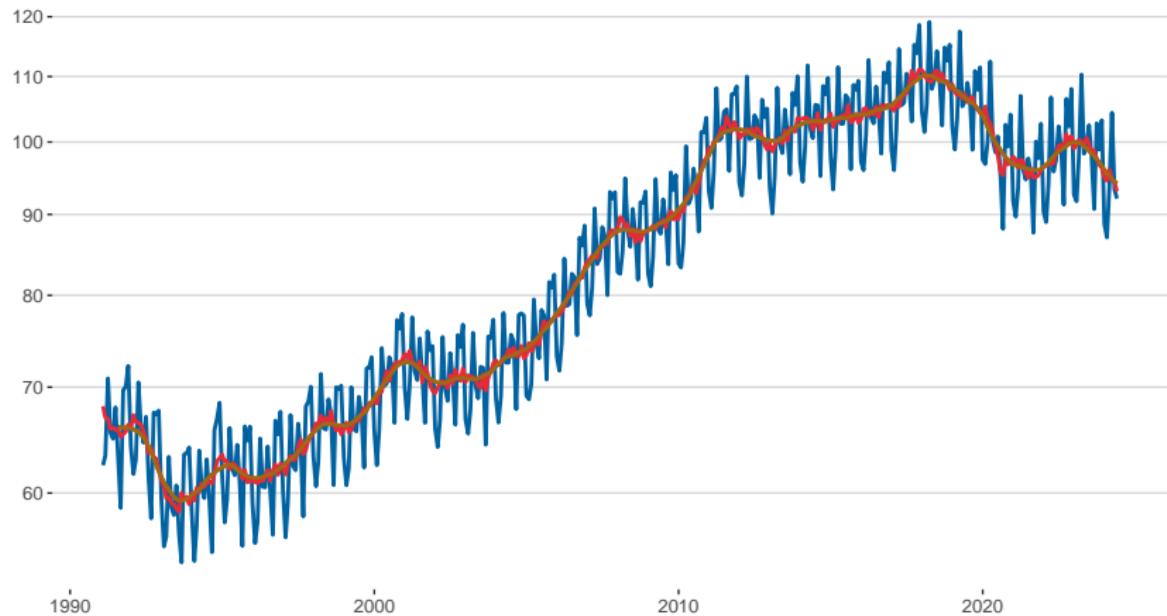
Preliminary *seasonally adjusted* data

$$\hat{z}_t^{(sa)} = \frac{z_t}{\hat{s}_t}$$

Interpretation

- Linearised data → Removal of normalised preliminary *seasonal*

## Step 4: seasonally adjusted series (II/II)



Modified industrial production (D 1), preliminary trend-cycle (D 2) & preliminary seasonally adjusted figures (D 6)

| Motivation

| Introduction to JD+

| RegARIMA pretreatment

- Regression equation
- TransReg plug-in
- ARIMA equation

| X-11 approach

- Basic principle
- Further issues

| ARIMA model-based approach

| Quality assessment

| Revision policies

| Composite time series

| Summary

## Next loop

Final UC estimates

- Preliminary estimates → Refinement

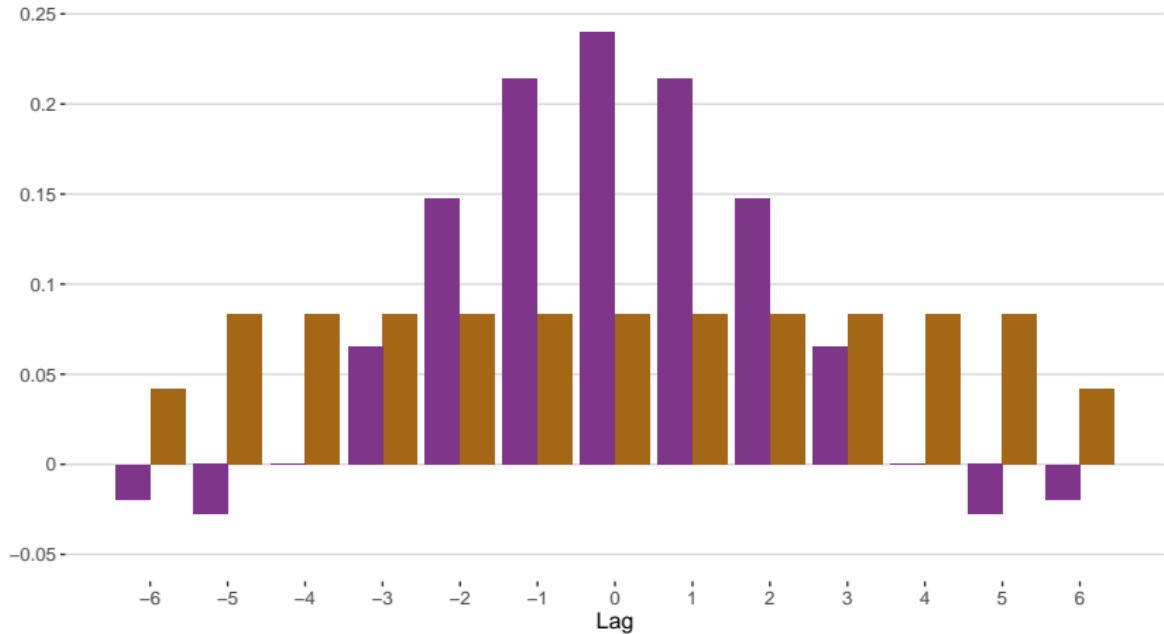
User customisation

- Options → Extended
- Trend-cycle filters → Henderson types
- Seasonal filters → Period-specific
- Extreme SI ratios → Down-weighting, replacement

Boundary issue

- Symmetric Henderson & seasonal filters → Asymmetric non-centred variants

## Henderson filters (I/III)



**Weights of X-11 trend-cycle filters (symmetric 13-term filters): Henderson & centred MA**

## Henderson filters (II/III)

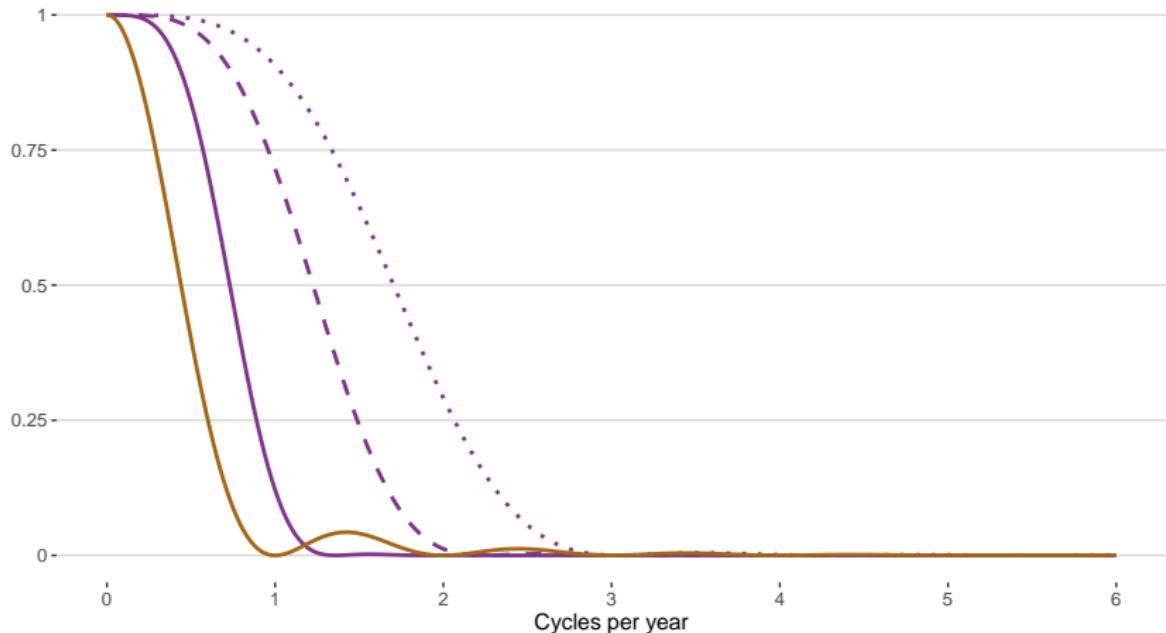
"Noise level"	Automatic selection rule		
	Low	Medium	High
I/C*	[0, 1)	[1, 3.5)	[3.5, $\infty$ )
Monthly data	9-term	13-term	23-term
Quarterly data	5-term	5-term	7-term

\* I/C is the ratio between the average absolute period-on-period changes of a temporary irregular and a temporary trend-cyclical component.

### Interpretation

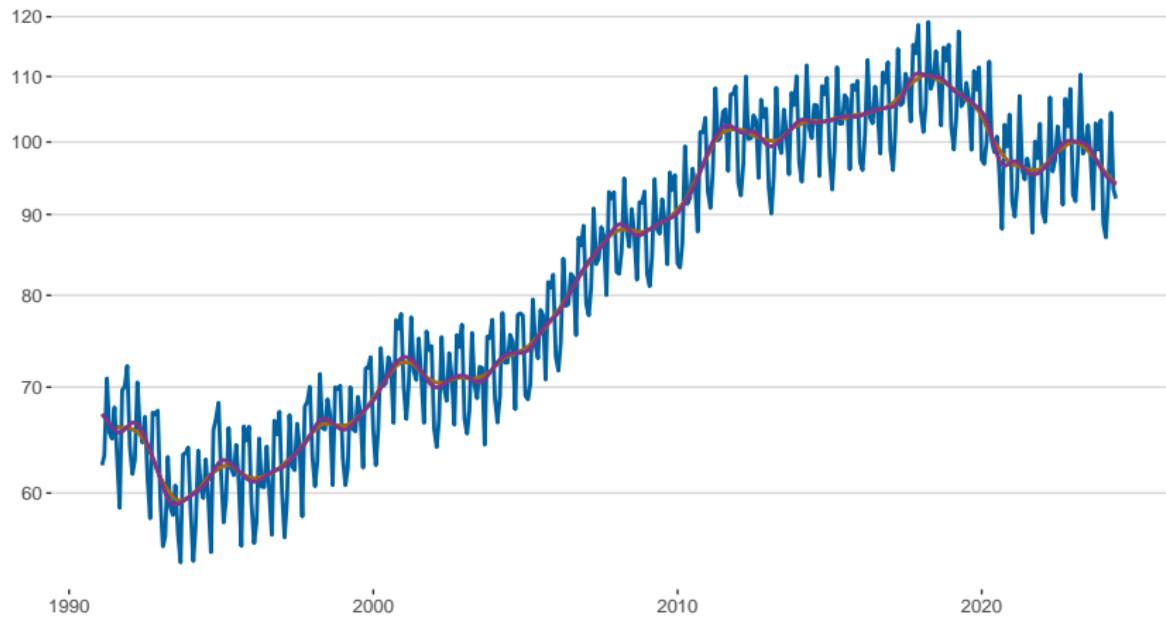
- I/C large  $\rightarrow$  Dominance of irregular (i.e. long filter)
- I/C small  $\rightarrow$  Dominance of trend-cycle (i.e. short filter)

## Henderson filters (III/III)



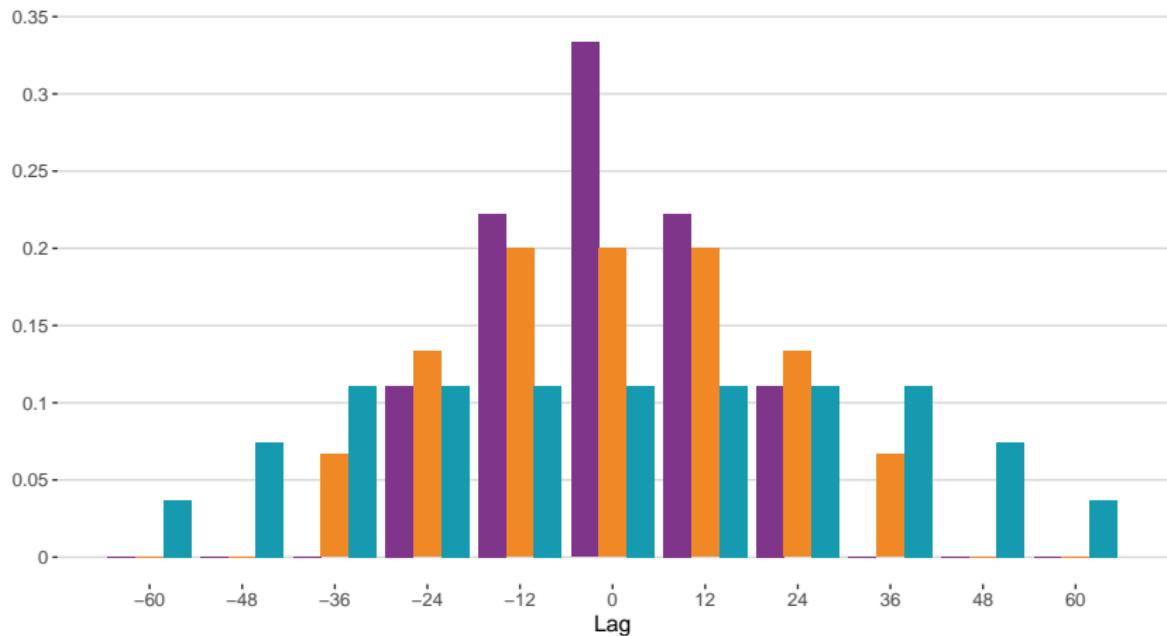
Squared gains of symmetric X-11 trend-cycle filters: **9-term** (dotted),  
**13-term** (dashed) & **23-term** (solid) **Henderson** & centred 12-term MA

## ■ Refined preliminary trend-cycle



**Modified industrial production (D 1), preliminary trend-cycle (D 2) & refined preliminary trend-cycle (D 7)**

## I Seasonal filters (I/VI)



Weights of symmetric X-11 seasonal filters:  $3 \times 3$ ,  $3 \times 5$  &  $3 \times 9$

## I Seasonal filters (II/VI)

Seasonal estimate ( $3 \times k$  filter)

$$\hat{s}_t = \frac{1}{3} \left[ (\tilde{si})_{t-12}^{(n)} + (\tilde{si})_t^{(n)} + (\tilde{si})_{t+12}^{(n)} \right], \quad n = (k-1)/2$$

Tentative averages (SI ratios)

$$(\tilde{si})_t^{(n)} = \frac{1}{2n+1} \sum_{j=-n}^n (\hat{si})_{t+12j}$$

## I Seasonal filters (III/VI)

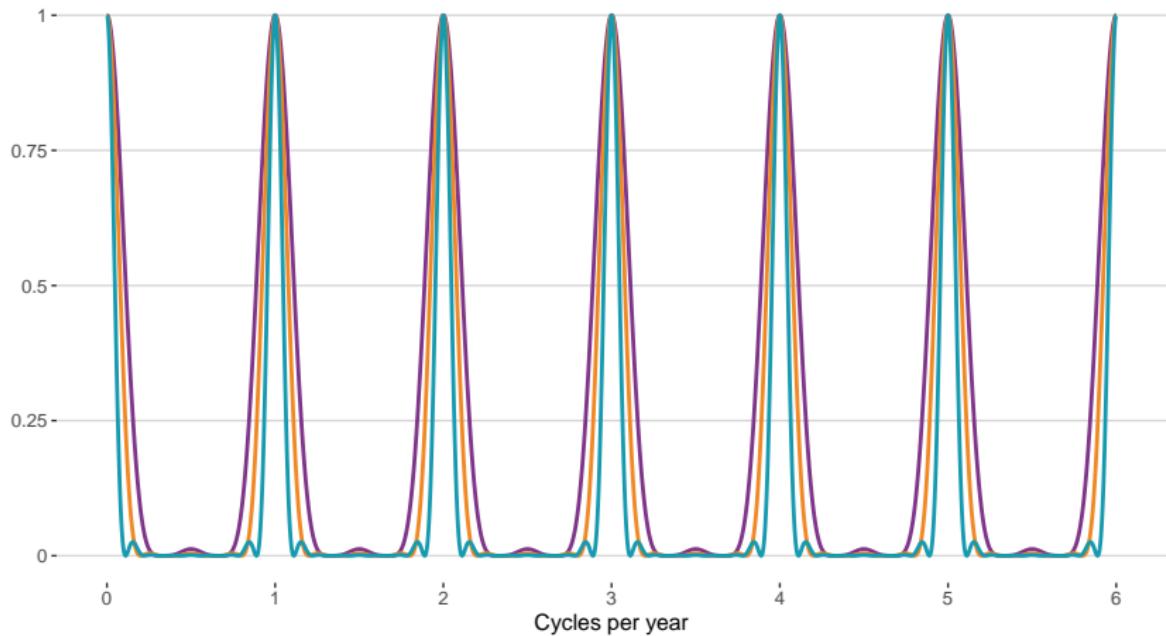
"Noise level"	Automatic selection rule				
	Low		Medium		High
I/S*	[0, 2.5)	[2.5, 3.5]	(3.5, 5.5)	[5.5, 6.5]	(6.5, $\infty$ )
Monthly data	$3 \times 3$	⌚	$3 \times 5$	⌚	$3 \times 9$
Quarterly data	$3 \times 3$	⌚	$3 \times 5$	⌚	$3 \times 9$

\* I/S is the ratio between the average absolute year-on-year changes of a temporary irregular and a temporary seasonal component. ⌚ Maximum of five I/S recalculations under omission of the respective last year, application of the  $3 \times 5$  seasonal filter if still no decision is found.

### Interpretation

- I/S large → Dominance of irregular (i.e. long filter)
- I/S small → Dominance of seasonal (i.e. short filter)

## I Seasonal filters (IV/VI)



Squared gains of symmetric X-11 seasonal filters:  $3 \times 3$ ,  $3 \times 5$  &  $3 \times 9$

## I Seasonal filters (V/VI)

### Seasonal factors (D 10) vs. SI ratios (D 8)

- Long-term evolution → Reflection
- Current end → Typical behaviour

### Airline model

- Parameter estimates → Guidance
- Details → ARIMA equation

### Additional information

- Data → Length
- Seasonality → Weak degree, changes (e.g. structural breaks)

## I Seasonal filters (VI/VI)

Option	Seasonal filter for X-11 table					
	B 5	B 10	C 5	C 10	D 5	D 10
X11Default	$3 \times 3$	$3 \times 5$	$3 \times 3$	$3 \times 5$	$3 \times 3$	$3 \times 5$
MSR	$3 \times 3$	$3 \times 5$	$3 \times 3$	$3 \times 5$	$3 \times 3$	I/S
Stable*	$\overline{(si)}_j$	$\overline{(si)}_j$	$\overline{(si)}_j$	$\overline{(si)}_j$	$\overline{(si)}_j$	$\overline{(si)}_j$
S3xk	$3 \times k$	$3 \times k$	$3 \times k$	$3 \times k$	$3 \times k$	$3 \times k$

\*  $\overline{(si)}_j$  means that the seasonal component is estimated by the period-specific averages of the (extreme-value corrected) SI ratios stored in the preceding X-11 table.

# I General problems

## Symmetric filters

- Finite input → Boundary issue
- Remedy → Asymmetric non-centred variants (Henderson & seasonal filters)

## Linear filters

- Extreme input → High sensitivity
- Remedy → Down-weighting, replacement (SI ratios)

## I Extreme SI ratios (I/V)

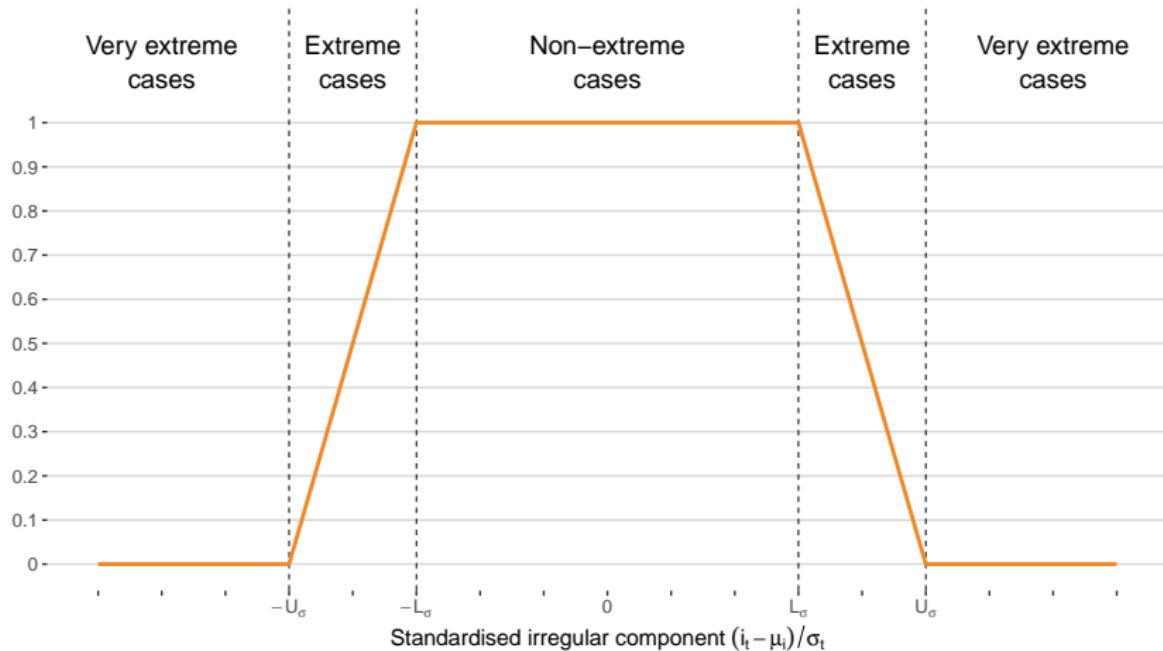
### Identification

- Irregular → Large deviation from expectation  $\mathbb{E}(i_t) = \mu_i$ 
  - Additive decomposition →  $\mu_i = 0$
  - Multiplicative decomposition →  $\mu_i = 1$
- Benchmark → Moving standard deviation ( $\sigma_t$ )
- Tolerances → Lower & upper  $\sigma$ -limits ( $L_\sigma, U_\sigma$ )

### Replacement value (D 9)

- Weighted average → Extreme SI ratio & four non-extreme close SI ratios (same period)
  - Extreme SI ratio → Weight  $\in [0, 1]$  (C 17)
  - Non-extreme SI ratios → Weight = 1

## Extreme SI ratios (II/V)



Weighting function for X-11 extreme value detection with  $\sigma$ -limit identifiers (dashed verticals)

## I Extreme SI ratios (III/V)

Non-extreme cases

$$\hat{i}_t \in [\mu_i - L_\sigma \sigma_t, \mu_i + L_\sigma \sigma_t]$$

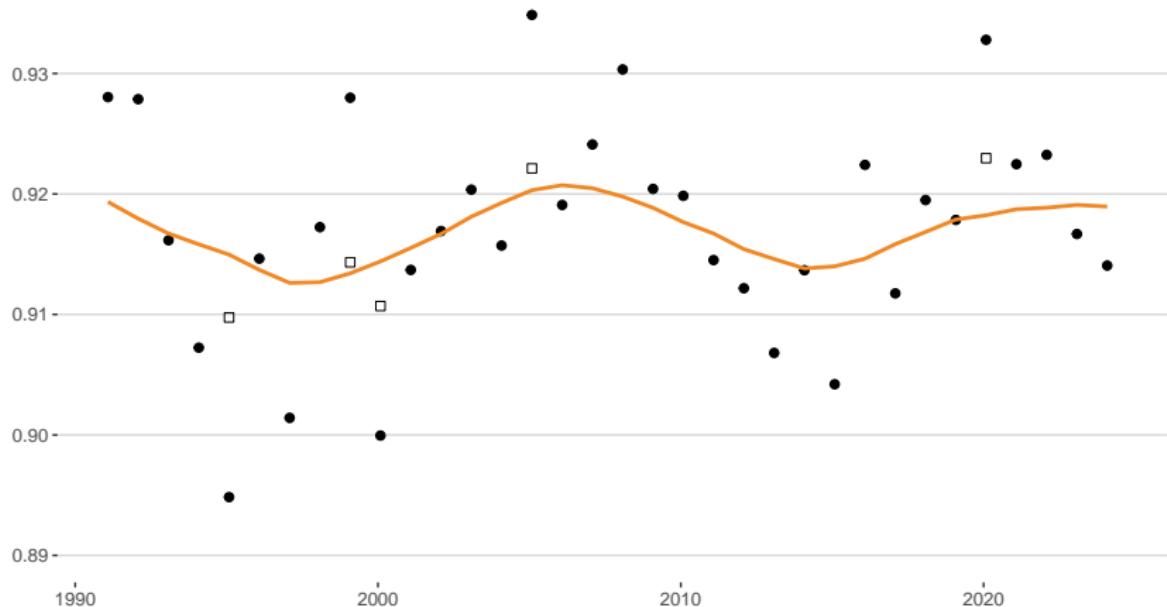
Extreme cases

$$\hat{i}_t \in (\mu_i - U_\sigma \sigma_t, \mu_i - L_\sigma \sigma_t) \cup (\mu_i + L_\sigma \sigma_t, \mu_i + U_\sigma \sigma_t)$$

Very extreme cases

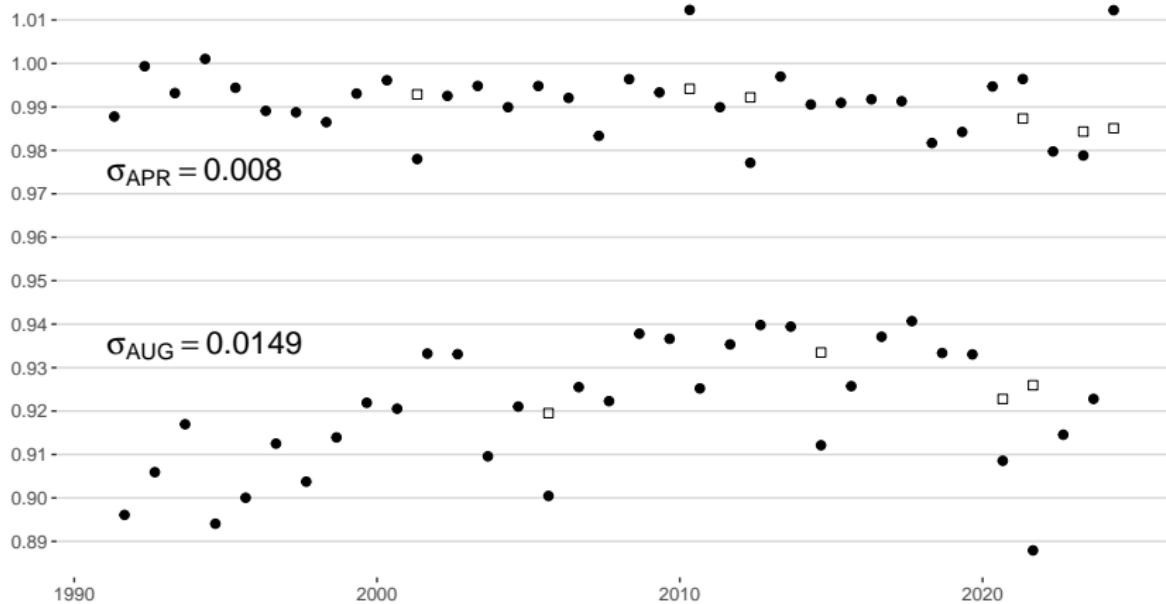
$$\hat{i}_t \notin (\mu_i - U_\sigma \sigma_t, \mu_i + U_\sigma \sigma_t)$$

## Extreme SI ratios (IV/V)



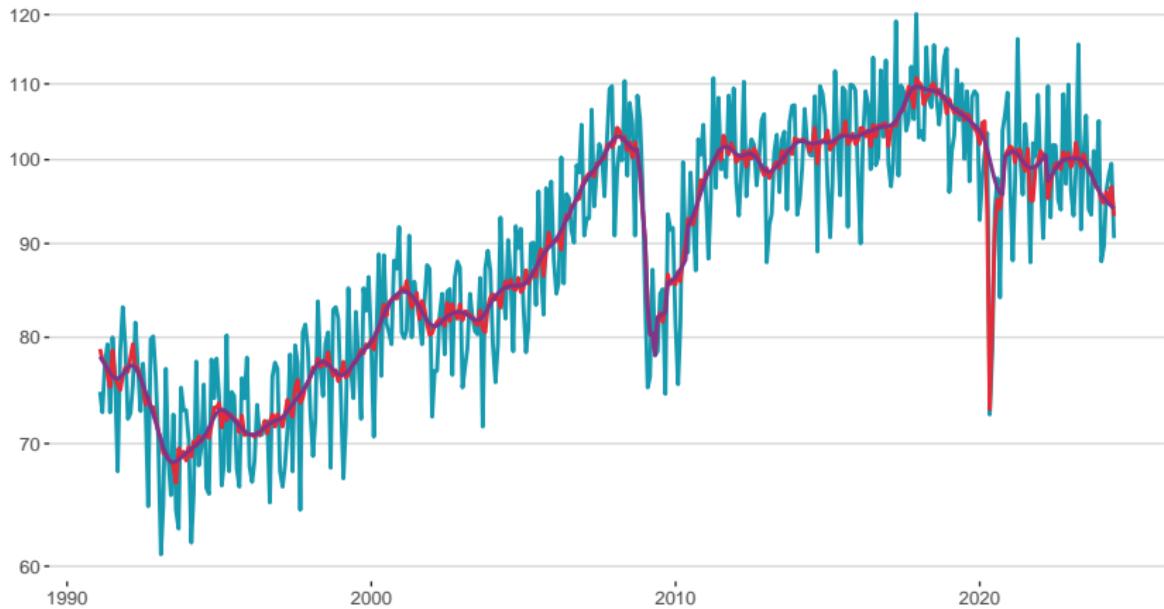
**Final SI ratios (D 8, dots), replacement values (D 9, squares) & final seasonal component (D 10) for industrial production in January**

## Extreme SI ratios (V/V)



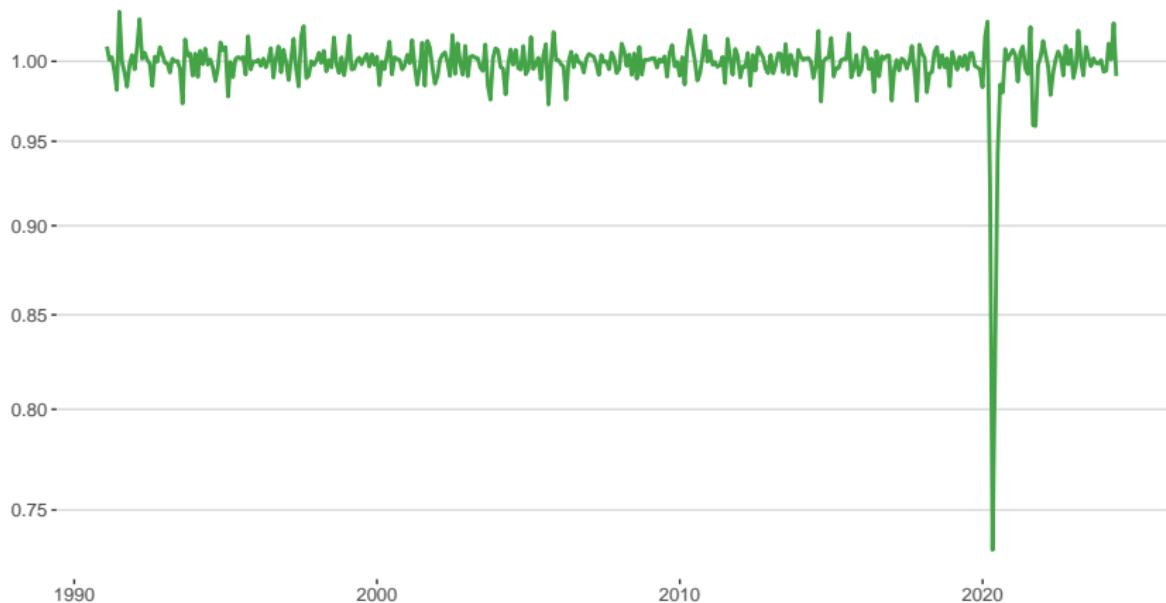
**Final SI ratios (D 8, dots) & replacement values (D 9, squares) for industrial production in April (top) & August (bottom)**

## Final estimates (I/II)



Industrial production (volume, 2021 = 100), final seasonally adjusted figures (D 11) & final trend-cycle (D 12)

## I Final estimates (II/II)



**Final irregular component** (D 13) for industrial production

# I Key messages

## X-11 approach

- ☞ Predefined trend-cycle & seasonal filters → Sequential application
- ☞ Basic 4-step principle → Trend-cycle estimation, detrending, seasonal estimation, seasonal adjustment

## Filter selection

- ☞ General idea → Volatility ratios
  - Dominant irregular → Longer filter
  - Dominant trend-cycle/seasonal → Shorter filter
- ☞ Automatic rules → I/C & I/S ratios

## X-11 extreme values

- ☞ Aberrant irregular values → Down-weighting & replacement
- ☞ Identification → Benchmark volatility & tolerance multipliers

# References (I/III)

General aspects & overviews

- ¶ D F Findley, B C Monsell, W R Bell, M C Otto & B-C Chen (1998), [New Capabilities and Methods of the X-12-ARIMA Seasonal-Adjustment Program](#), Journal of Business & Economic Statistics 16 (2), 127–152.
- ¶ D Ladiray & B Quenneville (2001), Seasonal Adjustment with the X-11 Method, Lecture Notes in Statistics Vol. 158, Springer, New York.
- ¶ J Shiskin & H Eisenpress (1957), [Seasonal Adjustments by Electronic Computer Methods](#), Journal of the American Statistical Association 52 (280), 415–449.
- ¶ J Shiskin, A H Young & J C Musgrave (1967), [The X-11 Variant of the Census Method II Seasonal Adjustment Program](#), Technical Paper No. 15, US Department of Commerce, Bureau of the Census, Washington, DC.

## References (II/III)

Properties of X-11 filters & UC estimates

- ¶ E B Dagum (1983), [Spectral Properties of the Concurrent and Forecasting Seasonal Linear Filters of the X-11-ARIMA Method](#), Canadian Journal of Statistics 11 (1), 73–90.
- ¶ E B Dagum, N Chhab & K Chiu (1996), [Derivation and Properties of the X11ARIMA and Census X11 Linear Filters](#), Journal of Official Statistics 12 (4), 329–347.
- ¶ E B Dagum, N Chhab & B Solomon (1991), [The Autocorrelation of Residuals from the X11ARIMA Method](#), Journal of Official Statistics 7 (2), 181–194.
- ¶ M Doherty (2001), [The Surrogate Henderson Filters in X-11](#), Australian & New Zealand Journal of Statistics 43 (4), 385–392.

# References (III/III)

Deutsche Bundesbank

-  Deutsche Bundesbank (1970), Seasonal adjustment by the Census Method, Monthly Report 22 (3), 37–41.
-  Deutsche Bundesbank (1991), Data, adjusted for seasonal and working-day variations, on the expenditure components of GNP, Monthly Report 43 (4), 35–40.
-  Deutsche Bundesbank (1999), The changeover from the seasonal adjustment method Census X-11 to Census X-12-ARIMA, Monthly Report 51 (9), 39–50.
-  Deutsche Bundesbank (2018), Gradual changeover to JDemetra+ software for seasonal adjustment of the official statistics, Monthly Report 70 (5), 50.

| Motivation

| Introduction to JD+

| RegARIMA pretreatment

- Regression equation
- TransReg plug-in
- ARIMA equation

| X-11 approach

- Basic principle
- Further issues

| ARIMA model-based approach

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| Composite time series

| Summary

# Reminder: UC model after linearisation

Pretreated

$$\begin{array}{lcl} \text{data} & = & \text{Trend-cycle} + \text{Seasonal} + \text{Irregular} \\ \downarrow & & \downarrow & & \downarrow \\ z_t & = & t_t + s_t + i_t \\ & & \downarrow & & \downarrow \\ & & \text{Long-term} & \text{Recurring intra-} & \text{Remaining} \\ & & \text{growth path} & \text{year movements} & \text{movements} \\ & & \searrow & & \swarrow \\ & & & \text{Seasonally adjusted (SA) data} & \end{array}$$

## Additional decomposition (optional)

- Irregular → Transitory & white noise
- Transitory → Stationary short-term movements

# Bottom-up principle

Pretreated  
data

$$\text{ARIMA} = \text{ARIMA} + \text{ARIMA} + \text{ARIMA}$$

↑                      ↑                      ↑  
Stochastic extensions

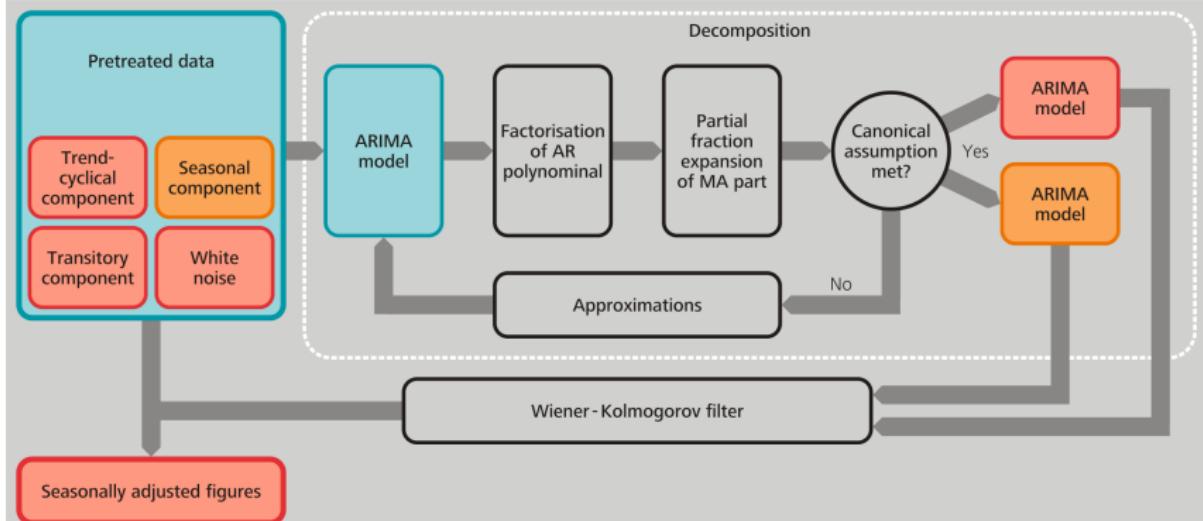
↑                      ↑                      ↑  
Main deterministic characteristics

↑                      ↑                      ↑  
Trend-cycle            Seasonal            Irregular

# Top-down estimation

## Basic principle of the SEATS seasonal adjustment algorithm

Workflow diagram



Deutsche Bundesbank

S3PR0086A.Chart

# I Assumptions

## Component models

- Linearity → ARIMA models
- Separability → No common AR roots
- Invertibility (of aggregate model) → No common MA unit roots
- Identifiability → Contemporaneously uncorrelated innovations & ARI orders  $\geq$  MA orders
  - Burman (1980) → Balanced & “bottom-heavy” models

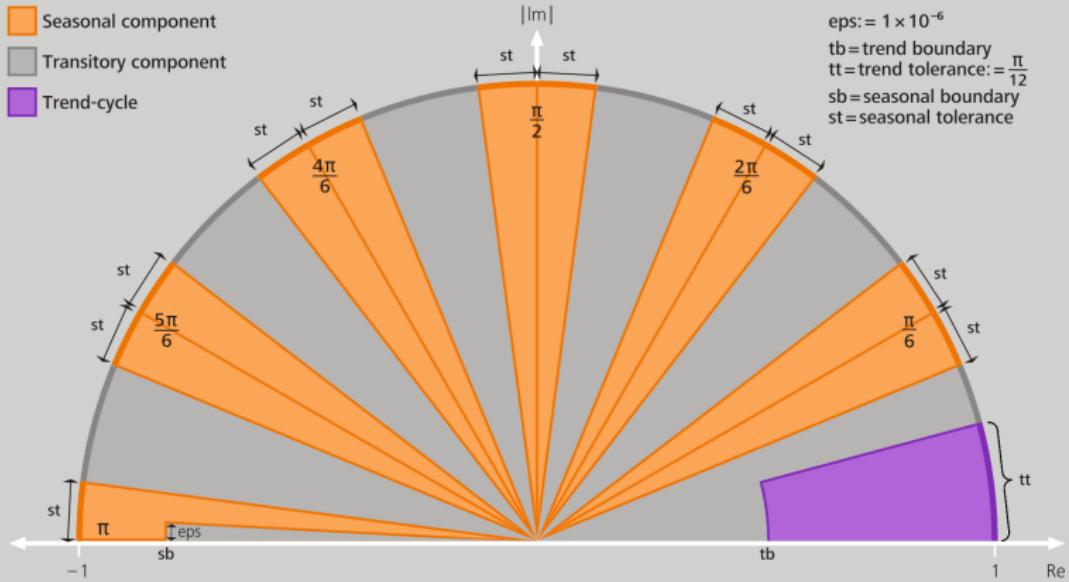
## Admissible decompositions

- Uniqueness → Canonical components

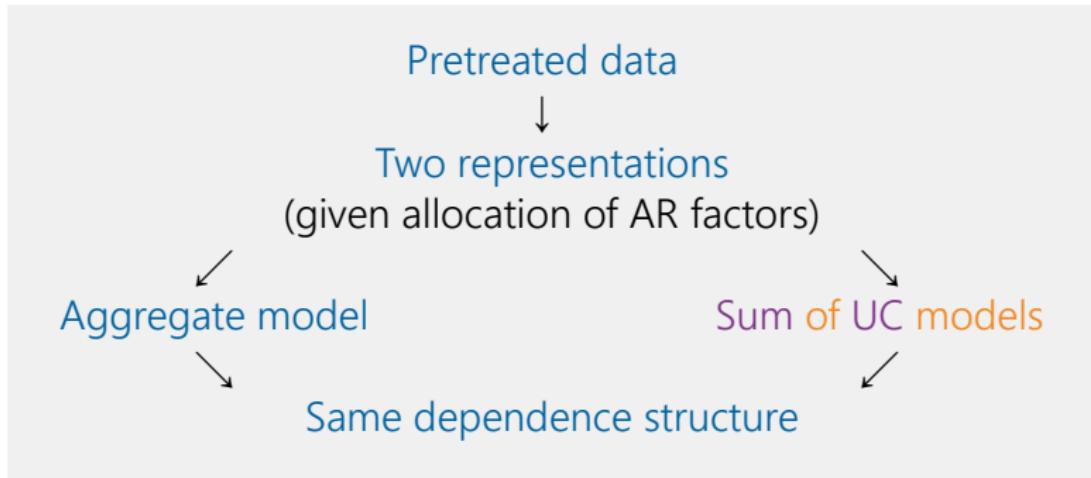
# I Factorisation of AR polynomial

## Assignment of AR factors in JDemetra+

Monthly time series, in radians



## ■ Partial fraction expansion of MA part



### Identifiable solution

- Autocovariances → Linear equation system

# Canonical assumption (I/II)

## Admissible decompositions

- UC spectra → Non-negative
- Number → Infinite

## Core issue

- White noise → Allocation amongst UCs

## Uniqueness

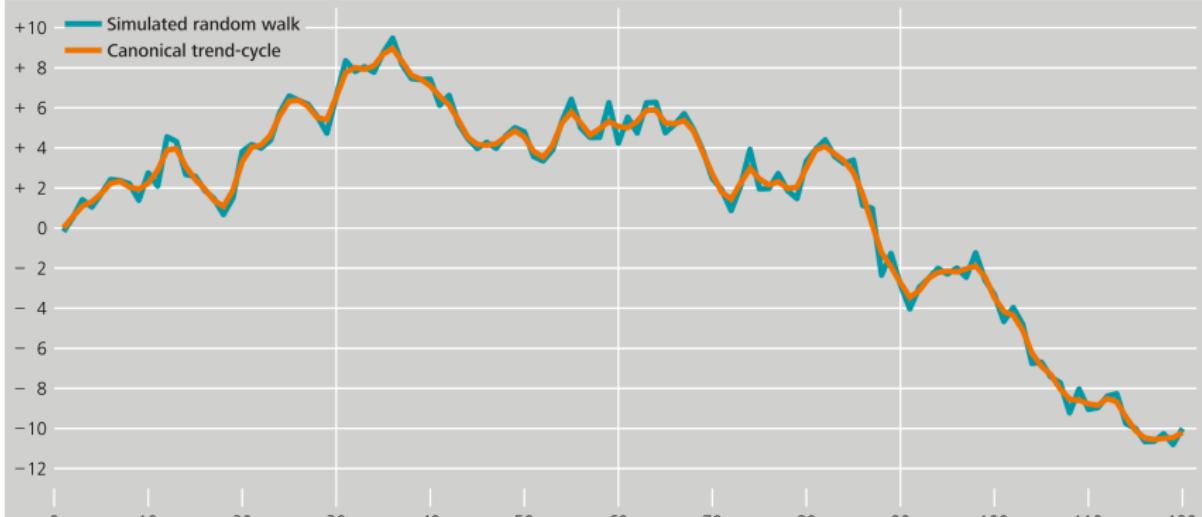
- Trend-cycle, seasonal, transitory → Maximum smoothness (i.e. absence of extractable additive white noise)

## Consequences

- UC spectra → Zeros
- UC innovations → Variance minimisation
- White noise → Variance maximisation

# Canonical assumption (II/II)

Canonical decomposition of a random walk with unit variance



Deutsche Bundesbank

S3PR0188.Chart

# I Overcoming inadmissibility

## Direct parameter replacement

- ARMA parameters → Heuristic replacement
- ARIMA orders → No changes

## Model order changes

- ARIMA orders → Heuristic changes

## Variance inflation

- ARIMA model → Additional artificial white noise

# Optimal filtering

## Optimal estimator (seasonal)

$$\hat{s}_{t|T} = \mathbb{E}(\textcolor{brown}{s}_t | \mathbf{z}_T)$$

- $\mathbf{z}_T = (\textcolor{brown}{z}_1, \dots, \textcolor{brown}{z}_T)^\top \rightarrow$  Finite sequence

### Conditional expectation

- Estimator  $\rightarrow$  Linear projection
- Optimality  $\rightarrow$  MSE sense
- Computation  $\rightarrow$  Kalman or Wiener-Kolmogorov filter

### Wiener-Kolmogorov filter

- General solution  $\rightarrow$  Infinite & stationary observations
- AMB extension  $\rightarrow$  Finite & non-stationary observations
  - ARIMA polynomials (UC models)  $\rightarrow$  Appropriate combination

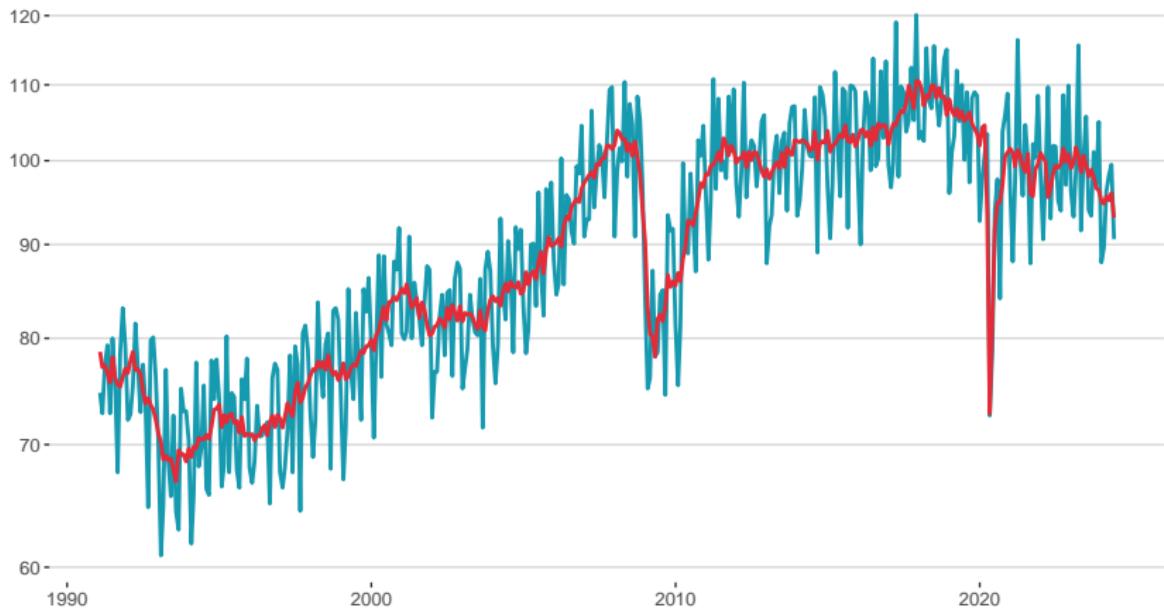
# Implementation

## AMB parameters

JD+ version 2.2.2

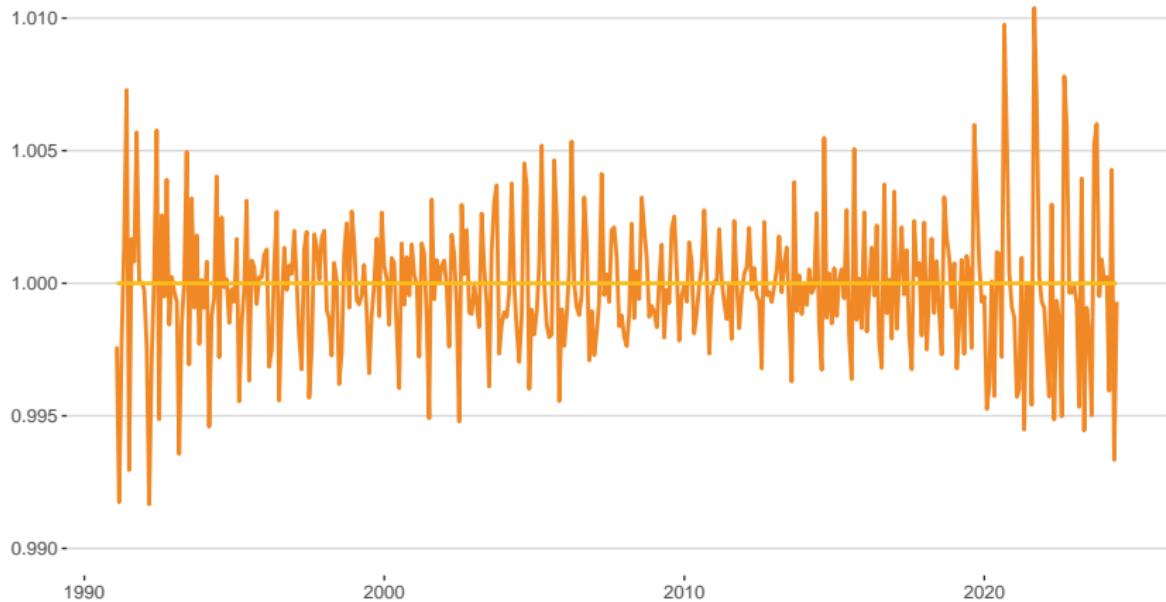
Name	Parameter	Range (default)
Approximation mode	Modification type for inadmissible models	None, Legacy, Noisy
MA unit root boundary	Modulus threshold for resetting MA "near-unit" roots	[0.9, 1] (0.95)
Trend boundary	Modulus threshold for assigning positive real AR roots	[0, 1] (0.5)
Seasonal tolerance	Degree threshold for assigning complex AR roots	[0, 10] (2)
Seasonal boundary	Modulus threshold for assigning negative real AR roots	[0, 1] (0.8)
Seas. boundary (unique)	Same modulus threshold for unique seasonal AR roots	[0, 1] (0.8)
Method	Estimation algorithm	Burman, Kalman, McElroy

# Final estimates



Industrial production (volume, 2021 = 100) & final seasonally adjusted figures (default specification)

# Comparison with X-11



Ratios between X-11 & AMB estimates for **calendar component** & **seasonal component**

# I Inference

## Model adequacy

- UCs & UC estimators → Different stochastic properties
- Meaningful comparison → Auto- & cross-covariances
  - UC estimators → Theoretical benchmark
  - UC estimates → Empirical counterpart

## Error analysis

- Total estimation error → Independent stationary ARMA components
  - Final ("historical") estimator → Estimation error
  - Preliminary estimator → Revision error
- Revision error diagnostics → Phase delay, speed of convergence, variance

# Key messages

## AMB approach

- ☞ Data model → Canonical decomposition into UC models
- ☞ UC estimators → MSE optimality
- ☞ Model adequacy → UC estimators versus estimates

## Advantages

- ☞ Data adaptability → Mass production
- ☞ UC estimates & forecasts → Standard errors
- ☞ Inference → Error analysis, model adequacy

# References (I/III)

General aspects & overviews

-  D F Findley, D P Lytras & A Maravall (2016), [Illuminating ARIMA model-based seasonal adjustment with three fundamental seasonal models](#), SERIEs 7 (1), 11–52.
-  A Maravall & D Pérez (2012), Applying and Interpreting Model-Based Seasonal Adjustment—The Euro-Area Industrial Production Series, in: W R Bell, S H Holan & T S McElroy (eds), Economic Time Series – Modeling and Seasonality, CRC Press, Boca Raton, 281–313.
-  A Maravall & D A Pierce (1987), [A Prototypical Seasonal Adjustment Model](#), Journal of Time Series Analysis 8 (2), 177–193.
-  G Mélard (2016), [On some remarks about SEATS signal extraction](#), SERIEs 7 (1), 53–98.

## References (II/III)

Theoretical foundation

- ¶ W R Bell & S C Hillmer (1984), [Issues Involved With the Seasonal Adjustment of Economic Time Series](#), Journal of Business & Economic Statistics 2 (4), 291–320.
- ¶ J P Burman (1980), [Seasonal Adjustment by Signal Extraction](#), Journal of the Royal Statistical Society A 143 (3), 321–337.
- ¶ D M Grether & M Nerlove (1970), [Some Properties of "Optimal" Seasonal Adjustment](#), Econometrica 38 (5), 682–703.
- ¶ A Maravall (1988), [A Note on Minimum Mean Squared Error Estimation of Signals with Unit Roots](#), Journal of Economic Dynamics & Control 12 (2–3), 589–593.

## References (III/III)

### Canonical components & models

- ¶ S C Hillmer & G C Tiao (1982), [An ARIMA Model-Based Approach to Seasonal Adjustment](#), Journal of the American Statistical Association 77 (377), 63–70.
- ¶ A Maravall (1987), [Minimum Mean Squared Error Estimation of the Noise in Unobserved Component Models](#), Journal of Business & Economic Statistics 5 (1), 115–120.
- ¶ A Maravall (1989), [On the Dynamic Structure of a Seasonal Component](#), Journal of Economic Dynamics & Control 13 (1), 81–91.
- ¶ A Maravall (1993), [Stochastic Linear Trends – Models and Estimators](#), Journal of Econometrics 56 (1–2), 5–37.

| Motivation

| Introduction to JD+

| RegARIMA pretreatment

- Regression equation
- TransReg plug-in
- ARIMA equation

| X-11 approach

- Basic principle
- Further issues

| ARIMA model-based approach

| Quality assessment

| Revision policies

| Composite time series

| Summary

# Overview

## Questions

- Data → Need for seasonal adjustment?
- SA data → Quality of seasonal adjustment?

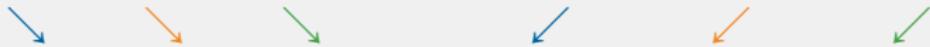
## Answers

- Dependence measures → Autocorrelations, periodogram
- Tests → Seasonality
- X-11 heuristics →  $M$ - &  $Q$ -statistics
- AMB diagnostics → UC estimators versus estimates

# Dependence measures (I/V)

Autocorrelation function (ACF)

Data<sub>t-1</sub> Data<sub>t</sub> Data<sub>t+1</sub> ... Data<sub>t+h-1</sub> Data<sub>t+h</sub> Data<sub>t+h+1</sub>



Normalised time-constant linear dependence



$$\text{ACF}(h) \in [-1, 1]$$

## Assumption

- Data → Weakly stationary

# Dependence measures (II/V)

Partial autocorrelation function (PACF)

Data<sub>t</sub>      Data<sub>t+1</sub>    ...    Data<sub>t+h-1</sub>      Data<sub>t+h</sub>



Latent dependencies



Normalised time-constant linear dependence  
corrected for latent factors



$$\text{PACF}(h) \in [-1, 1]$$

# Dependence measures (III/V)

Spectral density: basic idea

## Data

- Periodic base functions (e.g. cosine, sine) → Weighted sum
- Detection → Influential frequencies

## Interpretation

- ACF → Frequency-domain analogue
- Frequency  $\in [0, \pi]$  → Importance
- Estimator → Periodogram

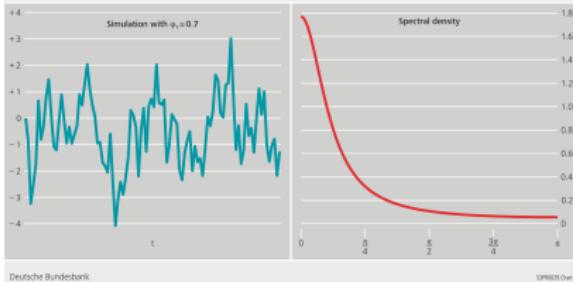
## Squared gain (of linear filter)

- Data & filtered data → Link between spectral densities
- Frequency  $\in [0, \pi]$  → Amplification, suppression
- Examples → X-11 trend & seasonal filters

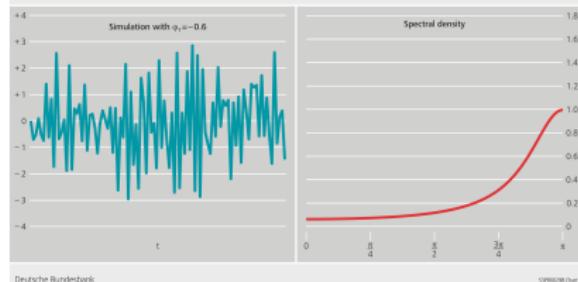
# Dependence measures (IV/V)

Periodogram: AR (1) process, unit WN variance

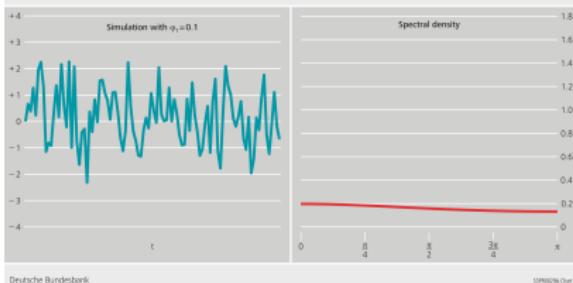
Dominance of long cycles



Dominance of short cycles



No dominance of any cycle



Cycles per year	1	2	3	4	5	6
Duration in months	12	6	4	3	2.4	2
Seasonal frequency	$\frac{\pi}{6}$	$\frac{2\pi}{6}$	$\frac{3\pi}{6}$	$\frac{4\pi}{6}$	$\frac{5\pi}{6}$	$\pi$
Duration in quarters	4	2				
Seasonal frequency	$\frac{\pi}{2}$	$\pi$				

# Dependence measures (V/V)

Initial questions: answers

## Seasonality indicator

- ACF, PACF → Peaks at “intra-year cycle” lags (especially 2, 3, 4, 6, 12)
- Periodogram → Peaks at seasonal frequencies

## Need for SA?

- Unadjusted data, transformed (modified) data, linearised data  
→ Peaks

## Quality of SA?

- Transformed SA data, irregular, regARIMA residuals → No peaks

# Seasonality tests in JD+ (I/X)

## Overview

Name	Variable checked for significance	Short
Modified <i>QS</i> -test	Autocorrelations at seasonal lags	QS
Friedman-test	ANOVA with repeated measures on intra-year ranks	FT
Kruskal-Wallis-test	ANOVA without repeated measures on overall ranks	KW
Test for spectral peaks	Tukey and AR(30) spectra at seasonal frequencies	SP
Periodogram-test	Weighted sum of periodogram at seasonal frequencies	PD
<i>F</i> -test on seasonal dummies	Effects of seasonal dummies in the "(pdq)(000) + mean + seasonal dummies" model*	SD

\* Variant 1:  $(pdq) = (011)$ , variant 2:  $(pdq)$  according to automatic model identification.

# Seasonality tests in JD+ (II/X)

## Ljung-Box-test

$$LB_H = \sum_{h=1}^H w(h) \text{ACF}^2(h), \quad \text{with } w(h) = \frac{T(T+2)}{T-h}$$

### Hypothesis

- Data → Zero autocorrelations (i.e. independence)

### Decision

- Rejection if  $LB_H$  too large

# Seasonality tests in JD+ (III/X)

Modified  $QS$ -test

$$QS = \begin{cases} w(12) \text{ACF}^2(12) + w(24) [\max\{0, \text{ACF}(24)\}]^2, & \text{ACF}(12) > 0 \\ 0, & \text{ACF}(12) \leq 0 \end{cases}$$

## Hypothesis

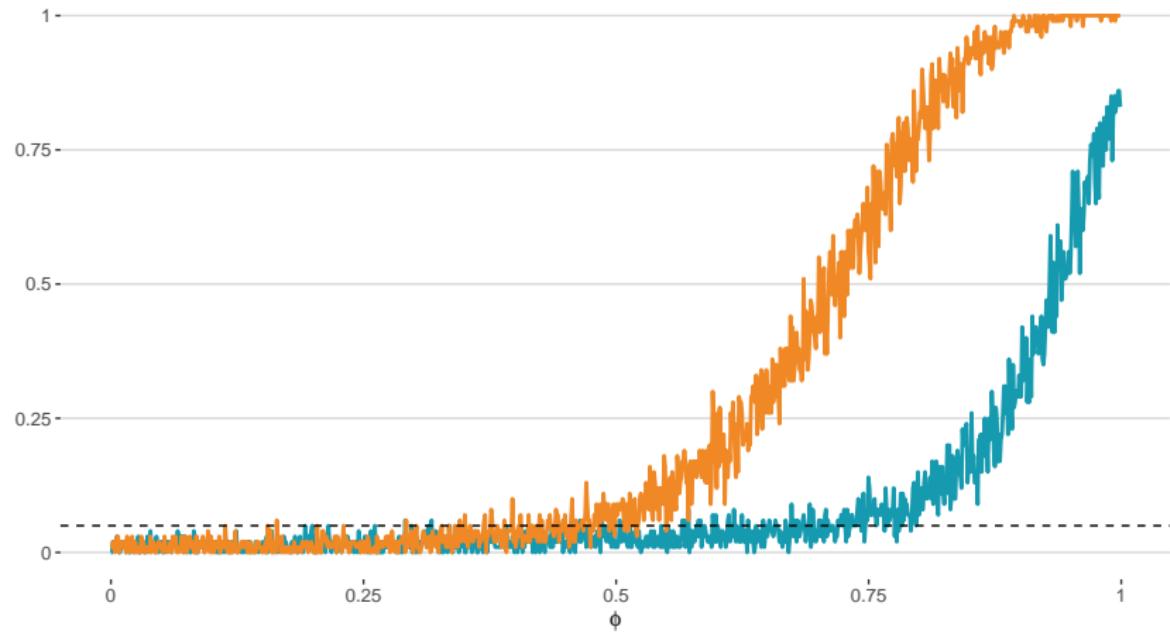
- Data → No positive autocorrelation at seasonal lags (i.e. no stable seasonality)

## Decision

- Rejection if  $QS$  too large

# Seasonality tests in JD+ (IV/X)

Modified  $QS$ -test: digression



**Empirical rejection rates for simulated non-seasonal AR(1) processes**  
with parameter  $\phi \in [0, 1]$  for  $\tau = 4$  &  $\tau = 12$  ( $T = 120, \alpha = 0.05$ )

# Seasonality tests in JD+ (V/X)

Friedman-test

$$FT = \frac{\text{Variance of month-specific mean ranks}}{\text{Variance of ranks within months}}$$

## Rank assignment

- Within each year  $\rightarrow 1 \leq \text{rank}_{ij} \leq \tau$

## Hypothesis

- Data  $\rightarrow$  Same month-specific mean ranks (i.e. no stable seasonality)

## Decision

- Rejection if  $FT$ -statistics too large

# Seasonality tests in JD+ (VI/X)

Kruskal-Wallis-test

$$KW = \frac{\text{Variance of month-specific mean ranks}}{\text{Variance of ranks within months}}$$

## Rank assignment

- Within observation period  $\rightarrow 1 \leq \text{rank}_{ij} \leq T$

## Hypothesis

- Data  $\rightarrow$  Same month-specific mean ranks (i.e. no stable seasonality)

## Decision

- Rejection if  $KW$ -statistics too large

# Seasonality tests in JD+ (VII/X)

Test for spectral peaks

## Idea

- Spectral peaks → Visual significance
- Tukey & AR(30) spectra → Combination

## Hypothesis

- Data → No visually significant seasonal peaks (i.e. no seasonality)

## Decision

- Rejection if too many visually significant seasonal peaks
- Consideration → Location of seasonal peaks

# Seasonality tests in JD+ (VIII/X)

Periodogram-test

$$PD = \text{Rescaled} \left[ 2 \sum_{j=1}^5 I(SF_j) + I(SF_6) \times \begin{cases} 1, & T \text{ even} \\ 0, & T \text{ odd} \end{cases} \right]$$

## Hypothesis

- Data → No seasonal peaks (i.e. no seasonality)

## Decision

- Rejection if  $PD$ -statistics too large

## Seasonality tests in JD+ (IX/X)

*F*-test on seasonal dummies

$SD = \text{Rescaled} \left( \hat{\beta}^\top \hat{\Sigma}_{\hat{\beta}}^{-1} \hat{\beta} \right) \text{ from model}$

$$\phi_p(B)(1 - B)^d \left( \text{Data}_t - \hat{\beta}^\top \text{Dummies}_t \right) = \mu + \theta_q(B) \varepsilon_t$$

### Hypothesis

- Data → Zero effects for seasonal dummies (i.e. no stable seasonality)

### Decision

- Rejection if  $SD$ -statistics too large

# Seasonality tests in JD+ (X/X)

## Examples

### Industrial production

Volume, 2021 = 100

Test	Linearised data		SA data	
	Statistic	p-value	Statistic	p-value
Modified QS	699.909	0	0.031	0.985
Friedman	339.923	0	5.205	0.921
Kruskal-Wallis	34.136	0	0.045	1.000
Periodogram	586.679	0	0.694	0.745
Seasonal dummies	559.518	0	0.606	0.824

### Warning

Test statistics and  $p$ -values have been obtained through the `{RJDemetra}` package and may differ from the figures displayed in the graphical user interface of JD+.

## Additional X-11 diagnostics (I/VI)

*F*-test: stable seasonality

$$F_S = \frac{\text{Variance of month-specific mean SI ratios}}{\text{Variance of SI ratios within months}}$$

### Hypothesis

- Seasonal factors → Same month-specific averages (i.e. no stable seasonality)

### Decision

- Rejection if  $F_S$  too large

## Additional X-11 diagnostics (II/VI)

*F*-test: moving seasonality

$$\left| (\hat{si})_{ij} - 100 \right| = \text{Year}_i + \text{Month}_j + \text{Residual}_{ij}$$

### Hypothesis

- SI ratios → **Absence of annual effects** (i.e. no moving seasonality,  $\text{Year}_1 = \text{Year}_2 = \dots = \text{Year}_T$ )

### Decision

- **Rejection if  $F_M$ -statistic too large**

# Additional X-11 diagnostics (III/VI)

*M*-statistics: basic idea

## Indication

- Seasonal adjustment → Quality
- Development → Statistics Canada

## Construction

- Domain → [0, 3]
- Acceptance region → [0, 1]

## Warning

- Relevance → Limited

# Additional X-11 diagnostics (IV/VI)

$M$ -statistics:  $M7$

$$M7 = \sqrt{\frac{1}{2}(T_1 + T_2)}, \quad \text{with } T_1 = \min\left\{\frac{7}{F_S}, 9\right\}, T_2 = \min\left\{\frac{3F_M}{F_S}, 9\right\}$$

## Interpretation

- “Ratio” → Stable ( $F_S$ ) & moving (evolutive) seasonality ( $F_M$ )

## Additional X-11 diagnostics (V/VI)

*Q*-statistic

$M$ -statistic <sup>1)</sup>	Weight as a percentage	$M$ -statistic <sup>1)</sup>	Weight as a percentage
$M1$	13	$M7$	16
$M2$	13	$M8$	7
$M3$	10	$M9$	7
$M4$	5	$M10$	4
$M5$	11	$M11$	4
$M6$	10		

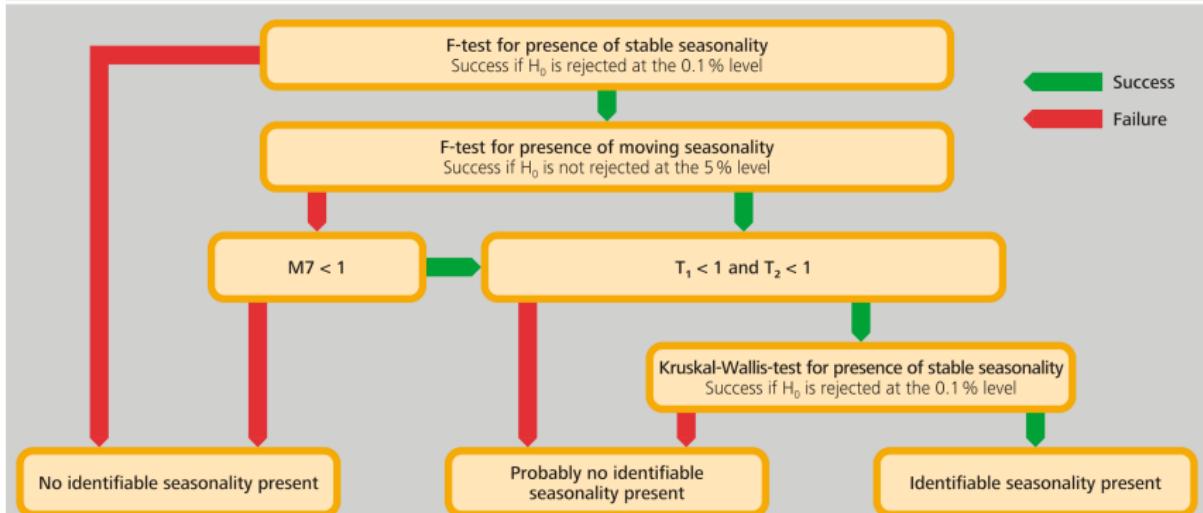
<sup>1</sup>  $M8$  to  $M11$  are not calculated for series shorter than six years and, hence, other weights apply.

# Additional X-11 diagnostics (VI/VI)

Overall test: identifiable seasonality

## Combined test for presence of identifiable seasonality

Each single null hypothesis ( $H_0$ ) states "no seasonality"



Source: Morry and Lothian (1978).

Deutsche Bundesbank

S3PR0139.Chart

# | Residual seasonality

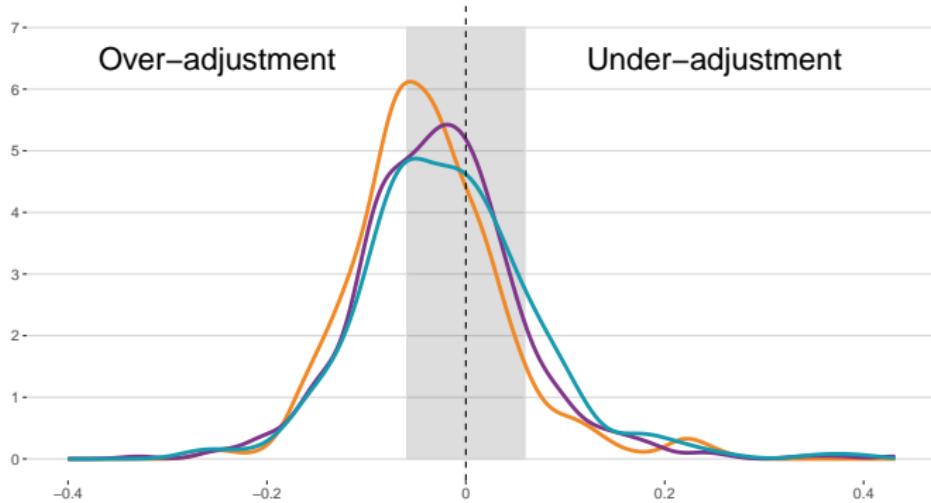
## Under-adjustment error

- Options, parameters → Inadequate choices
  - Seasonal filters → Overly stable
- SA data, irregular → Detectable seasonality
  - Mild form → Evolutive pattern, reduced amplitude, stationary formulation (no unit-root dynamics)

## Detection

- Tests for stable seasonality → Inadequate (in theory)
- Pragmatic solution → Established seasonality tests on suitable subspan (e.g. last 8 years)
- Advanced solution → Tailored seasonality tests

## Flip side



Gaussian-kernel **density estimates for ACF(12)** with average **Bartlett S.E.** (*shaded area*) obtained from differenced logged seasonally adjusted **industrial production** ( $n = 301$ ), **orders received** ( $n = 319$ ) & **turnover in industry** ( $n = 567$ )

# Key messages

## Main questions

- ☞ Data → Seasonality? Need for seasonal adjustment?
- ☞ SA data → No seasonality? Quality of seasonal adjustment?
  - Over- versus under-adjustment

## Tools

- ☞ Seasonality tests → Different manifestations of seasonality
- ☞ ACF, PACF, periodogram → Peaks at seasonal lags/frequencies
- ☞ X-11 heuristics →  $M$ - &  $Q$ -statistics  $\in [0, 1]$
- ☞ AMB diagnostics → UC estimators versus estimates

## I References (I/II)

-  B Chen, T S McElroy & O C Pang (2022), [Assessing Residual Seasonality in the U.S. National Income and Product Accounts Aggregates](#), Journal of Official Statistics 38 (2), 399–428.
-  D F Findley & C C Hood (2000), [X-12-ARIMA and Its Application to Some Italian Indicator Series](#), Annali Di Statistica: Serie X 20, 249–269.
-  J Lothian & M Morry (1978), [A Set of Quality Control Statistics for the X-11-ARIMA Seasonal Adjustment Method](#), Research Paper 78-10-005E, Seasonal Adjustment and Time Series Analysis Staff, Statistics Canada.
-  T S McElroy (2021), [A Diagnostic for Seasonality Based Upon Polynomial Roots of ARMA Models](#), Journal of Official Statistics 37 (2), 367–394.

## I References (II/II)

- ¶ T S McElroy & S H Holan (2009), [A Nonparametric Test for Residual Seasonality](#), Survey Methodology 35 (1), 67–83.
- ¶ T S McElroy & A Roy (2022), [A Review of Seasonal Adjustment Diagnostics](#), International Statistical Review 90 (2), 259–284.
- ¶ M Morry & J Lothian (1978), A Test for the Presence of Identifiable Seasonality When Using the X-11-ARIMA Program, Research Paper 78-10-002, Seasonal Adjustment and Time Series Analysis Staff, Statistics Canada.
- ¶ D Ollech & K Webel (2023), [A Random Forest-based Approach to Combining and Ranking Seasonality Tests](#), Journal of Econometric Methods 12 (1), 117–130.

| Motivation

| Introduction to JD+

| RegARIMA pretreatment

- Regression equation
- TransReg plug-in
- ARIMA equation

| X-11 approach

- Basic principle
- Further issues

| ARIMA model-based approach

| Quality assessment

| Revision policies

| Composite time series

| Summary

# Revisions

## Sources of revisions I

### Data-driven changes

- Estimates, imputed figures → substitution
- Errors → corrections
- Annual information → adjustments

### Methodological changes

- Definitions, classifications
- Recording/estimation methods → refinement, harmonisation
- Indices → base year switch (with new weighting scheme)

# Revisions

## Sources of revisions II

### Availability

- New Data

### Technical Changes

- Outliers, calendar effects → treatment, estimation
- Trend, seasonal → methodology

# Revisions

## Revision policies ESS Guidelines I

### Concurrent adjustment (C)

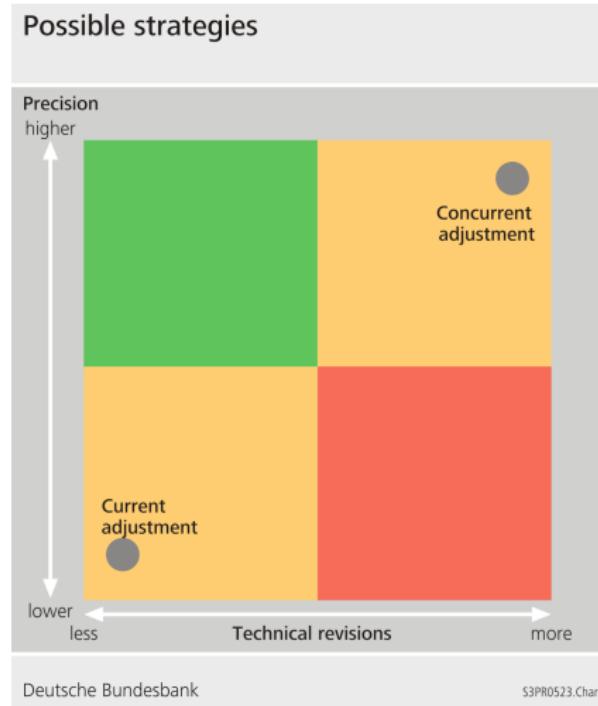
Re-identification of model, filters and outliers and re-estimation of parameters and components every time new or revised data become available

### Current adjustment (B)

Re-identification and re-estimation once a year (revision period) and usage of forecasted components in the meantime

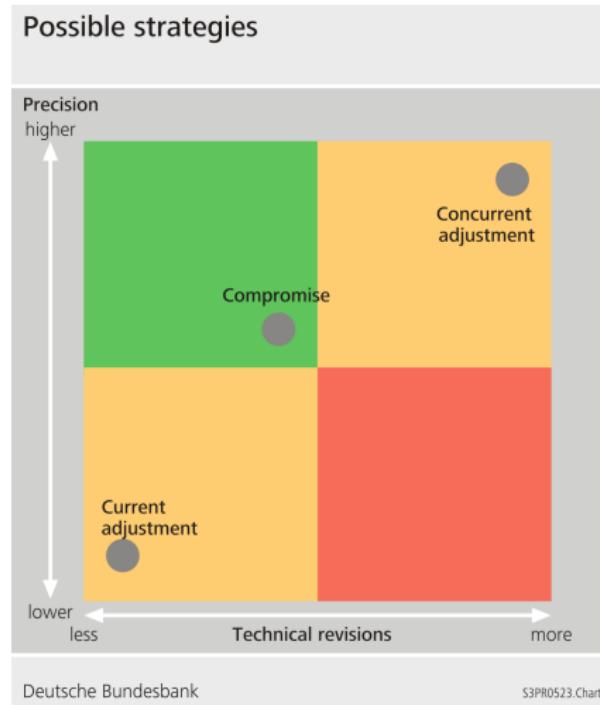
# Revisions

## Revision policies ESS Guidelines II



# Revisions

Recommended approaches ESS Guidelines I/II



# Revision policies

Recommended approaches ESS Guidelines II/II

## Partial concurrent adjustment (A)

Re-identification once a year, partial re-estimation every time new or revised data become available

## Controlled current adjustment (A)

Current adjustment combined with an internal check against the results of the partial concurrent adjustment

# Revisions

Available revision policies in JD+

Option	Meaning
Current adjustment (AO approach)	Fix model (including all parameters) handle new observation as AO
Fixed model	Re-estimation, with all parameters fixed
Estimate regression coefficients	Re-estimation of the regression coefficients
+ Arima parameters	and Re-estimation of the parameters of the ARIMA model
+ Last outliers	and Re-estimation of the outliers of the last year only
+ All outliers	and all the outliers
+ Arima model	and Re-estimation of the ARIMA model.
Concurrent	The reference specification is used

# Revisions

Extension of JDemetra+

## Basic idea

- Decision whether current factors are still appropriate
- Check current results against partial concurrent

## Graphical tools

- Seasonally adjusted series, seasonal components, S-I-ratios

## Pre-defined statistics

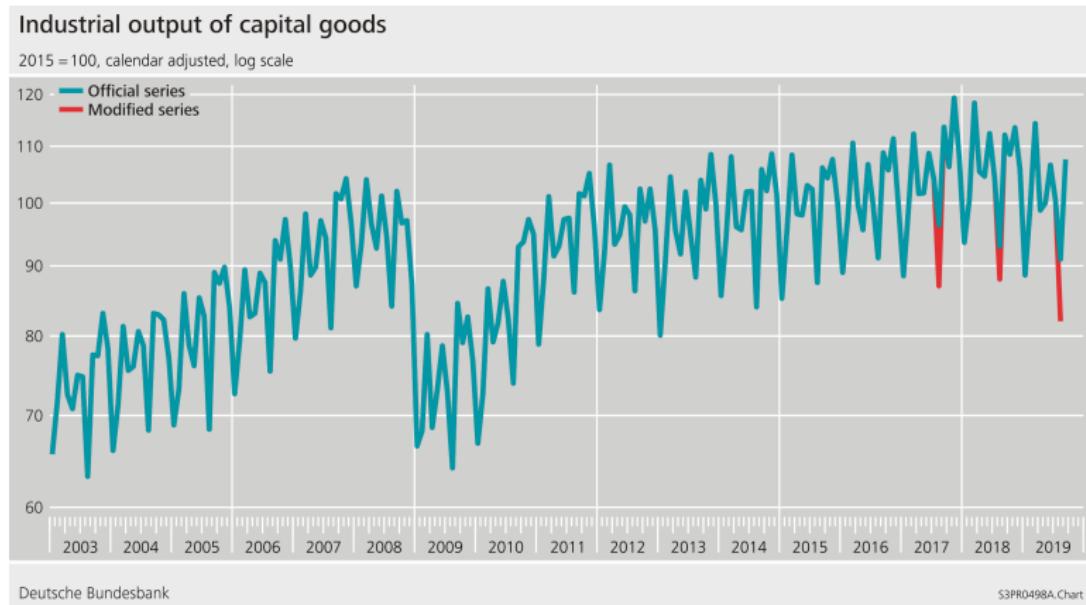
- Final filters, MSR and I/C-ratio,
- Seasonality tests and heteroscedasticity test
- D8B with current and new D10

## HTML-Report

- Summary of figures, tables and statistics (including pre-processing)

# New SA-View

Example: CompRes



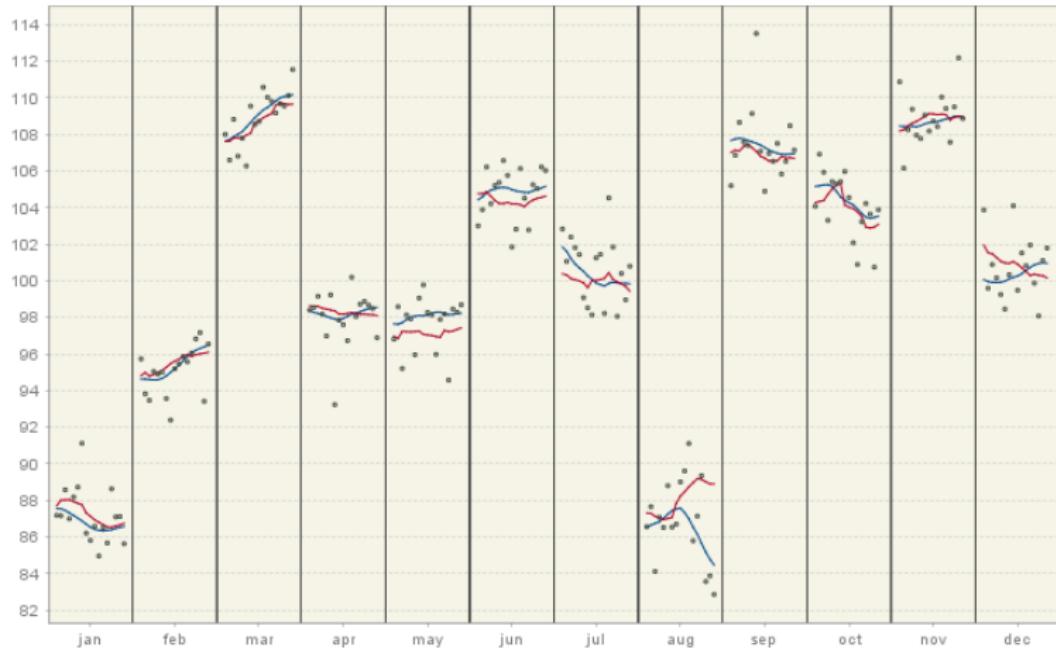
# New SA-View

Example: CompRes

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
	DBB											
2009									* 113,514	105,419	109,056	100,333
2010	86,208	* 92,39	108,536	97,848	99,779	105,759	98,139	86,703	107,074	105,977	108,178	* 104,099
2011	85,813	95,193	108,705	97,604	98,272	* 101,844	101,257	89,013	* 104,896	104,546	108,718	99,482
2012	86,592	95,463	110,575	* 96,735	98,134	102,817	101,445	89,613	106,958	102,077	108,426	101,52
2013	* 84,964	95,861	110,026	* 100,193	* 95,983	106,139	98,218	* 91,108	106,535	* 100,893	110,041	100,826
2014	86,512	95,568	109,807	98,054	97,891	104,515	* 104,531	85,794	107,512	103,228	109,412	101,957
2015	85,678	96,053	109,171	98,73	98,189	102,78	101,847	87,139	105,832	104,225	107,573	99,871
2016	* 88,636	96,83	109,673	98,872	* 94,575	105,251	98,061	* 89,352	106,527	103,646	109,504	* 98,078
2017	87,097	97,17	109,55	98,67	98,458	105,045	100,401	83,572	108,474	* 100,748	* 112,179	101,102
2018	87,12	* 93,418	110,126	98,487	98,281	106,222	98,963	83,881	107,142	103,881	108,871	101,794
2019	85,635	96,551	111,541	* 96,894	98,693	106,027	100,799	82,864				
	Seasonal Factor											
	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
2018									106,942	103,536	108,95	100,961
2019	86,585	96,477	110,165	98,548	98,233	105,167	99,835	84,47				
	Seasonal Factor (current)											
	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
2018									106,696	103,088	108,963	100,164
2019	86,751	96,099	109,649	98,107	97,426	104,627	99,432	88,9				

# New SA-View

Example: CompRes



# | How to use CompRes?

## Install plug-ins:

- CompRes-1.3.3.nbm
- CompResReport-1.3.3.nbm

## Save to workspace

- Calendar Factor
- Seasonal Factor

## Create HTML

- Summary Report for CompRes

# I CompRes with Excel

## Additional plug-in

- ExcelAdapter-1.2.nbm

## DataSourceUpdateOption

- de.bundesbank.jdemetra.exceladapter.excelConnection

## Save to Excel

- Calendar factor
- Seasonal factor
- Forecast

Advantage: use the results without JD+

# Useful links

## Guidelines

- ESS Guidelines

## Plug-ins

-  <https://github.com/bbkrd/CompRes>
-  <https://github.com/bbkrd/ExcelAdapter>

## Documentation

-  <https://bbkrd.github.io/pages/compres/>

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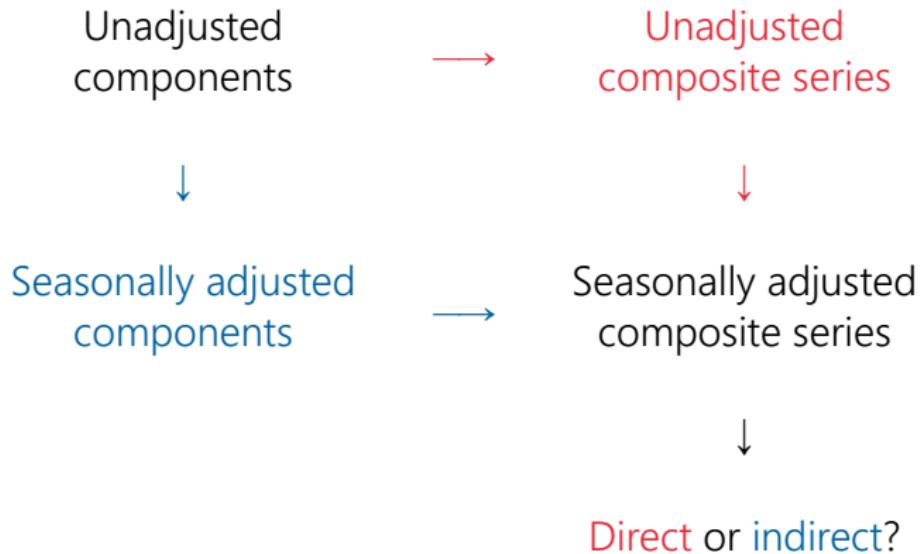
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Revision policies

Composite time series

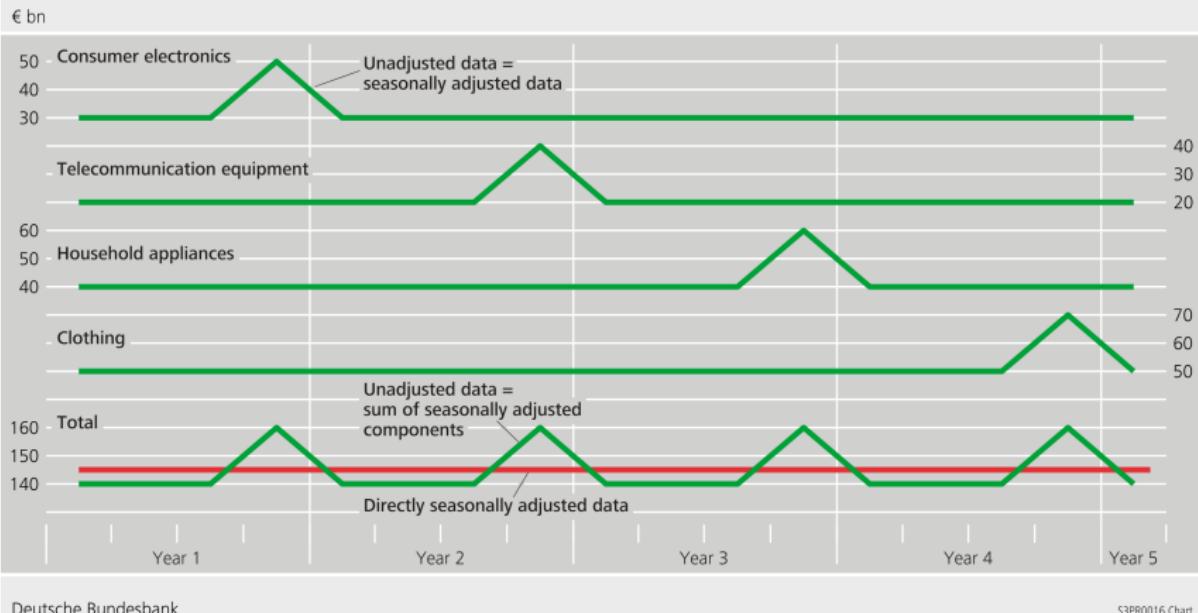
Summary

## I Two approaches & one question



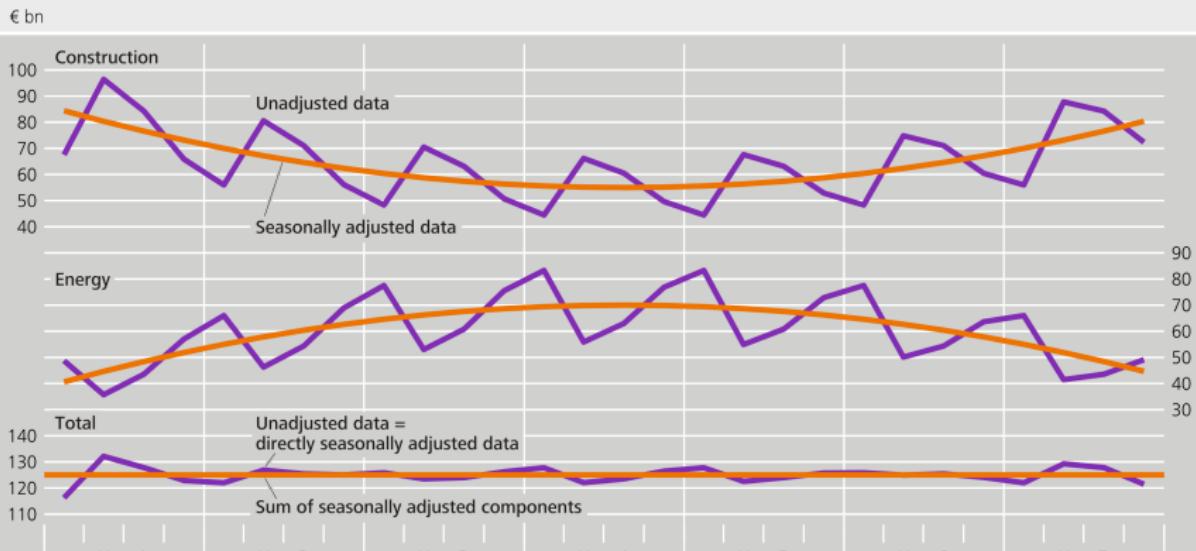
# Direct approach

## Thought experiment I – Retail turnover



# I Indirect approach

## Thought experiment II – Output



Deutsche Bundesbank

S3PR0017.Chart

# I Advantages

## Direct approach

- Residual seasonality → Less likely
- Component irregularities → Partial cancellation (given no positive crosscorrelation)

## Indirect approach

- Misinterpretation of moving seasonality as irregularity → Less likely
- Seasonality, calendar effects in components → More “precise” identification/estimation

## References

-  Deutsche Bundesbank (2010), [The whole and its parts: problems with the aggregation of seasonally adjusted data](#), Monthly Report 62 (6), 59–67.
-  J Geweke (1978), The Temporal and Sectoral Aggregation of Seasonally Adjusted Time Series, in: A Zellner (ed), Seasonal Analysis of Economic Time Series, U.S. Department of Commerce, Bureau of the Census, Washington, D.C., 411–427.
-  A Maravall (2006), [An Application of the TRAMO-SEATS Automatic Procedure; Direct Versus Indirect Adjustment](#), Computational Statistics & Data Analysis 50 (9), 2167–2190.
-  E Otranto & U Triacca (2002), [Measures to Evaluate the Discrepancy Between Direct and Indirect Model-Based Seasonal Adjustment](#), Journal of Official Statistics 18 (4), 511–530.

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# I Seasonal adjustment

## Goal

- ☞ Data → Extraction of news

## Seasonally adjusted (SA) data

- ☞ Components → Trend-cycle, irregular
- ☞ Calendar effects → Permanent elimination
- ☞ Outliers → Temporary removal (except for seasonal outliers)

## Cautionary remarks

- ☞ SA effects → Non-seasonal data dynamics
- ☞ SA data → Careful use in econometric models
  - Non-invertible estimators versus invertible models (e.g. VAR)
  - Business cycle analysis, cointegration & unit root tests

# Visibility in seasonally adjusted data

## Seasonal influences

- ☞ Deviation → Normal seasonal average
- ☞ Extreme weather conditions, atypical holiday constellations, etc.

## Random disruptions, unusual movements

- ☞ Understandable → Economic terms
- ☞ Large-scale orders, strikes, etc. → Outliers

## Revisions

- ☞ Unadjusted data → Corrections, new observations
- ☞ SA approach → Methodological changes

## Data errors

# I Seasonal adjustment in practice (I/II)

## Step 1: look at your data

- ☞ Time series plot → Visual outliers & seasonal behaviour
- ☞ Seasonality diagnostics → ACF/PACF, spectral graphs, tests

## Step 2: prepare your data for seasonal adjustment

- ☞ Log transformation, outliers, calendar effects → Smoothing ("linearisation")
- ☞ ARIMA model → Identification
- ☞ First guess → Automatic procedures
- ☞ Second guess → Expert knowledge (especially outliers & calendar effects), regARIMA residual analysis

## I Seasonal adjustment in practice (II/II)

### Step 3: seasonally adjust your pretreated data

- ☞ Specification → “Best” parameters
- ☞ X-11 approach → Trend & seasonal filters, extreme SI ratio detection

### Step 4: check your seasonally adjusted data

- ☞ Residual seasonality → Absence
- ☞ Quality diagnostics → See Step 1

# | Outlook: companion level II course

## Advanced topics in seasonal adjustment

- Date → 3–7 November 2025

## Selected topics

- Outliers → Modelling during strong economic changes
- Calendar effects → User-defined regression variables
- Seasonal adjustment → ARIMA model-based approach, composite time series, daily data, revision policies
- JD+ → Access via R