CROATIAN NATIONAL BANK

Surveys S-33

Seasonal Adjustment of Time Series and Calendar Influence on Economic Activity

Ante Čobanov

Zagreb, March 2018

HNB

SURVEYS S-33

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ISSN 1334-0131 (online)

HNB

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Abstract

This paper describes the process of the seasonal adjustment of data time series for Croatia, a process that involves cooperation between the Croatian National Bank and the Croatian Bureau of Statistics. The paper shows individual steps of the process, explains calendar effects, describes the revision policy for seasonally adjusted data and presents the seasonal adjustment of selected main monthly indicators of economic activity in the Republic of Croatia: industrial production, the volume of construction works and retail trade turnover. Working-day effect was identified for all indicators; leap year effect was identified for all but the volume of construction works, i.e. the Easter effect for retail trade turnover only. The described assumptions and limitations of the models applied are useful to end-users for the purpose of a better understanding of the published data and their use in further analysis.

Keywords:

seasonal adjustment, working-day effect, leap year effect, Easter effect, calendar effects, JDemetra+

JEL classification:

C87, C82

Contents

Abstract v

1 Introduction 1

2 Seasonal adjustment process 3
2.1 Pre-treatment of time series 4
2.2 Estimation of the seasonal component 6

3 Calendar effects 10
3.1 Easter effect 10
3.2 Leap year effect 13
3.3 Working-day effect 14

4 Seasonally adjusted data revision policy 18

5 Calendar effect on economic activity indicators in the Republic of Croatia 20

6 Conclusion 25

7 References 26

Appendix 27

1 Introduction

Central banks and statistical agencies, in addition to original statistics, publish seasonally and calendar adjusted data. The Croatian National Bank (CNB) and the Croatian Bureau of Statistics (CBS) in the Republic of Croatia (RC) cooperate in the seasonal adjustment process of time series of the most important macroeconomic indicators. The movements of such indicators, which recur in a similar manner in time periods of less than one year, are called seasonal movements, and the corresponding effects are called seasonal effects. In a seasonal adjustment process, it is necessary to identify and estimate seasonal effects using statistical procedures and carry out the adjustment of the original time series for them. Previously, the CNB and the CBS applied different methodologies for the estimation of seasonal effects, which led to differences in the seasonally adjusted results. However, cooperation between the two institutions has resulted in the definition of a common methodology and revision policy of seasonally adjusted data for individual time series, and quality control is applied constantly for the seasonal adjustment process of the most important macroeconomic indicators.

The seasonal adjustment process provides for a comparison of the current state of the economy relative to that in the previous period. For a time series of data characterised by the presence of seasonal movements, the comparison of adjacent months or quarters is irrelevant. For example, in the RC, every year the number of tourist nights spent in September is smaller than in August. Since the peak of the tourist season and the largest number of nights spent is always in July and August, the negative rate of change in September does not provide meaningful information about tourist activity during September. Meaningful information about an increase or decrease in tourist activity in September can only be obtained by time series adjustment for seasonal effects, using the rate of change calculated based on seasonally adjusted values for September and August.

However, before the estimation of seasonal effects, it is necessary to identify other relevant effects, such as the calendar effect. Calendar configuration can have a marked impact on economic activity, which is easily observed from the differences of year-on-year rates of change of original and calendar-adjusted indices. The most frequently present effects include: moving holiday effect, leap year effect and working-day effect. Easter is a moving holiday, which may fall in March or April. In the time period before Easter, household consumption increases. In leap years, February has an additional day for production or consumption relative to non-leap years. Also, if Sunday is a non-working day and economic activity is therefore reduced relative to the other weekdays, the number of Sundays in the observed month also impacts the total monthly production or consumption. Reduced economic activity can also occur on other weekdays or public holidays.

In addition to adjustment for calendar effects, prior to the estimation of seasonal effects, time series are adjusted for anomaly effects. Such appearances can be temporary or permanent. Temporary irregular movements of time series can be the consequence of adverse weather conditions[1] or natural disasters, such as floods

1 Examples of adverse weather conditions include extremely low temperatures and snow in winter months, which imply a reduced volume of construction works.

or earthquakes, while changes in national legislation or modifications of methodology[2] most frequently cause permanent changes in the movement of time series.

This paper gives an overview of the individual steps of the seasonal adjustment process, analyses calendar effects in detail, and derives the corresponding regression models used for the estimation of calendar effects. The paper also describes the revision policy of seasonally adjusted data and seasonal adjustment on the example of some important monthly indicators of economic activity in the RC: the total industrial production volume index, the total volume index of construction works and the total retail trade turnover index, with emphasis on the identification and estimation of calendar effects on economic activity. The working-day effect was identified for all indices, the leap year effect was identified for all indices, except the volume of construction works, and the Easter effect for retail trade turnover only. Regression models for the estimation of the working-day effect for industrial production volume and the volume of construction works indices assume the same economic activity from Monday to Friday, while the model for the retail trade turnover index assumes the same economic activity from Monday to Saturday.

In this paper, other regression models were also derived for the different assumptions of economic activity on individual weekdays, which were not integrated in software packages for seasonal adjustment, taking into account the Croatian holiday calendar. With regard to Easter, a model was derived in the paper, which in addition to growth in economic activity before Easter assumes a reduction in activity on Easter and Easter Monday, since on those days mostly all large retail chains and stores are closed, which is not the case of some other holidays or Sundays in the year. With regard to a significant impact of the calendar effects on economic activity, the derived regression models can be used in developing the model of forecasting the movements of original indices.

Information about the applied seasonal adjustment models of the important monthly indicators of economic activity, all assumptions and limitations of such models and the applied revision policy may be useful to the users of seasonally adjusted data. With regard to the applied methodology, it is important to know that the estimations of seasonally adjusted values for the latest observations are always temporary and that it would take several years to reach approximately their final values. Thus the final estimates[3] of seasonally adjusted values, made on a time span until December 2015, changed in absolute amounts on average by 0.61%, 0.55%, 0.45%, i.e. 0.43% over the last 4 years from the first estimates[4], for the indices of the industrial production volume, the volume of construction works and retail trade turnover in nominal and real terms. Therefore, the current rates of change on seasonally adjusted data may vary by as much as several percentage points from their final estimates, which should be taken into account when interpreting seasonally adjusted results.

Also, when using seasonally adjusted data in econometric models, it is desirable to know that seasonally adjusted data contain all identified outliers and that sudden increases or decreases in movements are sometimes the consequence of the regression variables applied. With regard to the revision policy, in practice, instead of a new seasonal adjustment with new observations, forecasted seasonal and calendar factors are often used.[5] Errors made by forecasting seasonal factors imply the errors of seasonally adjusted value estimates.

JDemetra+ software package, version 2.1.0, and method x11 were used in the analysis. Since February 2015, JDemetra+ has been officially recommended as the software package for conducting seasonal adjustment to all members of the European Statistical System (ESS) and the European System of Central Banks (ESCB). Detailed information about the seasonal and calendar adjustment process can be found in the JDemetra+ Reference Manual Version 1.1 (Sylwia Grudkowska, 2015), i.e. the ESS guidelines on seasonal adjustment (Eurostat, 2015). The x11 method is described in detail in the Seasonal Adjustment with the X-11 Method (Dominique Ladiray, Benoit Quenneville, Springer 2001).

2 Changes in methodology include administrative changes in the definition of an unemployed person, which impact the number of unemployed persons in the Employment Service records.

3 Seasonally adjusted values for the observed months or quarters were obtained by the estimation on a time span, which includes all available observations.

4 The seasonally adjusted value for the observed month or quarter at the time when the observation for the given month or quarter was also the latest available observation.

5 Only new observations are adjusted and seasonally adjusted values are not historically revised.

2 Seasonal adjustment process

The seasonal adjustment process can be divided into three basic steps: pre-treatment of a time series, estimation of the seasonal component and quality analysis.[6]

During the pre-treatment of a time series, calendar and anomaly effects are estimated. The purpose of the pre-treatment is twofold: to adjust the original time series (Y) for all effects other than seasonal and to forecast the time series using an adequate regression model, since future outcomes are also necessary for the estimation of recent seasonal movements. The main results of the adjustment are two time series: Y adjusted for all estimated regression effects and forecasted (x) and Y adjusted only for estimated calendar effects (Ycal). The estimations of all identified effects during the pre-treatment of the time series are simultaneous. Therefore, for a proper estimation of calendar effects, it is necessary to make a good specification of the entire regression model.[7]

In the second step of the seasonal adjustment process, seasonal effects are estimated on the observed time series. The goal is to decompose Y into three components: trend-cycle (TC), irregular (I) and seasonal (S). While the S-component extracts seasonal movements, the TC-component reflects the low-frequency movements of the time series, i.e. those whose time period exceeds one year. The I-component refers to the unexpected movements of the time series, which are the consequence of anomalies and accidental errors in data compilation. After estimating the S-component, the effects identified by the pre-treatment of the time series are assigned to the other components. For example, outliers that characterise a time series level shift[8] are assigned to the TC-component, while additive outliers[9] that characterise the irregularity of the individual moment of time are assigned to the I-component. A seasonally adjusted time series (SA) contains all such outliers since it consists of the TC-component and the I-component. It is obtained by adjusting the Y time series for the estimated S-component and calendar effects estimated during the pre-treatment of the time series. The most frequent methods used for the decomposition of a time series into components include x11 and seats. For analysis purposes in this paper we use the x11 method.[10]

Finally, attention should be drawn to the quality of seasonally adjusted data. Quality analysis results often indicate problems in the seasonal adjustment process, requiring changes in the previous steps of the process. Different diagnostic analyses are used, such as seasonality tests, spectral analysis, stability analysis or revision history. Apart from time series being candidates for seasonal adjustment if seasonality tests show the presence of seasonal movements in the original time series, it is important to reject the assumption of residual seasonal movements in tests, i.e. the presence of seasonal movements in the SA time series, the I-component or the TC-component. Although the time series is decomposed into components after a calendar effect adjustment, it is necessary to carry out an additional analysis of the presence of calendar effects in the SA time series, the estimated I-component and errors of the estimated regression model. Spectral analysis may be used for this purpose, in which the spectra of the estimated components are observed, i.e. graphical representations of the series transformed from the time to the frequency domain. For time series that contain seasonal and calendar effects, the original time series spectrum reveals significant peaks at seasonal frequencies, but it often does not reveal significant peaks at the frequency of the working-day effect since the working-day effect is obscured by other effects. For this reason, the spectra of the estimated components are observed and it is tested whether significant peaks have been removed by the appropriate calendar adjustment model. The presence of residual seasonal or calendar effects in the SA time series, the I-component and/or time series of regression model errors may be an indication of a model misspecification or disruption of the individual regression model

6 The author's choice of the division of the seasonal adjustment process into three segments does not necessarily correspond to the divisions and terms that can be found elsewhere in the literature.

7 For example, a time series should be adjusted for the identified outliers in February since they impact the estimation of the leap year effect.

8 Such outliers are abbreviated as LS (level shift).

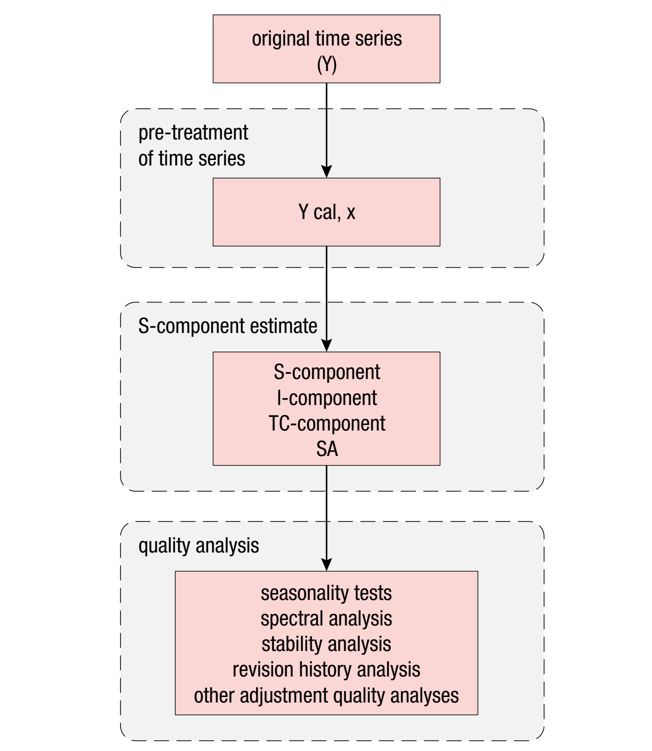
9 Such outliers are abbreviated as AO (additive outlier).

10 In JDemetra+ 2.1.0 software package, the x11 method is integrated with the X13 option, while the seats method is integrated within the TramoSeats option.

assumptions. Model parameters can be estimated at different time spans and changes in their size and sign can be determined with the aim of estimating model stability. Since the estimations of regression model parameters change as new observations become available, seasonally adjusted values change in the overall time span and published data are eventually revised. The stability of the applied model and the sizes of the revision also depend on the quality and characteristics of the original data. For a meaningful interpretation of seasonal adjustment results, the corresponding quality analysis results should also be taken into account.

Figure 1 shows the process of seasonal adjustment. The pre-treatment of the time series and the assessment of the S-component are described in more detail in the sections below.

Figure 1 Representation of the seasonal adjustment process



Source: CNB.

2.1 Pre-treatment of time series

The pre-treatment of a time series consists of a regression model estimation, where anomaly and/or calendar effects are modelled using regression variables with the assumption that regression errors follow the SARIMA process.

Definition 1 A time series is said to be an $\{x(t)\}_{t\in Z}$ SARIMA $(p,d,q)(P,D,Q)_s$ process if it meets the following differential equation:

$$\varphi(B)x(t) = \theta(B)a(t) \qquad a(t) \sim i.i.d.N(0,\sigma^2) \tag{1}$$

where backshift operator B $(Bx(t) = x(t-1)), \{a(t)\}_{t\in Z}$ is a 'white-noise' process, and $\phi(B)$ and $\Theta(B)$ are operators defined, as follows:

$$\varphi(B)=\varphi_{nar}(B)\varphi_{sar}(B)\delta_n(B)\delta_S(B) \quad (2)$$
$$\theta(B)=\vartheta_{nma}(B)\vartheta_{sma}(B) \quad (3)$$

where φ_{nar} and ϑ_{nma}, are respectively: a standard autoregressive (AR) polynomial of order p and a standard moving average (MA) polynomial of order q, φ_{sar} and ϑ_{sma}: a seasonal autoregressive (AR) polynomial of order P and a seasonal moving average (MA) polynomial of order Q, while δ_n and δ_S are a standard and seasonal differentiation operator of the order of integration d, i.e. D. Accordingly, operators: φ_{nar}, φ_{sar}, ϑ_{nma}, ϑ_{sma}, δ_n and δ_S take the following form:

$$\varphi_{nar}(B)=1-\varphi_1^{nar}B-\varphi_2^{nar}B^2-...-\varphi_p^{nar}B^p \quad \text{za} \quad \varphi_j^{nar}\in R \quad \forall j\in\{1,2,..,p\} \quad (4)$$
$$\varphi_{sar}(B)=1-\varphi_1^{sar}B^s-\varphi_2^{sar}B^{2s}-...-\varphi_P^{sar}B^{Ps} \quad \text{za} \quad \varphi_j^{sar}\in R \quad \forall j\in\{1,2,..,P\} \quad (5)$$
$$\vartheta_{nma}(B)=1+\vartheta_1^{nma}B+\vartheta_2^{nma}B^2+...+\vartheta_q^{nma}B^q \quad \text{za} \quad \vartheta_j^{nma}\in R \quad \forall j\in\{1,2,..,q\} \quad (6)$$
$$\vartheta_{sma}(B)=1+\vartheta_1^{sma}B^s+\vartheta_2^{sma}B^{2s}+...+\vartheta_Q^{sma}B^{Qs} \quad \text{za} \quad \vartheta_j^{sma}\in R \quad \forall j\in\{1,2,..,Q\} \quad (7)$$
$$\delta_n(B)=(1-B)^d \quad \text{za} \quad d\in\{0,1,2,3\} \quad (8)$$
$$\delta_s(B)=(1-B^s)^D \quad \text{za} \quad D\in\{0,1,2\} \quad (9)$$

where s = 4 for quarterly time series and s = 12 for monthly time series.

The given time series is $Y(t)$ and the total number of observations equals T. The impact of anomaly and/or calendar effects is modelled using a regression model, which in the matrix notation takes the following form:

$$y=R\beta+x \quad (10)$$

where y is of vector type $(T\times 1)$, the elements of which are either the natural logarithm of the original time series ($y(t)=\ln Y(t)$) or equal to the original time series ($y(t)=Y(t)$); R is of matrix type $(T\times k)$, whose k of columns $\{r_1,r_2,...,r_k\}$ represents the total of k regression variables, where each regression variable corresponds to the respective effect; β is of vector type $(k\times 1)$ whose elements $\{\beta_1,\beta_2,...,\beta_k\}$ are parameters assigned to the effects, which are to be estimated, and x is of vector type $(T\times 1)$ whose elements are regression errors:

$$x(t)=y(t)-\sum_{i=1}^{k}\beta_i r_i(t) \quad (11)$$

Regression errros follow the SARIMA process and in order to fully define the regression model, it is necessary to select a group of regression variables $\{r_i\}$, determine the orders of differentiation (d, D) and polynomials (p, q, P, Q) and, finally, estimate parameter sets: $\varphi=\{\varphi_1^{nar},..,\varphi_p^{nar};\varphi_1^{sar},..,\varphi_P^{sar}\}$, $\vartheta=\{\vartheta_1^{nma},..,\vartheta_q^{nma};\vartheta_1^{sma},..,\vartheta_Q^{sma}\}$ and $\beta=\{\beta_1,\beta_2,...,\beta_k\}$. The JDemetra+ software package comprises three procedures: transformation, automdl and outlier which enable, respectively: the choice of transformation of the original time series (logarithmic transformation or no transformation), the selection of the SARIMA process (the choice of the differentiation order (d, D) and polynomial orders (p, q, P, Q)), as well as outlier identification. The sets of parameters ϕ, ϑ and β are first estimated on an airline[11] model for the selected set of regression variables $\{r_i\}$ maximising the logarithm function of the maximum likelihood (L (β, ϕ, ϑ)). The maximisation of the maximum likelihood function is a non-linear problem, so that primarily parameters β are estimated for the given initial values of parameters ϕ and ϑ, and then, for such estimated parameters β, the values of parameters ϕ and ϑ are estimated. The process is iterative until convergence is achieved.[12] Parameters β, estimated according to the airline model, are tested for statistical significance. The procedure automatically checks the significance of the inclusion of a constant into the regression model. Alternative SARIMA processes are then tested, where the Hannan-Rissanen method is used for the selection of the differentiation order, and the degrees of polynomials are determined according to the information criterion.[13]

11 The SARIMA (0,1,1)(0,1,1)$_s$ process.

12 Convergence is realised up to the given tolerance factor, which is predefined in JDemetra+ software package.

13 The Bayesian Information Criterion (BIC) is used, and a model to which a minimum BIC-value corresponds; there is a set of empirical rules, according to which an airline model is selected, although it has a lareger BIC-value than the second suggested SARIMA model.

In outlier identification, attention should be paid to the number, the type and the interpretation of identified outliers. It is taken into account that the share of such values in the total number of original data is small, but sufficient for the estimated model to show improvement with respect to the model, which does not include additional outliers (e.g. the improvement of some diagnostic indicators). The number of identified outliers can be controlled by changing the value of the critical parameter within the outlier procedure. For the time series the movements[14] of which are not stable, a critical value larger than the preset value integrated in the software package is often used because, otherwise, too large a number of outliers would be identified. Special attention should be paid to the identified outliers at the end of the time series since they may be an indication of changes in the dynamics or preliminary data, which will be revised in the forthcoming periods. In such situations, additional information about the time series are used to reveal the causes and consequences of the inclusion and the exclusion of identified outliers in the seasonal adjustment process. A special treatment of the latest observations is necessary because their interpretation depends on future outputs.[15] Any outliers with a cause or economic interpretation[16] known in advance are modelled using regression variables, which are kept fixed in the regression model since the identification of the remaining outliers depends on already included regression variables.

The criteria of the minimum information criteria value are used for the selection of the final regression model: Akkaike (AIC), Akkaike adjusted for sample size (AICC) and the Bayesian Information Criterion (BIC), defined by the following formulas respectively:

$$AIC = -2L_N + 2h \tag{12}$$

$$AICC = -2L_N + 2h\left(1 - \frac{h+1}{N}\right)^{-1} \tag{13}$$

$$BIC = -2L_N + h \ln N \tag{14}$$

where L_N is the natural logarithm of the maximum likelihood function of the SARIMA regression model, h is the total number of estimated parameters that are estimated based on N data (for the original time series, which includes T observations, this number is effectively reduced due to differentiation and is $N = T - d - 4D$).

2.2 Estimation of the seasonal component

A time series is decomposed into components on time series x to prevent anomaly and calendar effects from impacting the estimation of seasonal effects. The decomposition may be additive or multiplicative.[17] In the case of an additive decomposition, a time series equals the sum of individual components, while in the case of a multiplicative decomposition it equals their product. The decomposition of a time series into components is an iterative process[18] of the application of different filters[19] for the purpose of a final estimation of the S-component. The process is iterative because the estimation of the S-component primarily requires an SI-component[20], which can be obtained by estimating the TC-component and its removal from time series x. Then, the SI-component should be decomposed into the S- and I-components. However, since extreme irregular values impact the S-component estimate[21], it is necessary to identify the extreme values of the I-component and

14 In particular the components of individual macroeconomic aggregates.

15 For instance, if the latest observation refers to an outlier, without future outputs it is not possible to determine whether it is a permanent level shift of a time series or a current irregularity.

16 For instance, the outbreak of the global economic crisis at the end of 2008.

17 Also, log-additive in the case of a logarithmic transformation of the original time series.

18 The process is iterative using the x11 method.

19 Symmetrical and asymmetrical moving average and Henderson filters are applied.

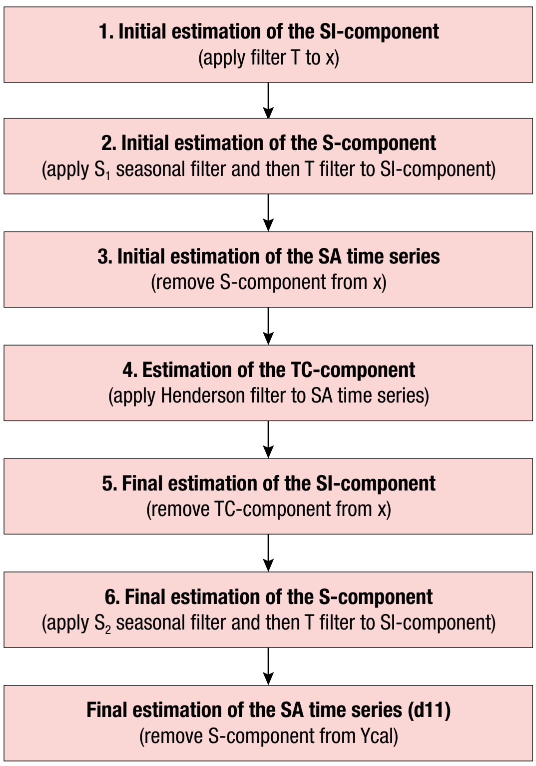
20 Seasonal-irregular component equals the sum or a multiple of the S-component and the I-component, depending on the additive or multiplicative decomposition.

21 The S-component is assessed using seasonal moving averages on the SI-component so that extreme irregular values impact the values of the obtained averages.

modify the SI-component for the identified extreme values. Individual components are re-estimated on several occasions during the whole procedure in order to obtain more precise estimates since individual components are non-observable, there is no unambiguous definition of the S-component[22] and its estimation depends on the method of the TC-component pre-estimation.

Without identifying the extreme values of the I-component, the S-component estimation procedure can be summarised in a single iterative process consisting of a total of six steps[23]: the initial estimation of the SI-component, the initial estimation of the S-component, the initial estimation of the SA time series, the estimation of the TC-component, the final estimation of the SI-component and the final estimation of the S-component. The SA time series can then be obtained by adjusting the Ycal time series for the estimated S-component. In this case, the SA time series can be obtained by a linear transformation from the original time series.[24] Such a process is shown in Figure 2, where T stands for the filter, which corresponds to the application of moving averages followed by the removal of the obtained estimate from the time series[25], and S stands for the seasonal filter of moving averages.

Figure 2 Linear part of the S-component estimation process by applying x11 method



Source: CNB.

If the extreme values of the I-component are identified, the method of modification of the SI-component depends on the lower and upper critical value, which are called sigmalim limits. In this process, the standard

22 Seasonal effects are visually easily observed by looking at the graphic representations of time series, but they cannot be defined unambiguously and may be interpreted exclusively in the context of the methodology used for their estimation.

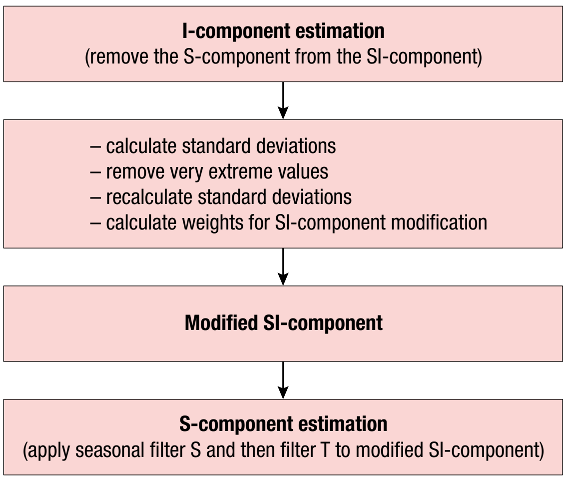
23 The author's choice of the division of the process into six steps does not necessarily correspond to the divisions and terms that can be found elsewhere in the literature.

24 The application of moving averages is a linear transformation, and the multiple use of moving averages (without the modification of the SI-component) is also a linear transformation.

25 For the monthly series and the initial estimation of the SI-component, for example, a 13-terms moving averages filter can be used for the purpose of the initial estimation of the TC-component and then remove the TC-component from time series x to obtain the estimation of the SI-component, which is symbolically marked by the application of the T filter on series x.

deviation is first associated to each year, which is calculated on a total of 20 I-component values, i.e. for the four quarters of the observed year and eight previous and future quarters.[26] Then, for each year, all values whose absolute deviations from the theoretical average[27] are larger than or equal to the multiple of the upper critical value and the standard deviation are identified. Such very extreme values are excluded from the computation and standard deviations are recalculated. After that, depending on the corresponding value of the new standard deviation and sigmalim limits, weights are assigned to all time periods. In a multiplicative case, for example, value 0 is assigned to all values whose absolute deviations from one are larger than or equal to the multiple of the upper critical value and the standard deviation, and value 1 is assigned to all values whose absolute deviations from one are lower than or equal to the multiple of the lower critical value and the standard deviation. Weights between 0 and 1 are linearly assigned to the other values. The SI-component is then modified in all periods to which a weight other than 1 is associated.[28] A simplified presentation of the process of identification of the I-component's extreme values is shown in Figure 3.

Figure 3 Non-linear part of the S-component estimation process applying x11 method



Source: CNB.

In addition to the modification of the SI-component, the S-component estimation is composed of three iterative processes: B, C and D.[29] In the case of the B and C iterations, individual inter steps are composed of a total of 20 time series (b1, ..., b20 ; c1, ...,c20)[30]. The result of the iterative process includes: the final S-component (d10), the final seasonally adjusted time series (d11), the final TC-component (d12) and the final I-component (d13).[31] The entire iterative process is shown in Figure 4.

The B iteration comprises the same steps as the iterative process without identifying the extreme values, but with two significant differences. The first difference is that the SI-component is modified during each estimation of the S-component. After each estimation of the S-component, the I-component is also estimated by removing the S-component from the SI-component. Extreme values of the I-component are then identified and the SI-component is modified for them. The S-component is re-estimated on the SI-component and a better S-component estimate is achieved. Another difference is that after the estimation of the TC component

26 Completely analogous for monthly time series, for the current, the previous two and the future two years.

27 In the additive case, the theoretical average is 0, and in the multiplicative case it is 1.

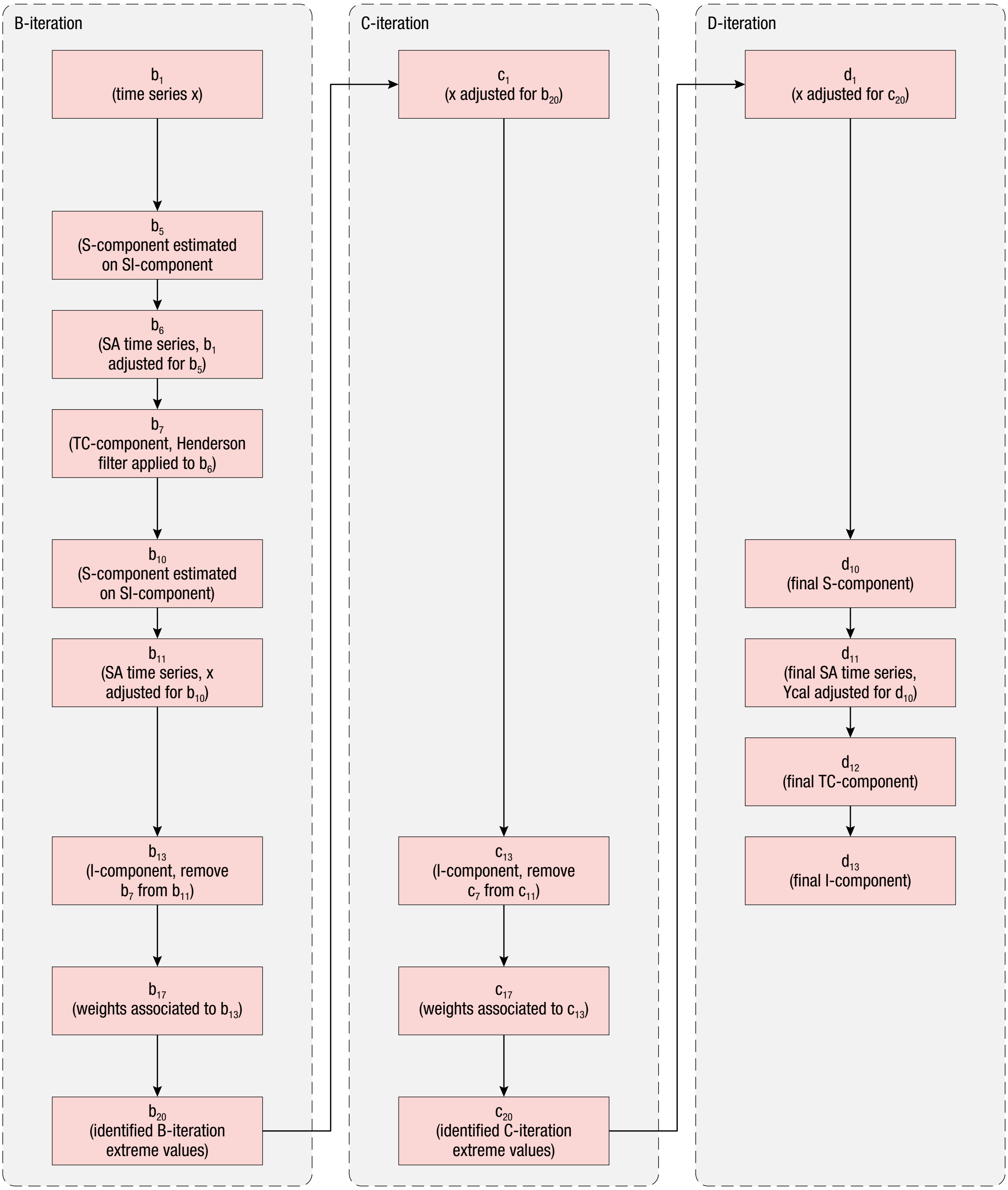
28 The value is replaced by the mean value of the adjacent years, whose assigned weight is 1.

29 The names of iterations B, C and D are taken from JDemetra+ software package.

30 The names of the time series are taken from JDemetra+ software package.

31 Designations d10, d11, d12 and d13 are taken from JDemetra+ software package.

Figure 4 Representation of the iterative process of the S-component estimation



Source: CNB.

and the final estimation of the S-component following modification, both components are removed from time series x. Extreme irregular values are identified on the I-component obtained in this way. The start of the C iterative process is time series x adjusted for the identified extreme irregular values of the B iteration (b20). The second difference also characterises the C iteration so that the start of the D iteration is time series x adjusted for extreme irregular values of the C iteration (c20). The usual iterative process of the above mentioned six steps can be carried out on a time series obtained in this way, and final estimates of the S-, TC- and I-components are eventually obtained. It is worth noting that c20 values have a significant impact on the assessment of the final S-component.[32] Since the above corrections are non-linear transformations, the SA time series cannot be obtained using a linear transformation from the original time series.

3 Calendar effects

Calendar configurations can have a marked impact on economic activity. Therefore, it is important to discuss in more detail the assumptions and derivations of regression models for the calendar effect estimation. With regard to the estimation of the working-day effect, only two regression models are integrated in JDemetra+ software package: the one that assumes different economic activity on different weekdays and another one that assumes the same economic activity from Monday to Friday. For individual time series, it is necessary to test alternative models based on different assumptions of economic activity on individual weekdays. Also, due to the specificity of the national calendar, there is a need to calculate regression variables specific for the RC. For this purpose, alternative regression models have been derived in the paper, which take into account the Croatian holiday calendar. Alternative models for the estimation of the Easter effect have also been derived, which assume a growth of economic activity in the time period before Easter and a decline in economic activity on Easter and Easter Monday.

3.1 Easter effect

Bell and Hillmer (1983) were the first to suggest a simple regression model for estimating moving holiday effects. The Bell-Hillmer interval model assumes the existence of a time interval of w days length, which begins on the w-day before Easter and ends the day before Easter, in which economic activity changes. Further, we refer to such a time interval as the w-interval. The Bill-Hillmer model also assumes the same economic activity on the w-interval days, but it is also possible to define models with different effects of individual days. Such models are included in the analysis if it is known that the effect of a day differs from the effect of the remaining days or if an increase or a decrease in economic activity is expected with each following day.

In this paper, we focus only on the Bell-Hillmer interval model and assume that w-interval lengths of a minimum of one to a maximum of fifteen days are possible. In addition, we also include a possible change in economic activity on Easter and Easter Monday in the analysis. Standard software packages for seasonal adjustment most often contain three regression variables for estimating the Easter effect, constructed by using the Bell-Hillmer interval model, with w-interval lengths equal to one, eight or fifteen days respectively. The length of eight or fifteen days assumes a change in economic activity starting on a Saturday, one or two weeks before Easter. In this paper, we also analyse the possibility that a change in economic activity occurs on Mondays, i.e. at the start of the week. Also, although Easter and Easter Monday are non-working days and, as such, contribute to the working-day effect, we also test the additional possibility of a decrease in economic activity due to the specificity that most large retail chains and stores are closed on Easter and Easter Monday, which is not the case with some other holidays or Sundays in a year.

It is sufficient to carry out the analysis of the Easter effect for quarterly time series. As the date of Easter may vary between 22 March and 25 April, Easter may fall in the first or the second quarter, i.e. in March or April, depending on the frequency of the observed time series. As a result, regression variables disappear in all of the remaining quarters, i.e. months. Since March belongs to the first quarter, and April belongs to the

32 In corrected periods the division of contributions changes between the seasonal and the irregular component, which consequently has an impact on the rates of change of the seasonally adjusted time series.

second quarter, the values of regression variables in March and April are identical to the values of regression variables in the first and the second quarter respectively.

In deriving a regression model for the estimation of Easter effects, we assume that $n^{(w)}(g,q)$ is the number of days that belong to the w-interval and are in year g and quarter q and that the value of the regression variable in that period is equal to the share of the w-interval within the given quarter and stands at:

$$H^{(w)}(t) = H^{(w)}(g,q) = \frac{n^{(w)}(g,q)}{w} \qquad (15)$$

For example, in 2015, Easter was on 5 April and if we assume that $w = 8$, regression variable values in 2015 were:

$$H^{(8)}(2015,1) = \frac{4}{8} \quad H^{(8)}(2015,2) = \frac{4}{8} \quad H^{(8)}(2015,3) = 0 \quad H^{(8)}(2015,4) = 0 \qquad (16)$$

since of the total of eight days four belong to the first quarter (28, 29, 30 and 31 March), and four to the second quarter (1, 2, 3 and 4 April). We also assume that the Easter effect is present in the analysed time series and that in the regression model (10) a logarithm transformation of the original time series was selected. Furthermore, we have estimated parameter $\hat{\beta}_1$ corresponding to regression variable $r_1(t) = H^{(w)}(t)$, and we assume that the estimated parameter is much smaller than one and, without loss of generality, it is positive[33]. In addition to the above assumptions, the original time series should be adjusted for the following adjustment factor:

$$\exp\left[\hat{\beta}_1 H^{(w)}(t)\right] \approx 1 + \hat{\beta}_1 H^{(w)}(t) \qquad (17)$$

By adjusting the original time series for such obtained factors, the following is obtained:

$$\frac{Y(g,q)}{\exp\left[\hat{\beta}_1 H^{(w)}(g,q)\right]} \approx Y(g,q) - \hat{\beta}_1 H^{(w)}(t) Y(g,q) \qquad (18)$$

According to the relation (18), the estimated parameter $\hat{\beta}_1$ can be interpreted so that value $100\hat{\beta}_1/w$ represents a percentage decrease in the time series contributed to by the individual w-interval day in the observed quarter. The adjusted time series values are obtained by dividing the original time series by adjustment factors since in the regression model (10) the total adjustment factor can be shown as a product of contributions of individual regression variables:

$$\exp\left[\sum_{i=1}^{k} \hat{\beta}_i r_i(t)\right] = \prod_{i=1}^{k} \exp\left[\hat{\beta}_i r_i(t)\right] \qquad (19)$$

However, certain corrections of regression variables have to be made because the adjustment factor value according to the relation (17) is always higher than or equal to 1, and at least in one of the first two quarters it is higher than 1. As a result, the adjusted time series has a lower level than the original time series in each quarter to which at least one day of the w-interval belongs, and in each year g the sum of quarterly contributions of the original time series adjusted for factors (17) is lower than the sum of the quarterly contributions of the original time series:

$$\sum_{q=1}^{4} \frac{Y(g,q)}{\exp\left[\hat{\beta}_1 H^{(w)}(g,q)\right]} < \sum_{q=1}^{4} Y(g,q) (\forall g) \qquad (20)$$

For this reason *modified* regression variables $\tilde{H}^{(w)}(g,q)$ are defined, the value of which in year g and quarter q equals the corresponding value of regression variable $H^{(w)}(g,q)$ reduced by its average value $H^{*}(q)$ on the given time interval of the years from N_0 to N_1 ($N_1 > N_0$):

$$\tilde{H}^{(w)}(t) = \tilde{H}^{(w)}(g,q) = H^{(w)}(g,q) - H^{*}(q) \qquad (21)$$

33 Since we anticipate Easter effects in the retail trade turnover time series, we may assume that economic activity increases before Easter.

$$H^*(q) = \frac{1}{N_1 - N_0}\sum_{g'=N_0}^{N_1} H^{(w)}(g',q) = \frac{n^*(q)}{w} \tag{22}$$

In the relation (22) $n^*(q)$ stands for the average number of w-interval days in quarter q. For each year g the following applies: $\sum_{q=1}^{4} H^{(w)}(g,q) = 0$ and $\sum_{q=1}^{4} H^*(q) = 0$ therefore:

$$\sum_{q=1}^{4} \tilde{H}^{(w)}(g,q) = 0\text{, tj. } \prod_{q=1}^{4} \exp\left[\hat{\beta}_1 \tilde{H}^{(w)}(g,q)\right] = 1\,(\forall g) \tag{23}$$

Requiring discussion is the manner in which the selection of modified regression variables impacts a calendar adjusted time series and how the estimated parameters are interpreted in this case. If the seasonal operator of differentiation is of the order of integration of at least one ($D\geq1$), then the estimated parameters in the regression model do not depend on the selection of regression variables $H^{(w)}(t)$ or $\tilde{H}^{(w)}(t)$. In the regression model, the regression of a differentiated time series on differentiated regression variables is carried out, and there is no difference in seasonally differentiated variables $H^{(w)}(t)$ and $\tilde{H}^{(w)}(t)$. Then, neither the selection of the SARIMA model nor information criteria values depend on the selection of regression variables. Although a calendar adjusted time series depends on the selection of modified regression variables, which differ depending on the averaging period, the original time series adjusted for seasonal and calendar effects does not depend on that selection. In order to confirm this, $H_1^*(q)$ and $H_1^*(q)$ correspond to two different selections, N_0 and N_1, $\tilde{H}_{(1)}^{(w)}$ and $\tilde{H}_{(2)}^{(w)}$ are the corresponding modified regression variables and $\Delta H(q) = H_2^*(q) - H_1^*(q)$. Then the ratio of corresponding adjustment factors is:

$$\frac{\exp\left(\hat{\beta}_1 \tilde{H}_{(2)}^{(w)}(g,q)\right)}{\exp\left(\hat{\beta}_1 \tilde{H}_{(1)}^{(w)}(g,q)\right)} = \exp\left(\hat{\beta}_1 \Delta H(q)\right) \approx 1 + \hat{\beta}_1 \Delta H(q) \tag{24}$$

According to the relation (24), the ratio of adjustment factors does not depend on year g, and since $\sum_{q=1}^{4} \Delta H(q) = 0$, the average annual value of the ratio is 1. Therefore, the ratio of the adjustment factor can be interpreted by a multiplicative seasonal effect, which will be removed by the adjustment of the time series for seasonal effects. By applying modified regression variables, the adjustment factor has the following form:

$$\exp\left[\hat{\beta}_1 \tilde{H}^{(w)}(g,q)\right] \approx 1 + \hat{\beta}_1\left[H^{(w)}(g,q) - H^*(q)\right] = 1 + \hat{\beta}_1\left[\frac{n^{(w)}(g,q)}{w} - \frac{n^*(q)}{w}\right] \tag{25}$$

According to the relation (25), the estimated parameter $\hat{\beta}_1$ can be interpreted so that value $\hat{\beta}_1\left[\frac{n^{(w)}(g,q)}{w} - \frac{n^*(q)}{w}\right]$ represents a percentage change of the time series contributed to by the deviation of the number of w-interval days relative to the average number of w-interval days in the observed quarter.

Considering the periodic nature of the Easter calendar, regression variables should be corrected for their average value on the period of repeating, since time series contributions, which are the consequence of periodic movements, are not assigned to the calendar component. If the Easter calendar is repeated every $4(N_1-N_0)$ quarters, regression variables (15) should be modified precisely by their average value on that interval. In the case of Easter, such a time period is 5 700 000 years, but in literature approximative averaging on shorter time intervals are most frequently used. Since the Gregorian calendar, adopted in October 1582, repeats itself every 400 years, the first approximation includes the averaging according to the first period of the Gregorian calendar, i.e. on the interval from the fourth quarter of 1582 to the fourth quarter of 1982. Another approximation often used includes the period from 1600 to 2099. Table 1 shows Easter dates in the time period from 1998 to 2027, and Table 2 shows the number of Easter occurrences on the observed date for the previously mentioned different time span selections. For the estimation of Easter effect we use modified regression variables according to relations (21) – (22), and averaging is made on a time interval from 1600 to 2099.

Since in the Republic of Croatia the day after Easter (Easter Monday) is a holiday, the analysis of Easter effects can be made by constructing two types of modified regression variables. The first regression variable (A) corresponds to increased economic activity before Easter and we assume that such activity increases on the a-day before Easter and ends on the b-day before Easter (the interval includes both the a and the b day before

Easter, $a \geq b \geq 1$). Another regression variable (B) corresponds to reduced economic activity during Easter and such reduced activity ends on the c day ($c = 1$ if it ends on Easter, $c = 2$ if it ends on Easter Monday). The designation ($-a$, $-b$, c) stands for the selection of two regression variables: $A^{(-a,-b)}$ and $B^{(-b,c)}$ which in year g and quarter q are defined, as follows:

$$A^{(-a,-b)} = \frac{n^{(-a,-b)}(g,q)}{a-b+1} - \mu^{(-a,-b)}(q) \tag{26}$$

$$B^{(-b,c)} = \frac{n^{(-b,c)}(g,q)}{c+b-1} - \mu^{(-b,c)}(q) \tag{27}$$

We take it into consideration that two effects are observed using two regression variables, the first in the time period from the a day before Easter until the b day before Easter (the first interval), and the second one from the b day before Easter until Easter ($c = 1$) or Easter Monday ($c = 2$) (the second interval). Fully analogous to previous considerations, $n^{(-a,-b)}(g,q)$ and $n^{(-b,c)}(g,q)$ represent the number of days from the first, i.e. the second interval, which are in year g and quarter q, while $\mu^{(-a,-b)}(q)$ and $\mu^{(-b,c)}(q)$ are the corresponding averagings in the time period from 1600 to 2099.

Since we wish to test a number of different regression models for the estimation of the Easter effect, $\{(-a, -b, c)\}$, we introduce the following designations:

$$AICC^{*} = \min_{\{(-a,-b,c)\}} AICC^{(-a,-b,c)} \tag{28}$$

$$\Delta AICC^{*} = AICC^{0} - AICC^{*} \tag{29}$$

where $AICC^{0}$ is defined by the relation (13) for a model that does not include regression variables for the estimation of Easter effect (initial model), and $AICC^{(-a,-b,c)}$ represents the AICC-value of the model obtained when two regression variables are added to the initial model: $A^{(-a,-b)}$ and $B^{(-b,c)}$ (alternative model), where the number of model parameters increased by 2. Let $(-a, -b, c)^{*}$ be the selection of two regression variables such that the AICC-value $AICC$ matches the corresponding alternative model, and let L_N^0 and L_N^* be the corresponding natural logarithms of the functions of the maximum likelihood for the initial and alternative model respectively. If $\Delta AICC^{*} \leq 0$, no Easter effect is identified, and if $\Delta AICC^{*} > 0$, the initial and the alternative model are compared using a *likelihood-ratio* statistical test. Assuming that the initial model is appropriate, the test statistic:

$$LR = -2[L_N^0 - L_N^*] \tag{30}$$

has approximately the χ^2 distribution with 2 degrees of freedom. Accordingly, the alternative model is accepted with the level of significance α if it applies for test statistic LR:

$$LR > \chi^2_{2,\alpha} \tag{31}$$

where $\chi^2_{2,\alpha}$ is the critical value χ^2 of the distribution with 2 degrees of freedom for the level of significance α.

3.2 Leap year effect

The leap year effect is the impact of an extra day on economic activity in the February of a leap year. In leap years, the first quarter has 91 days, and in non-leap years there is one day fewer. The value of the corresponding regression variable in year g and quarter q $pg(g,q)$, may be expressed in the following way:[34]

34 Fully analogous for monthly time series. The calculation does not contain additional corrections (e.g. not every year is divisible by 4 and a leap year).

$$pg(g,q) = 0{,}75 \text{ za } q = 1 \text{ and it is a leap year}$$
$$pg(g,q) = -0{,}25 \text{ za } q = 1 \text{ and it is a non-leap year} \quad (32)$$
$$pg(g,q) = 0 \text{ for } q \neq 1$$

The average number of days in the first quarter is 90.25. If we assume that the leap year effect is multiplicative, the adjustment of the original time series can be made before the pre-treatment of the time series, i.e. by dividing the data from the first quarter by the number 90/90.25 = 0.997 if the year is a non-leap year, or by number 91/90.25 = 1.0083 if the year is a leap year. The estimation of the effect using a regression model can result in a wrong estimate of the corresponding parameter if there are extreme values in February that are not identified by a time series pre-treatment. Therefore, when interpreting the obtained results, account should be taken of identified outliers in February, and the sign and the size of the estimated parameter. The procedure for an automatic identification and estimation of the leap year effect is integrated in the JDemetra+ software package. However, by using user-defined regression variables[35] for the working-day effect estimation, it is not possible to perform an automatic estimation of the leap year effect. Therefore, we also use a user-defined regression variable for the leap year effect, which we keep in the regression model if it is statistically significant and the sign and the size of the estimated parameter are in line with the expectation.

3.3 Working-day effect

The working-day effect is the impact of changes in the number of working days on economic activity in a given time period. For a month in a year that has 31 days, if the first three days of the month are Friday, Saturday and Sunday, then Friday, Saturday and Sunday occur five times and the other days four times in that month. For a month in a year that has 30 days, if the first two days of the month are Tuesday and Wednesday, then Tuesday and Wednesday occur five times and the other days four times in that month. An extra day in March, which has 31 days, as against the 30 days in April, is an occurrence that is repeated each year in the same way and contributes to the seasonal effect. A cyclical change in the order of days within a month, i.e. a change in the days in a week, which occur four or five times, contributes to the working-day effect, assuming that at least some weekdays are characterised by different economic activity.[36]

With regard to quarterly series, a quarter may have 90, 91 or 92 days. While each weekday occurs four or five times a month, it occurs 12, 13 or 14 times in the quarters. The second quarter has precisely 13 weeks, i.e. 91 days, therefore, each weekday occurs precisely 13 times and there is no cyclical change in the order of weekdays in that quarter. In leap years, the first quarter also has 91 days, and in non-leap years there is one day fewer. The third and the fourth quarter have precisely 92 days, i.e. one day more than 13 weeks. The extra day that occurs in the third quarter is the day before the extra day that occurs in the fourth quarter. For example, if Tuesday is the day that occurs 14 times in the third quarter, then Wednesday is the day that occurs 14 times in the fourth quarter, as was the case in 2014. In 2015, Wednesday was the day that occured 14 times in the third quarter, i.e. the following day relative to the day that had occurred 14 times in the observed quarter of the previous year if the year was a non-leap year. The day that occurs 12 times in the first quarter, in a non-leap year, is the same day that occurs 14 times in the third quarter.

The working-day effect in quarterly time series is smaller and more difficult to identify than in monthly time series. Since for quarterly time series it is a day that occurs once more or less relative to 13 repeats quarterly, for monthly time series two or three days occur once more relative to four repeats a month. Also, assuming that there is no difference in economic activity between Monday, Tuesday, Wednesday and Thursday, there is no working-day effect for quarterly time series within the range from 2013 to 2015 because days characterised by the same economic activity alternate cyclically. In practice, the same economic activity is most frequently assumed for specific weekdays, so that a larger number of observations relative to monthly time series

35 In JDemetra+ software package, the user can upload time series and use them in regression models.

36 Economic activity on Sundays most frequently differs from economic activity during weekdays.

is required for the identification and estimation of the effect for quarterly time series. For example, there is no sense in assuming that more or less is manufactured at industrial plants on Tuesday than on Wednesday, but with regard to the retail trade turnover, Friday and Saturday may be characterised by different activity relative to the other weekdays considering the end of the working week and that the majority of stores are also open on Saturday when people have more free time and thus more time for consumption.

When deriving regression models of the working-day effect we limit ourselves to monthly time series.[37] Regression variables are derived with the assumption that the monthly data are a cumulative aggregate of daily values.[38] Let us assume that the j day of the week contributes to the overall monthly data with α_j, where $j = 1$, 2, 3, 4, 5, 6 and 7 refer to the days of the week from Monday to Sunday respectively. D_{jt} is the number of occurrences of the j day of the week in month t, is the average contribution of the specific day of the week to the cumulative monthly data and N_t is the total number of days in month t. Then the following relations apply:

$$\bar{\alpha} = \frac{\sum_{j=1}^{7} \alpha_j}{7} \tag{33}$$

$$N_t = \sum_{j=1}^{7} D_{jt} \tag{34}$$

The cumulative contribution of all days in a month can be shown, as follows:

$$\sum_{j=1}^{7} \alpha_j D_{jt} = \sum_{j=1}^{7} (\alpha_j - \bar{\alpha} + \bar{\alpha}) D_{jt} = \bar{\alpha} N_t + \sum_{j=1}^{6} (\alpha_j - \bar{\alpha})(D_{jt} - D_{7t}) \tag{35}$$

The relation (35) defines a total of 6 contrast regression variables $D_{jt} - D_{7t}$, $j \in \{1, 2, 3, .., 6\}$. Since the order of the days in a week per month is cyclically repeated every 28 years, the following applies:

$$\sum_{k=1}^{28} (D_{jt+12k} - D_{7t+12k}) = 0 \quad (\forall j) \tag{36}$$

Therefore, the sum of contributions $\sum_{j=1}^{6} (\alpha_j - \bar{\alpha})(D_{jt} - D_{7t})$ for all months in the time period of 28 years disappears:

$$\sum_{k=1}^{28} \sum_{j=1}^{6} (\alpha_j - \bar{\alpha})(D_{jt+12k} - D_{7t+12k}) = \sum_{j=1}^{6} (\alpha_j - \bar{\alpha}) \sum_{k=1}^{28} (D_{jt+12k} - D_{7t+12k}) = 0 \tag{37}$$

If we assume different economic activity for days of the week from Monday to Saturday, the relation (35) can be written in the following form:

$$\sum_{j=1}^{7} \alpha_j D_{jt} = \bar{\alpha} N_t + \sum_{j=1}^{6} a_j^{(6)} A_{jt}^{(6)} \tag{38}$$

where $a_j^{(6)} = (\alpha_j - \bar{\alpha})$, i.e. $A_{jt}^{(6)} = (D_{jt} - D_{7t})$. Then, in the regression model we use a total of six regression variables $\{A_{jt}^{(6)}, j \in \{1, 2, 3, ..., 6\}\}$ and estimate a total of six parameters $\{a_j^{(6)}, j \in \{1, 2, 3, ..., 6\}\}$. In the relation (38), the contribution $\bar{\alpha} N_t$ corresponds to the average contribution of all days, and contribution $\sum_{j=1}^{6} a_j^{(6)} A_{jt}^{(6)}$ does not disappear only for those days whose number of occurrences in month t is different from the number of occurrences of Sundays in the observed month. If Sunday occurs five times in the observed month, then all days of the week from Monday to Saturday, which in the observed month occur four times, contribute to the effect, and the corresponding values of the contrast variables in the observed month are negative. In addition, those days of the week the economic activity of which is larger than the average economic activity $(\alpha_j > \bar{\alpha})$ and which occur four times, will contribute to increasing the adjusted value of time series in month t relative to the original value, and weekdays the economic activity of which is smaller than the average economic activity $(\alpha_j < \bar{\alpha})$ and which occur four times will contribute to its reduction. If Sunday occurs four times in the

37 When adjusting quarterly time series in the RC, the working-day effect is mostly not identified because of the short time span of time series.

38 The derived regression models are valid for the flow time series, and not valid for the stock time series.

observed month, then all weekdays from Monday to Saturday, which occur five times, contribute to the effect, and the corresponding values of contrast variables in the observed month are positive. The weekdays in which economic activity is larger than the average economic activity $(\alpha_j > \bar{\alpha})$ and which occur five times contribute to a decrease in the adjusted time series value in month t relative to the original value, and the weekdays on which economic activity is smaller than the average economic activity $(\alpha_j < \bar{\alpha})$ and which occur five times will contribute to its increase.

If we assume that economic activity on the days of the week from Monday to Saturday equals $(a_j^{(6)} = a^{(6)})(\forall j)$ and is larger than on Sunday $(\alpha_j > \alpha_7)(\forall j)$, trivially it follows that $a^{(6)} > 0$. In addition to the above assumption and designation $A_t^{(6)} = \sum_{j=1}^{6} A_{jt}^{(6)}$, the relation (38) can be written in the following form:

$$\sum_{j=1}^{7} \alpha_j D_{jt} = \bar{\alpha} N_t + a^{(6)} A_t^{(6)} \tag{39}$$

According to the relation (39), if Sunday occurs five times in the observed month, all weekdays from Monday to Saturday, which occur four times in the observed month, contribute to the effect. These days contribute to increasing the adjusted value of time series relative to the original value. If Sunday occurs four times in the observed month, then all days of the week from Monday to Saturday that occur five times contribute to the effect and to a decrease in the adjusted time series value relative to the original data.

The following designations are introduced for the derivation of regression models with the assumption of the same economic activity on specific days of the week:

$$\overline{a^{(k)}} = \frac{\sum_{j=1}^{k} a_j^{(k)}}{k} \tag{40}$$

$$A_t^{(k)} = \sum_{j=1}^{k} A_{jt}^{(k)} \tag{41}$$

$$A_{jt}^{(k-1)} = A_{jt}^{(k)} - A_{kt}^{(k)} \tag{42}$$

$$a_j^{(k-1)} = a_j^{(k)} - \overline{a^{(k)}} \tag{43}$$

By using the above introduced designations, analogous to the derivation of the relation (35), the following applies:

$$\sum_{j=1}^{k} a_j^{(k)} A_{jt}^{(k)} = \overline{a^{(k)}} A_t^{(k)} + \sum_{j=1}^{k-1} a_j^{(k-1)} A_{jt}^{(k-1)} \quad k \in \{2,3,4,5,6\} \tag{44}$$

By using the relation (44), the cumulative contribution of all days in the month can be shown in the following way:

$$\sum_{j=1}^{7} \alpha_j D_{jt} = \bar{\alpha} N_t + \sum_{k=l+1}^{6} \overline{a^{(k)}} A_t^{(k)} + \sum_{j=1}^{l} a_j^{(l)} A_{jt}^{(l)} \quad l \in \{1,2,3,4,5,6\} \tag{45}$$

If we assume that economic activity is the same in the first l days of the week, i.e. $a_j^{(l)} = a^{(l)}$ $(\forall j \in \{1,\ldots,l\})$, we transform relation (45) into the following form:

$$\sum_{j=1}^{7} \alpha_j D_{jt} = \bar{\alpha} N_t + \sum_{k=l+1}^{6} \overline{a^{(k)}} A_t^{(k)} + a^{(l)} A_t^{(l)} \tag{46}$$

Alternatively, by using the same assumption and relation (38), the following also applies:

$$\sum_{j=1}^{7} \alpha_j D_{jt} = \bar{\alpha} N_t + \tilde{a} \sum_{j=1}^{l} A_{jt}^{(6)} + \sum_{j=l+1}^{6} a_j^{(6)} A_{jt}^{(6)} \tag{47}$$

Accordingly, the working-day effect with the assumption of the same economic activity in the first l days of the week can be modelled using regression variables $\{A_t^{(k)}, k = l, \ldots, 6\}$ according to relation (46) or regression variables $\sum_{j=1}^{l} A_{jt}^{(6)}$ and $\{A_{jt}^{(6)}, j = l+1, ..., 6\}$ according to relation (47), where $\left(a_7^{(6)} = -\sum_{j=1}^{6} a_j^{(6)}\right)$.[39]

If we assume the same economic activity on working days ($l = 5$) and the same economic activity on Saturday and Sunday $(a_7^{(6)} = a_6^{(6)})$, since $a_7^{(6)} = -(5\tilde{a} + a_6^{(6)})$, the following is obtained:

$$a_6^{(6)} = \frac{-5}{2}\tilde{a} \tag{48}$$

By incorporating relation (48) into relation (47), a regression model is obtained :

$$\sum_{j=1}^{7} \alpha_j D_{jt} = \bar{a}N_t + \tilde{a}\left(\sum_{j=1}^{5} A_{jt}^{(6)} - \frac{5}{2} A_{6t}^{(6)}\right) \tag{49}$$

If we assume the same economic activity on weekdays from Monday to Thursday ($l = 4$) and the same economic activity on Friday, Saturday and Sunday $(a_7^{(6)} = a_6^{(6)} = a_5^{(6)})$, since $(a_7^{(6)} = a_6^{(6)} = a_5^{(6)})$, the following is obtained:

$$a_6^{(6)} = a_5^{(6)} = \frac{-4}{3}\tilde{a} \tag{50}$$

By incorporating relation (50) into relation (47), the following regression model is obtained:

$$\sum_{j=1}^{7} \alpha_j D_{jt} = \bar{a}N_t + \tilde{a}\left(\sum_{j=1}^{4} A_{jt}^{(6)} - \frac{4}{3}(A_{5t}^{(6)} + a_{6t}^{(6)})\right) \tag{51}$$

If $l = 4$, we can also assume that economic activity is the same on Fridays and Saturdays, and different on Sundays, and the regression model has the following form:

$$\sum_{j=1}^{7} \alpha_j D_{jt} = \bar{a}N_t + \tilde{a}\sum_{j=1}^{4} A_{jt}^{(6)} + a_5^{(6)}(A_{6t}^{(6)} + A_{5t}^{(6)}) \tag{52}$$

In addition, if we assume that economic activity is the same at weekends, and different on Fridays, the regression model is:

$$\sum_{j=1}^{7} \alpha_j D_{jt} = \bar{a}N_t + \tilde{a}_1\left(\sum_{j=1}^{4} A_{jt}^{(6)} - 2A_{6t}^{(6)}\right) + \tilde{a}_2\left(A_{5t}^{(6)} - \frac{1}{2}A_{6t}^{(6)}\right) \tag{53}$$

Table 10 gives an overview of a total of seven previously constructed regression models for the estimation of working-day effect for monthly time series, with the assumption that monthly data are a cumulative sum of daily values. The corresponding assumption of economic activity on specific weekdays is given for each model.[40]

For the estimation of the working-day effect we use a total of six contrast regression variables defined by relation (35), $D_{jt} - D_{7t}, j \in \{1, 2, 3, ..., 6\}$. In order to include public holidays in the analysis, we assume that economic activity on holidays is identical to that on Sundays. Then in relation (35) variable D_{7t} refers to the number of non-working days in the observed month. For example, on 25 December 2015, Christmas fell on a Friday so that the number of Fridays in that month was reduced by one, and the number of non-working days was increased by one. The inclusion of public holidays leads to the correction of contrast variables. If we use t_1 to designate December 2015, variable D_{5t_1} is then reduced by 1, i.e. variable D_{7t_1} is increased by 1, which results in a decrease in the contrast variable value by 2 in the observed month. A correction should be made for all months in which public holidays do not fall on a Sunday.

In the RC, we differentiate between two types of holidays: fixed and moving. Holidays that occur on a fixed date are called fixed, and those that occur on a certain number of days after Easter are called moving holidays. Fixed holidays include: New Year's Day (1 January), Epiphany (6 January), Labour Day (1 May),

39 Calendar adjusted values of a time series do not depend on the selection of the regression model since regression variables of a model can be obtained by the linear transformations of regression variables of another model.

40 For example, 'Mo-Th/Fr/Sa-Su' means that economic activity is the same on weekdays from Monday to Thursday, the same on Saturdays and Sundays, but different between Thursdays, Fridays and Saturdays, i.e. the symbol '/ ' divides the week into periods of different economic activity.

Anti-fascist Resistance Day (22 June), Statehood Day (25 June), Day of Victory and Patriotic Gratitude (5 August), Assumption Day (15 August), Independence Day (8 October), All Saints' Day (1 November), Christmas Day (25 December) and St Stephen's Day (26 December). Moving holidays include Easter Monday and Corpus Christi. Easter Monday is on the first Monday after Easter, and Corpus Christi on a Thursday precisely 60 days after Easter. Table 3 contains a list of weekdays for fixed public holidays in the Republic of Croatia from 2002 to 2016. In addition, Corpus Christi was introduced as a public holiday in 2002 and Statehood Day was on 30 May before 2002. Also, the funeral of the late President Franjo Tuđman was a non-working day, Monday 13 December 1999. As many as three Mondays were non-working days in 2000 because of national elections: 3 January, 24 January and 7 February.

Contrast regression variables should be corrected for the long-term effects of the distribution of public holidays on specific weekdays. The adjustment method is described in detail in Grudkowska (2015). All contrast regression variables are corrected by +1 in each month for each fixed holiday in the observed month. With regard to moving holidays, Tables 4 and 5 show the corrections of contrast regression variables for March and April because of Easter Monday, i.e. for May and June because of Corpus Christi. Since the probability that a fixed holiday falls on a specific weekday is equal to +1/7, the probability that in a month that contains one fixed holiday we have an extra day we treat as a Sunday is +6/7. Therefore, the average effect on variable D_{7t} in the observed month is +6/7, and on variable D_{jt} it is –1/7, due to which contrast regression variables change by the amount of –1/7 – 6/7 = –1 and are to be corrected by +1. With regard to moving holidays, since Easter falls within the time period from 22 March to 25 April, Corpus Christi may fall between 21 May and 24 June, i.e. Easter Monday may fall between 23 March and 26 April. Corpus Christi may be in May or June, and the probability of it being in May is equal to the probability of Easter being on 1 April or earlier, which is $p_1 = 133/500$.[41] By analogy, Easter Monday may be in March or April, and the probability of its falling in March is equal to the probability of Easter falling on 30 March or earlier, which is $p_2 = 94/500$.[42] Contrast regression variables for the month of March will be corrected so that the contrast variable that corresponds to a Monday is increased by $2p_2$, and others are increased by p_2. Contrast variables for the month of April will be corrected so that the contrast variable that corresponds to a Monday is increased by $2(1-p_2)$, and others are increased by $(1-p_2)$. Similarly, contrast variables for the month of May will be corrected so that the contrast variable that corresponds to a Thursday is increased by $2p_1$, and others are increased by p_1. Contrast variables for the month of June will be corrected so that the contrast variable that corresponds to a Thursday is increased by $2(1-p_1)$, and others are increased by $(1-p_1)$.

4 Seasonally adjusted data revision policy

The revision of seasonally adjusted data is implied by three factors. The first factor is the changes in original data due to the official revisions of bureaus of statistics, the second factor is the changes in the estimated model parameters as a result of new observations, while the third factor is the changes in the applied seasonal adjustment models. According to the first factor, each change in original data logically results in the change in seasonally adjusted data. According to the second factor, each new observation brings new information about the time series and implies changes in the estimated regression model parameters, which impacts the final S-component estimate and leads to revision history of the published rates of change of the SA time series. With regard to the third factor, the seasonal adjustment model can change in two cases: during the pre-treatment of a time series or the estimation of the S-component. In the first case, there may be a change in the transformation of the original time series, a change in the number and type of identified outliers, a change in the SARIMA

41 The computation based on the approximation used in the computation of regression variables for the adjustment of time series for the Easter effect.

42 The computation based on the approximation used in the computation of regression variables for the adjustment of time series for the Easter effect.

process and a change in the selection of regression variables for the adjustment of time series for calendar or other effects. In the second case, there may be a change in sigmalim limits and a change in the selection of the S- and TC-component estimation filters.

The revision policy defines the method and periods in which seasonally adjusted data are revised. One of the possibilities used in practice is that models are tested once a year, while the model is kept unchanged during one year. The unchanging model assumes that the following are without changes: the transformation of the original time series, the selection of the SARIMA process, the critical value for outlier identification, the selections of filters for the estimation of the S- and TC-components and the sigmalim limits. Also, the unchanging model assumes that the selections of regression variables for the estimation of calendar and anomaly effects are without changes. In estimating the S-component, pre-set filters for the estimation of the S- and TC-components are used in individual iterative steps, while automatic procedures are integrated in final step, which are used for the selection of filters depending on the relations of the estimated components.[43] The selections of filters according to the automatic procedures from the D-iteration, that are used for the final estimation of the S- and TC-components, can be fixed and kept unchanged during all iterations. By such a fixing of filters a potential revision of seasonally adjusted data within the year due to the change in filters is avoided. A change in sigmalim limits can be the consequence of a targeted decrease or increase in sensitivity[44] to the identification of extreme irregular values. For example, if some periods are extremely irregular, when the SI-component is split into the S- and I-components, the I-component will have a larger contribution, and the S-component will have a smaller contribution in a case in which sigmalim limits are larger, i.e. sensitivity to the identification of extreme irregular values is reduced. Then, the SA time series level is also higher in that period, which may result in a reduced rate of the SA time series in the subsequent period. Although changes in sigmalim limits are rare in practice, it is important to take into account the identified extreme values at the end of time series because, without future observations, it is often impossible to discern whether it is the case of a change in the intensity of seasonal movements or extreme irregularities.

Seasonally adjusted data may change between annual testings of the seasonal adjustment model because of the change in estimated model parameters and/or change in the number and type of identified outliers. Since in this case automatic procedures for the transformation of the original time series, the identification of the SARIMA process and the estimation of calendar effect are excluded, it is very likely that the number and the type of identified outliers will also be without change when new observations are added because the degree of freedom for the outlier identification is reduced. In addition, in order to avoid a revision of seasonally adjusted data with every new observation, forecasted seasonal and calendar factors[45] are used in practice, i.e. new seasonally and calendar adjusted data are computed by dividing original indices by forecasted factors in a multiplicative case, or by deduction in an additive case. In this case, there is no revision history of the SA time series. Factors may be forecasted up to 12 months and more, but for the forecasting of distant periods deviations of the recent estimations of the SA time series from the values obtained using the forecasted factors are larger. The extents of the deviations depend on the characteristics of the original time series and the stability of seasonal movements. At the Croatian National Bank, models are most frequently tested once a year, using December as the reference period. Model parameters are estimated with April and August as reference periods, while during January, February and March factors forecasted in December; during May, June and July, factors forecasted in April; and during September, October and November, factors forecasted in August are used.

43 The 3×3, 3×5 or 3×9 moving average filters are used for the estimation of the seasonal component and the Henderson filter with 5, 7, 13 or 23-terms for the estimation of the trend-cycle component.

44 Sensitivity to the identification of extreme irregular values decreases with an increase in sigmalim limits, while it increases with a decrease in sigmalim limits.

45 The forecasted values of the S-component and calendar component are known as forecasted factors.

5 Calendar effect on economic activity indicators in the Republic of Croatia

The analysis of calendar effects was made for monthly indicators of economic activity: the total industrial production volume index, the total volume index of construction works and the total retail trade turnover index (in real and nominal terms). In the JDemetra+ software package it is possible to use pre-defined seasonal adjustment specifications.[46] By applying such a specification, the working-day effect is identified for all time series, while the Easter effect is identified for retail trade turnover indices. The above is in line with expectations, since at least some industrial plants, construction companies and retail stores are closed on weekends, or at least on Sundays, so that production, the volume of construction works and retail trade turnover are reduced on such days. Also, in the time period before Easter retail trade turnover increases, as expected, because of sales and an increase in household consumption. For this reason, different models of adjustment for the working-day effect were tested for all time series, and different models of adjustment for the Easter effect were tested for the retail trade turnover index.

In total, three models were tested for the working-day effect: the *wd1* model that does not include public holidays and assumes the same economic activity on the days from Monday to Friday, the *wd2* model that includes public holidays and assumes the same economic activity on the days from Monday to Friday and the *wd3* model that includes public holidays and assumes the same economic activity on the days from Monday to Saturday. For the Easter effect, models were tested that assume an increase in the retail trade turnover 15, 13, 8 or 6 days before Easter, designated as (–15,–1), (–13,–1), (–8,–1) and (–6,–1) models respectively.[47] The leap year effect has also been tested, i.e. whether there is an increase in production, the volume of construction works or retail trade turnover because of an extra working day in February in a leap year, designated as the *ly* model. The overall calendar adjustment model consists of the selection of individual models for working days, Easter and leap year effects, while the model without a calendar adjustment is designated as *x*.

The previously identified outliers[48] for the total industrial production index include: a level shift in December 2008 (*ls2008.12*), an additive outlier in August 2011 (*ao2011.8*) and a level shift in January 2012 (*ls2012.1*). In December 2008, due to the global economic crisis, a decline in the production of all GIG components was recorded, in particular of durable consumer goods, a decline in production in manufacturing, which resulted in the accumulation of inventories. In the third quarter of 2011, industrial production declined primarily due to the weakening of both foreign and domestic demand, with the sharpest fall in output levels recorded in capital goods (CNB, Bulletin 175). In January 2012, foreign and domestic demand declined and the production of tobacco and drinks also declined (CNB Bulletin 180).

The previously identified outliers for the total volume index of construction works include: a level shift in January 2008 (*ls2008.1*) and an additive outlier in February 2012 (ao2012.2). Many public investments were planned at the end of 2007, and previously planned facilities were built in January and February 2008. A constant slowdown in the growth of housing loans and a drop in the planned real estate investments of households was recorded in the rest of 2008 (CNB, Bulletin 139) and stagnation in government investment in road construction in addition to a markedly reduced number of building permits for all types of buildings (CNB, Bulletin 140).

The previously identified outliers for the total retail trade turnover index (in nominal and real terms) include: a temporary change in August 2007 (tc2008.8)[49] and a level shift in January 2009 (ls2009.1). In August 2007, a very high level of retail trade turnover in real terms was recorded, primarily the consequence of a

46 Such specifications contain pre-set automatic procedure settings, predefined sigmalim limits and the value of the critical paremeter for outlier identification.

47 For each choice of the regression model, an additional effect of adding a regression variable by which the decline in activity on Easter and Easter Monday was tested, but such models were rejected.

48 The previously identified outliers and as such preset in seasonal adjustment specifications.

49 Such an outlier is abbreviated as TC (temporary change).

strong growth in demand during the main tourist season and favourable movements in the labour market. In addition, the sales of motor vehicles, motor fuels and lubricants rose sharply. In January 2009, a negative impact on the movement in retail trade was attributed to the weakening of consumer optimism due to worsened economic conditions at the time, coupled with more difficult borrowing conditions and increased burden of the existing repayments. The purchase of motor vehicles, primarily cars, fell sharply due to the decline in demand by natural and legal persons. In addition, the ban on Sunday trading also contributed to the decline in retail trade.

The results of the analysis for different tested calendar adjustment models are given in tables 6, 7, 8 and 9, for the total index of the industrial production volume, the total volume index of construction works and the total index of real retail trade turnover (in nominal and real terms) respectively. The tables contain the corresponding information criteria values (aic, aicc, bic, bicc), the identified SARIMA processes, the lists of outliers[50], the selections of original indices transformations, with designation 1 for logarithmic transformation or 0 for no transformation and the selections of constants in regression models, with designation 1 for the added constant or 0 for no constant.

The decision on the final selection of a regression model is based on the criterion of the minimum information criteria value. For the total industrial production index the following was selected: the additive model without a constant, the SARIMA process (011)(011) with included regression variables for the estimation of the working-day (wd2) and the leap year (ly) effects and without additional outliers. For the total volume index of construction works the following was selected: the multiplicative model without a constant, the SARIMA process (110)(011) with regression variables for the estimation of the working-day effect (wd2) and without additional outliers. For the total retail trade turnover index in nominal terms the following was selected: the multiplicative model without a constant, the SARIMA process (011)(011) with regression variables for the estimation of the working-day (wd3), the leap year (ly) and Easter (–13,–1) effects and without additional outliers. For the total retail trade turnover index in real terms, two regression models were taken into consideration, both containing regression variables for the estimation of the working-day effect (wd3). The first model is multiplicative and without a constant, the SARIMA process (011)(011) with regression variables for the estimation of the leap year (ly) and Easter effects (–13,–1), and the second one, also multiplicative and without a constant, the SARIMA process (110)(011) with regression variables for the estimation of the leap year (ly) and Easter effects (–6,–1). Considering the final selection of the model for the retail trade turnover index in nominal terms and since according to the relation (31) it is not possible to reject the first suggested model relative to the second one, although it has higher information criteria values, the first model was selected for the retail trade turnover index in real terms.

Regression analysis results, taking into consideration previous calendar adjustment selections, are presented in Tables 11, 12, 13 and 14. The tables show all regression variables, corresponding parameter estimates, assigned t-statistics, p-values and the time span of the original data (span) and the time span on which the estimation of the regression model was made[51] (modelspan). They also show the F-test results for calendar adjustment models that include two or more regression variables. For the time series for which an airline model is identified, the tables show the estimates of the ma(1) and sma(1) parameters, designated as Theta(1) and BTheta(1) respectively. For the time series for which the (110)(011) model is identified, the table shows the ar(1) and sma(1) parameter estimates, designated as Phi(1) and BTheta(1) respectively.

Figures 5, 7, 9 and 11 show original indices (y), seasonally adjusted indices (sa) and calendar adjusted indices (ycal), and figures 6, 8, 10 and 12 show the corresponding year-on-year rates of change (yoy) for original and calendar adjusted indices, i.e. month-on-month rates of change (mom) for seasonally adjusted indices. Estimations were made with the latest observation for December 2015[52] and the figures show the results

50 The list does not include outliers that are pre-set in seasonal adjustment specifications.

51 If the time span for the regression model estimation excludes observations in the initial years, they are excluded for the purpose of better quality calendar and seasonal effects in recent periods.

52 According to the revision policy, seasonal adjustment models selected in December 2015 were applied in 2016 and no changes were made to the models on the occasion of the model retesting in December 2016.

for 2014 and 2015.[53] The above rates of change are often used for the interpretation of economic trends. However, in addition to differences in the amount, the rates of change are often different by their sign, which can apparently give contradictory information about economic trends.

For example, for the volume index of construction works, in January 2015 a positive month-on-month rate of the seasonally adjusted index was observed, standing at 2.3%, a positive year-on-year rate of the calendar adjusted index of 0.3%, while the year-on-year rate of change of the original index was negative, standing at –3.1%. Public holidays in January 2014 were on Monday and Wednesday, and in January 2015 they were on Tuesday and Thursday so that there was no difference in economic activity of these months due to public holidays. However, in January 2014, Wednesday, Thursday and Friday occurred five times, while in January 2015, Thursday, Friday and Saturday occurred five times. Therefore, by adjusting for the working-day effect, the level of the original time series in January 2014 decreased due to an extra working day, and in 2015 it increased, which led to a positive year-on-year rate of the calendar adjusted index.

For the industrial production volume index, the year-on-year rate of change of the original and the calendar adjusted index in December 2014 stood at 6.9% and 4.7% respectively. Monday, Tuesday and Wednesday occurred five times in December 2014, and Tuesday, Wednesday and Thursday in December 2015. However, public holidays in December 2014 were on Thursday and Friday, and in 2015 on Friday and Saturday; again there was an extra working day in December 2014 relative to December 2015, which resulted in a difference in the rate of 2.2 percentage points.

For the retail trade turnover index in real terms, in April 2015, the month-on-month rate of the seasonally adjusted index was 1%, the year-on-year rate of the calendar adjusted index was 3.3%, while the year-on-year rate of change of the original index was 1.5%. Since Tuesday and Wednesday occurred five times in April 2014, and Wednesday and Thursday occurred five times in April 2015, and Easter Monday was the only holiday that was not on a Sunday in the mentioned months, there was no working-day effect in the mentioned months because we assumed the same economic activity on the days from Monday to Saturday. Therefore, the only difference of the year-on-year rate of the original and calendar adjusted indices is caused by the early date of Easter in 2015, 5 April, relative to 2014 when it was on 20 April.

Table 15 contains the results of percentage revisions (rev_t) of the final SA time series ($SA_{t/L}$) estimate relative to the current estimate ($SA_{t/t}$), where L stands for December 2015, and $SA_{i/j}$ stands for the seasonally adjusted value at time i, for estimation with the latest observation j. Table 15 contains the calculations for the mean percentage revision (mean), root mean square deviation from the mean value (rmse) and mean absolute percentage revision (absmean), for the last four years.

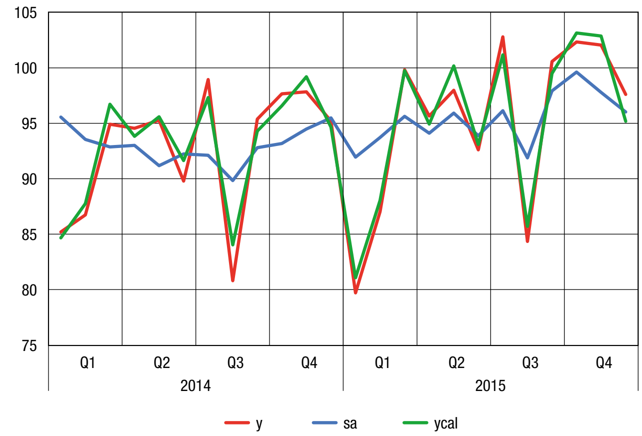
$$rev_t = 100\left(\frac{SA_{t/L}}{SA_{t/t}} - 1\right) \tag{54}$$

According to the results in Table 15, the final estimates of the SA time series value made on the time span up to December 2015 changed in absolute amounts on average by 0.61%, 0.55%, 0.45%, i.e. 0.43% over the last 4 years from the first estimates, for the indices of industrial production volume, the volume of construction works and retail trade turnover (in nominal and real terms) respectively. Thus the difference of the final rate of change relative to its first estimate can amount to a couple of percentage points, which should be taken into account when interpreting seasonal adjustment results.

Also, the seasonal adjustment of economic activity indicators was made by a direct approach, i.e. all effects were identified on aggregated indices. An alternative approach is to make the adjustment of the total index by aggregating the adjusted sub-components. However, the errors of such estimates would be major since individual aggregate components are most frequently characterised by a larger instability of seasonal movements and more identified outliers.

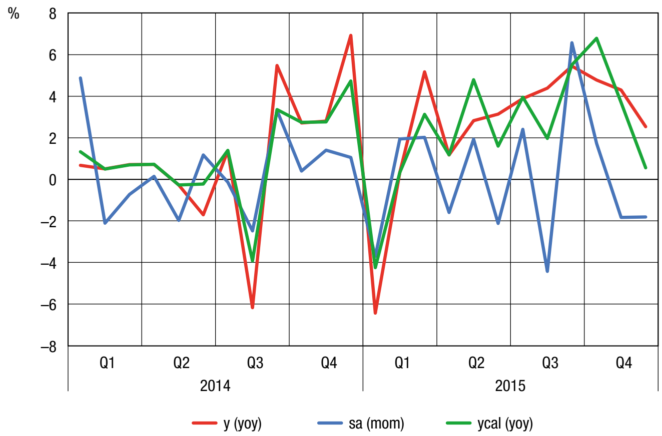
53 When estimating the S-component, filters for the estimation of the S- and TC-components are not fixed and there may be differences relative to the officially published seasonal and calendar adjusted data.

Figure 5 Original, seasonal and calendar adjusted total industrial production volume index



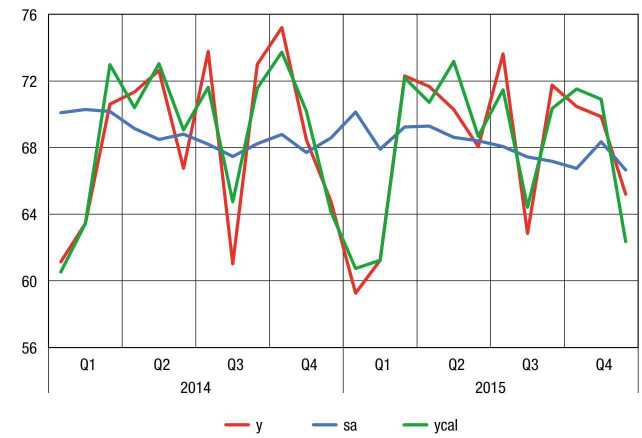
Source: Author's calculation.

Figure 6 Rates of change of total industrial production volume index



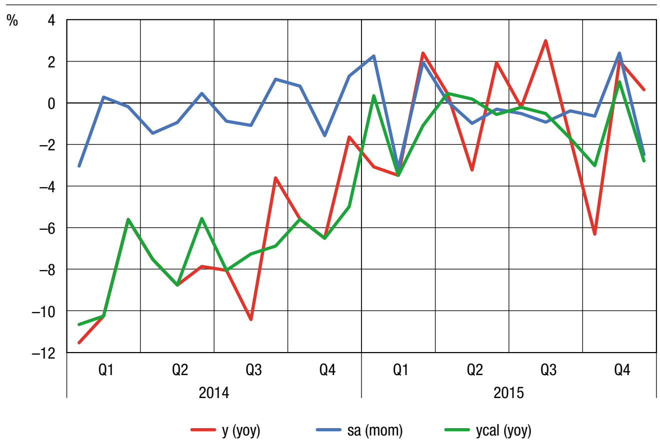
Source: Author's calculation.

Figure 7 Original, seasonal and calendar adjusted total volume index of construction works



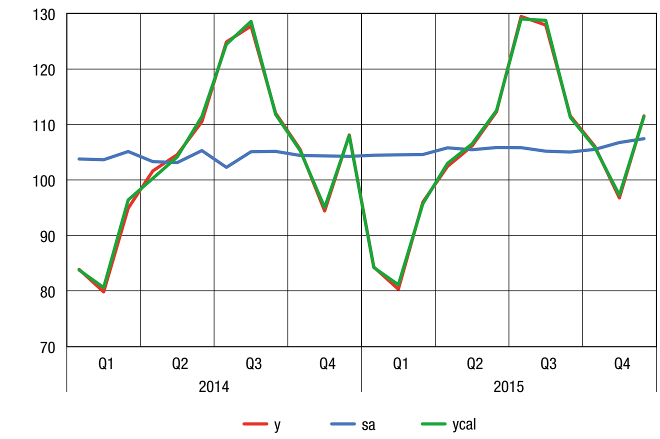
Source: Author's calculation.

Figure 8 Rates of change of total volume index of construction works



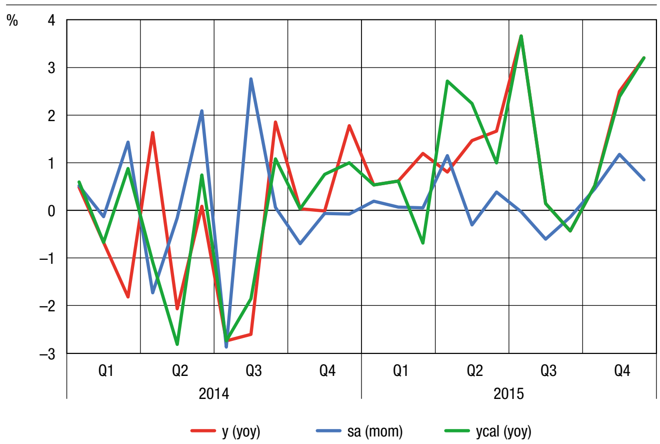
Source: Author's calculation.

Figure 9 Original, seasonal and calendar adjusted total value retail trade turnover index



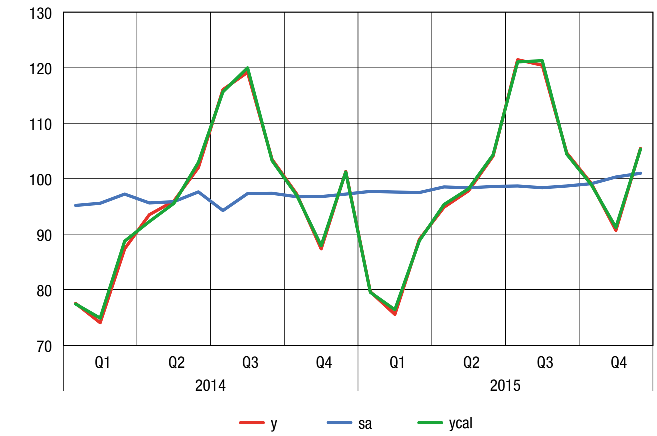
Source: Author's calculation.

Figure 10 Rates of change of total retail trade turnover index in nominal terms



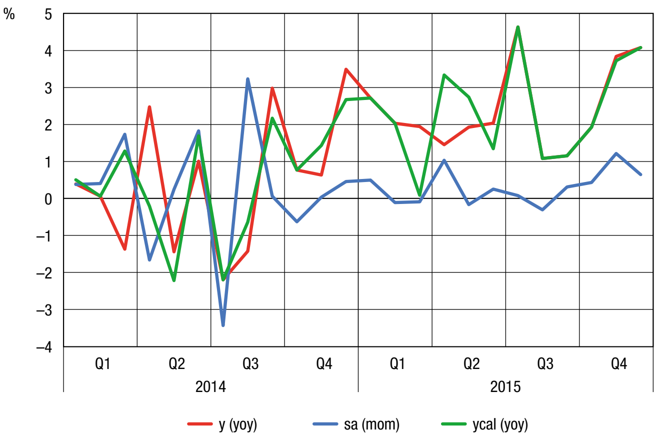
Source: Author's calculation.

Figure 11 Original, seasonal and calendar adjusted total retail trade turnover index in real terms



Source: Author's calculation.

Figure 12 Rates of change of total retail trade turnover index in real terms



Source: Author's calculation.

6 Conclusion

The paper describes the steps of the seasonal adjustment process, and the main indicators of economic activity in the RC were seasonally adjusted: industrial production, volume of construction works and retail trade turnover. The working-day effect was identified for all of the above indicators, the leap year effect was identified for all but the volume of construction works, and the Easter effect for the retail trade turnover only. Regression models used for the estimation of the working-day effect for industrial production volume and the volume of construction works assume the same economic activity from Monday to Friday and reduced activity at weekends, while for the retail trade turnover they assume the same economic activity from Monday to Saturday and reduced activity on Sundays. All of the above models assume reduced activity on public holidays. The regression model used for the estimation of Easter effect for the retail trade turnover assumes growth in activity that lasts for 13 days, starting on Monday, two weeks before Easter, and ending on Saturday, the day before Easter.

Since the calendar has a significant impact on economic activity, regression models for the estimation of calendar effects derived in the paper can be used when developing econometric models to forecast the movements of original indices. The assumptions and limitations of the applied models can be used in the interpretation of seasonal adjustment results. Thus month-on-month rates of change of seasonally adjusted time series are often used for the analysis of recent movements, and such series are the result of the regression model estimation during the pre-treatment of time series and the seasonal component estimation. During the pre-treatment, calendar and outlier effects are adjusted. For the estimation of the individual calendar effect, a single parameter is estimated, by which the average calendar effect on the given time span is identified and the possibility of its time dependence is neglected. Also, a seasonally adjusted time series contains all atypical values, which are assigned to the irregular or trend-cycle component through the adjustment process. The final seasonal component estimate depends on the stability of the seasonal movements of the original series, the time span of the regression model estimation, methodological and other changes made when constructing original series, and on the applied method for the seasonal component estimation. For this reason, the estimates of seasonally adjusted values for the latest observations are always temporary and require several years to reach their approximate final values. In specific periods, the errors made by use of forecasting seasonal and calendar factors also contribute to the estimation error and the users of seasonally adjusted data should be informed about the revision policy applied.

7 References

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Appendix

Table 1 Easter dates in the time period from 1998 to 2027

Year	Easter	Year	Easter
1998	12 April	2013	31 March
1999	4 April	2014	20 April
2000	23 April	2015	5 April
2001	15 April	2016	27 March
2002	31 March	2017	16 April
2003	20 April	2018	1 April
2004	11 April	2019	21 April
2005	27 March	2010	12 April
2006	16 April	2021	4 April
2007	8 April	2022	17 April
2008	23 March	2023	9 April
2009	12 April	2024	31 March
2010	4 April	2025	20 April
2011	24 April	2026	5 April
2012	8 April	2027	28 March

Table 2 Number of Easter occurrences on the observed dates for different selections of time spans

Date	1st span*	2nd span*	3rd span*	Date	1st span*	2nd span*	3rd span*
22/3	27,550	4	3	9/4	186,200	9	12
23/3	54,150	6	7	10/4	192,850	16	18
24/3	81,225	2	2	11/4	186,200	17	21
25/3	110,200	7	9	12/4	192,850	13	18
26/3	13,300	12	15	13/4	189,525	12	14
27/3	165,300	13	15	14/4	189,525	14	15
28/3	186,200	10	12	15/4	192,850	12	18
29/3	192,850	12	13	16/4	186,200	17	22
30/3	189,525	12	18	17/4	192,850	15	17
31/3	189,525	16	22	18/4	197,400	14	16
1/4	192,850	15	17	19/4	220,400	12	17
2/4	186,200	14	15	20/4	189,525	10	15
3/4	192,850	10	16	21/4	162,450	14	17
4/4	186,200	11	16	22/4	137,750	12	14
5/4	192,850	17	21	23/4	106,400	4	6
6/4	189,525	17	18	24/4	82,650	4	6
7/4	189,525	11	15	25/4	42,000	4	5
8/4	192,850	12	15				

* The 1st, the 2nd and the 3rd span refer to the following periods of time respectively:: 5.7 million years, the first cycle of the Gregorian calendar, 1600 – 2099.

Table 3 Days of the week* for fixed public holidays in the Republic of Croatia from 2002 to 2016**

Public holidays:	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
New Year's Day	Tu	We	Th	Sa	Su	Mo	Tu	Th	Fr	Sa	Su	Tu	We	Th	Fr
Epiphany	Su	Mo	Tu	Th	Fr	Sa	Su	Tu	We	Th	Fr	Su	Mo	Tu	We
Labour Day	We	Th	Sa	Su	Mo	Tu	Th	Fr	Sa	Su	Tu	We	Th	Fr	Su
Anti-fascist Resistance Day	Sa	Su	Tu	We	Th	Fr	Su	Mo	Tu	We	Fr	Sa	Su	Mo	We
Statehood Day	Tu	We	Fr	Sa	Su	Mo	We	Th	Fr	Sa	Mo	Tu	We	Th	Sa
Day of Victory and Patriotic Gratitude	Mo	Tu	Th	Fr	Sa	Su	Tu	We	Th	Fr	Su	Mo	Tu	We	Fr
Assumption Day	Th	Fr	Su	Mo	Tu	We	Fr	Sa	Su	Mo	We	Th	Fr	Sa	Mo
Independence Day	Tu	We	Fr	Sa	Su	Mo	We	Th	Fr	Sa	Mo	Tu	We	Th	Sa
All Saints' Day	Fr	Sa	Mo	Tu	We	Th	Sa	Su	Mo	Tu	Th	Fr	Sa	Su	Tu
Christmas Day	We	Th	Sa	Su	Mo	Tu	Th	Fr	Sa	Su	Tu	We	Th	Fr	Su
St Stephen's Day	Th	Fr	Su	Mo	Tu	We	Fr	Sa	Su	Mo	We	Th	Fr	Sa	Mo

* Mo, Tu, We, Th, Fr, Sa and Su refer to the days from Monday to Sunday.
** 02, 03, ..16 refer to the years from 2002 to 2016 respectively.

Table 4 Correction of contrast regression variables due to Easter Monday

Month	D_{7t}	D_{1t}	$D_{jt}\ j \neq 1,7$	$\Delta(D_{1t}-D_{7t})$	$\Delta(D_{jt}-D_{7t})\ j \neq 1$
March	$+p_2$	$-p_2$	0	$-2p_2$	$-p_2$
April	$+(1-p_2)$	$-(1-p_2)$	0	$-2(1-p_2)$	$-(1-p_2)$

Table 5 Correction of contrast regression variables due to Corpus Christi

Month	D_{7t}	D_{4t}	$D_{jt}\ j \neq 4,7$	$\Delta(D_{4t}-D_{7t})$	$\Delta(D_{jt}-D_{7t})\ j \neq 1$
May	$+p_1$	$-p_1$	0	$-2p_1$	$-p_1$
June	$+(1-p_1)$	$-(1-p_1)$	0	$-2(1-p_1)$	$-(1-p_1)$

Table 6 Regression models and corresponding information criteria values for the total industrial production volume index

Model	SARIMA	Outliers	log	const	aic	aicc	bic	bicc
wd1+ly	(011)(011)	x	0	0	743.67	744.66	768.02	2.00
wd1	(011)(011)	x	0	0	751.20	751.96	772.50	2.02
wd2+ly	(011)(011)	x	0	0	720.59*	721.58*	744.94*	1.87*
wd2	(011)(011)	x	0	0	729.83	730.60	751.14	1.90
wd3+ly	(011)(011)	x	0	0	743.68	744.66	768.02	2.00
wd3	(011)(011)	x	0	0	753.14	753.90	774.45	2.04
ly	(311)(011)	x	0	0	797.71	799.24	828.15	2.37
x	(311)(011)	x	0	0	803.42	804.66	830.81	2.38

* The minimum value of the corresponding information criterion on the observed set of models.

Table 7: Regression models and corresponding values of information criteria for the total volume index of construction works

Model	SARIMA	Outliers	log	const	aic	aicc	bic	bicc
wd1+ly	(011)(011)	x	1	0	515.05	516.18	533.76	–6.97
wd1	(011)(011)	x	1	0	514.98	515.82	531.02	–6.99
wd2+ly	(110)(011)	x	1	0	491.40	492.53	510.11	–7.18
wd2	(110)(011)	x	1	0	490.16*	491.00*	506.20*	–7.22*
wd3+ly	(210)(011)	tc(2–2009)	1	0	548.76	550.61	572.81	–6.56
wd3	(210)(011)	tc(2–2009)	1	0	550.12	551.59	571.51	–6.58
ly	(211)(111)	tc(2–2009), tc(1–2007)	1	0	561.62	564.40	591.02	–6.44
x	(210)(011)	tc(1–2010)	1	0	579.85	581.32	601.23	–6.43

* The minimum value of the corresponding information criterion on the observed set of models.

Table 8 Regression models and corresponding values of information criteria for the total retail trade turnover index in nominal terms

Model	SARIMA	Outliers	log	const	aic	aicc	bic	bicc
wd1	(0,1,1)(0,1,1)	x	0	0	524.85	525.60	541.52	1.66
wd1+ly	(1,1,0)(0,1,1)	x	1	0	514.26	515.27	533.71	–7.69
wd1+ly+(–15,–1)	(0,1,1)(0,1,1)	x	1	0	493.57	494.88	515.81	–7.83
wd1+ly+(–13,–1)	(0,1,1)(0,1,1)	x	1	0	492.82	494.13	515.06	–7.84
wd1+ly+(–8,–1)	(0,1,1)(0,1,1)	x	1	0	498.22	499.53	520.45	–7.79
wd1+ly+(–6,–1)	(0,1,1)(0,1,1)	x	1	0	504.05	505.36	526.28	–7.75
wd1+(–15,–1)	(2,1,1)(0,1,1)	x	0	0	501.86	503.51	526.87	1.53
wd1+(–13,–1)	(2,1,1)(0,1,1)	x	0	0	502.10	503.75	527.11	1.54
wd1+(–8,–1)	(0,1,1)(0,1,1)	x	0	0	513.21	514.22	532.67	1.59
wd1+(–6,–1)	(0,1,1)(0,1,1)	x	0	0	514.20	515.21	533.66	1.59
wd2	(0,1,1)(0,1,1)	x	0	0	529.70	530.45	546.38	1.70
wd2+ly	(1,1,0)(0,1,1)	x	1	0	519.02	520.03	538.47	–7.65
wd2+ly+(–15,–1)	(0,1,1)(0,1,1)	x	1	0	498.00	499.31	520.23	–7.79
wd2+ly+(–13,–1)	(0,1,1)(0,1,1)	x	1	0	496.92	498.23	519.15	–7.80
wd2+ly+(–8,–1)	(0,1,1)(0,1,1)	x	1	0	501.63	502.94	523.87	–7.76
wd2+ly+(–6,–1)	(0,1,1)(0,1,1)	x	1	0	505.24	506.55	527.47	–7.73
wd2+(–15,–1)	(2,1,1)(1,1,0)	x	0	0	502.43	504.08	527.44	1.54
wd2+(–13,–1)	(2,1,1)(1,1,0)	x	0	0	501.97	503.62	526.98	1.54
wd2+(–8,–1)	(2,1,1)(1,1,0)	x	0	0	506.60	508.25	531.61	1.57
wd2+(–6,–1)	(2,1,1)(1,1,0)	x	0	0	508.53	510.18	533.54	1.59
wd3	(0,1,1)(0,1,1)	x	0	0	527.02	527.77	543.70	1.67
wd3+ly	(1,1,0)(0,1,1)	x	1	0	515.36	516.37	534.81	–7.68
wd3+ly+(–15,–1)	(0,1,1)(0,1,1)	x	1	0	492.03	493.34	514.26	–7.84
wd3+ly+(–13,–1)	(0,1,1)(0,1,1)	x	1	0	489.95*	491.26*	512.18*	–7.86*
wd3+ly+(–8,–1)	(0,1,1)(0,1,1)	x	1	0	491.05	492.36	513.28	–7.86
wd3+ly+(–6,–1)	(0,1,1)(0,1,1)	x	1	0	492.70	494.01	514.94	–7.84
wd3+(–15,–1)	(2,1,1)(1,1,0)	x	0	0	499.05	500.70	524.06	1.51
wd3+(–13,–1)	(2,1,1)(0,1,1)	x	0	0	497.97	499.62	522.98	1.50
wd3+(–8,–1)	(2,1,1)(1,1,0)	x	0	0	500.90	502.56	525.92	1.52
wd3+(–6,–1)	(0,1,1)(1,1,0)	x	0	0	502.86	503.87	522.31	1.50
ly+(–15,–1)	(0,1,1)(0,1,1)	x	1	0	507.07	508.08	526.53	–7.74
ly+(–13,–1)	(0,1,1)(0,1,1)	x	1	0	506.55	507.56	526.01	–7.74
ly+(–8,–1)	(0,1,1)(0,1,1)	x	1	0	510.80	511.81	530.25	–7.71

Model	SARIMA	Outliers	log	const	aic	aicc	bic	bicc
ly+(–6,–1)	(0,1,1)(0,1,1)	x	1	0	513.90	514.91	533.35	–7.68
ly	(0,1,1)(0,1,1)	x	1	0	521.14	521.89	537.82	–7.65
(–15,–1)	(2,1,1)(0,1,1)	x	0	0	509.15	510.46	531.38	1.57
(–13,–1)	(2,1,1)(0,1,1)	x	0	0	509.26	510.57	531.49	1.57
(–8,–1)	(2,1,1)(0,1,1)	x	0	0	514.47	515.78	536.70	1.62
(–6,–1)	(2,1,1)(0,1,1)	x	0	0	516.63	517.94	538.86	1.63
x	(0,1,1)(0,1,1)	x	0	0	530.83	531.36	544.72	1.69

* The minimum value of the corresponding information criterion on the observed set of models.

Table 9: Regression models and corresponding values of information criteria for the total retail trade turnover index in real terms

Model	SARIMA	Outliers	log	const	aic	aicc	bic	bicc
wd1	(0,1,1)(0,1,1)	x	0	0	526.48	527.23	543.15	1.67
wd1+ly	(1,1,0)(0,1,1)	x	1	0	514.91	515.92	534.36	–7.66
wd1+ly+(–15,–1)	(0,1,1)(0,1,1)	x	1	0	496.24	497.55	518.47	–7.78
wd1+ly+(–13,–1)	(0,1,1)(0,1,1)	x	1	0	496.09	497.40	518.33	–7.79
wd1+ly+(–8,–1)	(0,1,1)(0,1,1)	x	1	0	502.04	503.35	524.27	–7.74
wd1+ly+(–6,–1)	(0,1,1)(0,1,1)	x	1	0	504.47	505.78	526.70	–7.72
wd1+(–15,–1)	(2,1,1)(0,1,1)	x	0	0	503.51	505.16	528.52	1.54
wd1+(–13,–1)	(2,1,1)(0,1,1)	x	0	0	504.76	506.41	529.77	1.55
wd1+(–8,–1)	(0,1,1)(0,1,1)	x	1	0	502.04	503.35	524.27	–7.74
wd1+(–6,–1)	(0,1,1)(0,1,1)	x	1	0	504.47	505.78	526.70	–7.72
wd2	(0,1,1)(0,1,1)	x	0	0	531.08	531.83	547.75	1.71
wd2+ly	(1,1,0)(0,1,1)	x	1	0	519.69	520.70	539.15	–7.62
wd2+ly+(–15,–1)	(0,1,1)(0,1,1)	x	1	0	500.98	502.28	523.21	–7.75
wd2+ly+(–13,–1)	(0,1,1)(0,1,1)	x	1	0	500.53	501.84	522.77	–7.75
wd2+ly+(–8,–1)	(0,1,1)(0,1,1)	x	1	0	505.84	507.15	528.08	–7.71
wd2+ly+(–6,–1)	(0,1,1)(0,1,1)	x	1	0	505.75	507.05	527.98	–7.71
wd2+(–15,–1)	(2,1,1)(0,1,1)	x	0	0	503.93	505.58	528.94	1.55
wd2+(–13,–1)	(2,1,1)(0,1,1)	x	0	0	504.64	506.29	529.65	1.55
wd2+(–8,–1)	(2,1,1)(0,1,1)	x	0	0	510.86	512.51	535.87	1.60
wd2+(–6,–1)	(0,1,1)(1,1,0)	x	0	0	510.30	511.95	535.31	1.59
wd3	(0,1,1)(0,1,1)	x	0	0	528.24	528.99	544.91	1.68
wd3+ly	(0,1,1)(0,1,1)	x	1	0	517.90	518.91	537.35	–7.63
wd3+ly+(–15,–1)	(0,1,1)(0,1,1)	x	1	0	494.84	496.15	517.07	–7.80
wd3+ly+(–13,–1)	(0,1,1)(0,1,1)	x	1	0	493.53*	494.84*	515.76*	–7.81*
wd3+ly+(–8,–1)	(0,1,1)(0,1,1)	x	1	0	495.81	497.11	518.04	–7.79
wd3+ly+(–6,–1)	(1,1,0)(0,1,1)	x	1	0	492.07*	493.38*	514.30*	–7.82*
wd3+(–15,–1)	(2,1,1)(0,1,1)	x	0	0	501.24	502.90	526.26	1.52
wd3+(–13,–1)	(2,1,1)(0,1,1)	x	0	0	501.64	503.29	526.65	1.53
wd3+(–8,–1)	(0,1,1)(0,1,1)	x	0	0	513.98	514.99	533.43	1.59
wd3+(–6,–1)	(0,1,1)(1,1,0)	x	0	0	505.69	506.70	525.14	1.52
ly+(–15,–1)	(0,1,1)(0,1,1)	x	1	0	509.71	510.72	529.17	–7.69
ly+(–13,–1)	(0,1,1)(0,1,1)	x	1	0	509.65	510.66	529.11	–7.69
ly+(–8,–1)	(0,1,1)(0,1,1)	x	1	0	514.28	515.29	533.74	–7.66
ly+(–6,–1)	(0,1,1)(0,1,1)	x	1	0	514.82	515.83	534.27	–7.65
ly	(0,1,1)(0,1,1)	x	1	0	522.30	523.05	538.98	–7.62
(–15,–1)	(2,1,1)(0,1,1)	x	0	0	510.69	512.00	532.92	1.58

Model	SARIMA	Outliers	log	const	aic	aicc	bic	bicc
(–13,–1)	(2,1,1)(0,1,1)	x	0	0	511.56	512.87	533.79	1.58
(–8,–1)	(2,1,1)(0,1,1)	x	0	0	517.38	518.69	539.62	1.63
(–6,–1)	(2,1,1)(0,1,1)	x	0	0	517.50	518.80	539.73	1.63
x	(0,1,1)(0,1,1)	x	0	0	532.81	533.34	546.70	1.70

* The minimum values of the corresponding information criterion on the observed set of models.

Table 10 Regression models for the adjustment of time series for the working-day effect

Regression model	Assumptions*
$\sum_{j=1}^{6} a_j^{(6)} A_{jt}^{(6)}$	Mo/Tu/We/Th/Fr/Sa/Su
$\tilde{a}\sum_{j=1}^{6} A_{jt}^{(6)}$	Mo–Sa/Su
$\tilde{a}\sum_{j=1}^{5} A_{jt}^{(6)} + a_6^{(6)} A_{6t}^{(6)}$	Mo–Fr/Sa/Su
$\tilde{a}\left(\sum_{j=1}^{5} A_{jt}^{(6)} - \frac{5}{2} A_{6t}^{(6)}\right)$	Mo–Fr/Sa–Su
$\tilde{a}\left(\sum_{j=1}^{4} A_{jt}^{(6)} - \frac{4}{3}(A_{5t}^{(6)} + A_{6t}^{(6)})\right)$	Mo–Th/Fr–Sa–Su
$a\sum_{j=1}^{4} A_{jt}^{(6)} + a_5^{(6)}(A_{5t}^{(6)} + A_{6t}^{(6)})$	Mo–Th/Fr–Sa/Su
$\tilde{a}_1\left(\sum_{j=1}^{4} A_{jt}^{(6)} - 2A_{6t}^{(6)}\right) + \tilde{a}_2\left(A_{5t}^{(6)} - \frac{1}{2} A_{6t}^{(6)}\right)$	Mo–Th/Fr/Sa–Su

* Weekdays from Monday to Sunday are abbreviated as: Mo, Tu, We, Th, Fr, Sa and Su.
'a-b' stands for the same economic activity from day a to day b.
'a/b' stands for different economic activity of periods a and b.

Table 11 Result of the regression analysis** for the total industrial production volume index

	Parametar	t-stat	p-value
Theta(1)	–0.58	–8.84	0.00
BTheta(1)	–0.76	–11.94	0.00
wd2*	0.54	10.92	0.00
ly*	4.08	3.37	0.00
ls(2008.12)	–7.57	–4.26	0.00
ao(2011.8)	–4.76	–2.43	0.02
ls(2012.1)	–7.30	–4.03	0.00

* F-Test = 65.59 (0.0000)
** Span: 1998.1 – 2015.12, modelspan: 2002.1 – 2015.12.

Table 12 Result of the regression analysis* for the total volume index of construction works

	Parametar	t-stat	p-value
Phi(1)	0.28	2.95	0.00
BTheta(1)	–0.63	–7.73	0.00
wd2	0.01	19.85	0.00
ls(2008.1)	0.13	5.54	0.00
ao(2012.2)	–0.11	–6.37	0.00

* Span: 2000.1 – 2015.12, modelspan: 2006.1 – 2015.12.

Table 13 Result of the regression analysis** for the total retail trade turnover index

	Parametar	t-stat	p-value
Theta(1)	–0.17	–1.84	0.07
BTheta(1)	–0.32	–3.63	0.00
wd3*	0.001	4.50	0.00
ly*	0.04	5.15	0.00
(–13,-1)*	0.03	6.06	0.00
ls(2009.1)	–0.05	–3.56	0.00
tc(2007.8)	0.05	3.86	0.00

* F-Test = 23.39 (0.0000)
** Span: 2005.1–2015.12, modelspan: 2005.1–2015.12

Table 14 Result of the regression analysis** for the total retail trade turnover index in real terms

	Parametar	t-stat	p-value
Theta(1)	–0.21	–2.31	0.02
BTheta(1)	–0.30	–3.49	0.00
wd3*	0.001	4.44	0.00
ly*	0.04	5.51	0.00
(–13,-1)*	0.03	5.69	0.00
ls(2009.1)	–0.06	–3.88	0.00
tc(2007.8)	0.05	3.78	0.00

* F-Test = 23.51 (0.0000)
** Span: 2005.1–2015.12, modelspan: 2005.1–2015.12

Table 15 Percentage revision* of the final estimate of seasonally adjusted time series relative to the current estimate

	mean (%)	Rmse(%)	Absmean(%)
Industrial production volume index	–0.02	0.83	0.61
Volume index of construction works	0.01	0.77	0.55
Retail trade turnover index in nominal terms	0.13	0.57	0.45
Retail trade turnover index in real terms	0.18	0.56	0.43

* Span: 2011.12–2015.11

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ISSN 1334-014X (online)