Time series analysis – an indispensable tool in monitoring current economic trends

Today, time series analysis is an indispensable element in monitoring and forecasting economic trends. This tool permits to adjust the economic time series for influences impairing the detection of the medium to long-term trend of a series. Such factors occurring in the original data may be seasonal influences, calendar influences - such as differing weekday structures per month or quarter, moving holidays, varying school vacations or plant holidays - and extreme or other irregular values which may be caused, for instance, by strikes. Consequently, most analytical methods aim at decomposing the observed time series data into components. These are the trend cycle component reflecting the medium to long-term "basic trend", a seasonal component and a calendar component through which seasonally and calendar adjusted values can be determined, and a residual component.
Since 1972, the Federal Statistical Office has calculated and published the results of time series analyses according to the Berlin procedure (BV). Since 2004 the BV4.1 version is used. Starting in 2001, as a special service the Federal Statistical Office publishes for the most important economic indicators seasonally adjusted series according to the X-12-ARIMA procedure, too. These results are determined in coordination with the German Federal Bank. The two procedures BV4.1 and X-12-ARIMA are based on different mathematical-statistical techniques and may thus lead to differing results. Taking into account the results obtained by both procedures permits to reach more reliable conclusions on the current economic situation.

Notes on how to interpret the analysis results

Both the trend cycle components of major macro-economic series and the relevant original data adjusted for seasonal and possible calendar influences are very important for assessing the current economic situation. Generally it should be noted that estimating the time series components at the current end of the series naturally involves some uncertainty. There are two reasons for this. On the one hand, the values observed at the current end of a series are often only provisional and will be revised over time. On the other hand, as future series data become available for analysis, the analytical methods effect certain revisions of previous results without the time series values as such being changed.
The **trend cycle component** of BV4.1 is frequently used as a short-term economic indicator as it shows the medium to long-term "basic trend" of the series and its shape is smooth, without infra-annual oscillations. The experience gained from the revisions caused by including further series values shows that, when based on the trend cycle component, a reliable assessment of the trend at the end of a series of monthly (quarterly) values - in particular in periods of business cycle changes - can be expected only with a delay of 3 to 5 months (1 to 2 quarters), i.e. after an additional 3 to 5 (1 to 2) series values have become available. As far as the BV4.1 procedure is concerned, it is helpful in this context not to examine the current development of the trend cycle component separately, but to compare it with the developments of the different trend cycle components that were determined successively in the past. It is sufficient here to examine in detail the ends (consisting of the last two values) of any curve (cf. graphs showing the trend cycle components and the ends of previously estimated trend components on our web-pages presenting "Economic Indicators"). These ends show how any new monthly value made the trend cycle component move up or down, thus providing information on what corrective movements should be expected from month to month. In many cases, they indicate changes in the "basic trend" of the series earlier than does the current development of the trend cycle component alone. If there is a considerable difference between the current estimate and the previous month's estimate of the trend cycle component for a specific observation period at the end of the series (e.g. for the last but one value in the series), this may already indicate a change in the economic development even though no change of direction has been indicated as yet. In particular, a trend revealed by the sequence of trend cycle component ends suggests that a change of direction is occurring or, at least, that the present development of the series has come to an end.
Seasonally (and calendar) adjusted values correspond to a trend cycle component overlaid with short-term disruptions. Immediate conclusions on the current economic development can thus only be drawn from those economic time series for which such disruptions are not significant (e.g. the series of unemployed). In all other cases, there are two options. The first one is to smooth out the seasonally adjusted values by using mathematical methods (e.g. moving averages) or just intellectually. The second one is to quantify the effects of short-term disruptions on the basis of additional information (e.g. on climatic features) and by applying adequate mathematical techniques in order to explicitly remove these disruptions from the seasonally adjusted values. In the first case, the reliability of the analysis results corresponds to that of considering just

the trend cycle component. In the second case, the quality of the results depends, among others, on whether it is possible to gather all the required additional information.
A major uncertainty in the assessment of short-term economic trends in time series by means of seasonally adjusted values is the risk that substantial revisions may occur over a period of several years. This is due to the fact that, in contrast to the values of the trend cycle component, new series values do not cause a step-by-step approximation of previous seasonally adjusted values to the final situation. In fact, it can be observed frequently that a new series value primarily causes revisions of former seasonally adjusted values which belong to the same seasonal period.

Time series analyses with BV4.1 and X-12-ARIMA

The BV4.1 procedure

In Germany, the decomposition and the seasonal adjustment of economic time series with the BV procedure have a long tradition. In the late sixties the mathematical bases were developed at the Berlin Technical University and the German Institute for Economic Research (DIW). Shortly after (1972) the Federal Statistical Office established a first practicable version of the procedure to provide the general public with information on trends and seasonally adjusted data of major business-cycle indicators. Since 2004 the BV4.1 version is used.

Part one of the BV4.1 procedure deals with the identification of (potential) outliers. It is based initially on the assumption, that within sufficiently short moving time intervals of fixed length - the so-called basic spans - the time series is the realisation of a Normal stationary process. That way the conditional distributions of the observations (data) from the time series directly left and/or right from outside of the particular basic spans (backward and forward identification of outliers) are determined. If the difference between an observation and a thus determined (conditional) expected value exceeds a certain user-defined multiple of its (conditional) standard deviation, then the observation is regarded as an outlier.

If required, the next step is an integrated estimation of outliers, calendar effects and of the effects of series specific user-defined variables. Based on the general additive model for time series decomposition (i.e. $O = T + S + KA + A + EX + R$ where $O =$ time series, $T =$ trend-cycle component, $S =$ seasonal component, $KA =$ calendar component, $A =$ user-defined component, $EX =$ outlier component, and $R =$ residual component) this is done using the following linear regression model

$$O = \sum_{i=1}^{h} \mu_i T_i + \sum_{i=1}^{k} \nu_i S_i + \sum_{i=1}^{l} \alpha_i KA_i + \sum_{i=1}^{m} \beta_i A_i + \sum_{i=1}^{n} \gamma_i EX_i + \varepsilon$$

($T_i =$ trend-cycle regressors, $S_i =$ seasonal regressors, $KA_i =$ calendar regressors, $A_i =$ series specific user-defined regressors, $EX_i =$ series specific outlier dummy regressors according to the outliers identified with the first part of the procedure, $\varepsilon =$ error term), but transformed by the linear filter procedure F for trend-cycle and seasonal adjustment introduced since the BV4 version of the procedure (Nourney, M.: Umstellung der Zeitreihenanalyse, Wirtschaft und Statistik, Heft 11/83, Nourney, M. (1984): Seasonal adjustment by frequency determined filter procedures, Statistical Journal of the United Nations ECE 2). The result is:

$$F(O) = F\left(\sum_{i=1}^{h} \mu_i T_i\right) + F\left(\sum_{i=1}^{k} \nu_i S_i\right) + \sum_{i=1}^{l} \alpha_i F(KA_i) + \sum_{i=1}^{m} \beta_i F(A_i) + \sum_{i=1}^{n} \gamma_i F(EX_i) + \varepsilon^*,$$

with $\varepsilon^* = F(\varepsilon)$ indicating the new error term. As it can be assumed that the following holds true

$$F\left(\sum_{i=1}^{h} \mu_i T_i\right) \approx 0 \text{ and } F\left(\sum_{i=1}^{k} \nu_i S_i\right) \approx 0,$$

parameters α_i, β_i, γ_i and thus the components KA, A and EX are estimated by the model

$$F(O) = \sum_{i=1}^{l} \alpha_i F(KA_i) + \sum_{i=1}^{m} \beta_i F(A_i) + \sum_{i=1}^{n} \gamma_i F(EX_i) + \varepsilon^{**},$$

using the ordinary least squares criterion.

In part three of the procedure, the trend-cycle component and the seasonal component of the time series to be analysed are estimated, using the time series adjusted for outliers, calendar effects and effects of the user-defined variables. Again, this is done with the respective BV4 filters.

By default the BV4.1 modelling approach for the calendar component is based on eight calendar regressors, namely the series of the differences between the monthly or quarterly numbers of the individual weekdays Monday through Saturday which are not public holidays, the number of Sundays and the number of public holidays which are not public holidays, and the corresponding average numbers regarding all periods of the same name.

For detailed information on the mathematical methodology please see: Speth, H.-Th.: The BV4.1 Procedure for Decomposing and Seasonally Adjusting Economic Time Series.

The BV4.1 procedure is universally applicable, i.e. apart from the outlier and calendar adjustment option, normally no additional series-specific parameter specifications have to be made.

For non-commercial purposes, the Federal Statistical Office provides the BV4.1 procedure as a free download.

The X-12-ARIMA procedure
For important economic time series, the Federal Statistical Office publishes values that have been seasonally adjusted in accordance with the X-12-ARIMA procedure in addition to the analysis results based on the BV4.1 procedure. X-12-ARIMA includes the most recent enhancements to the long-established X-11 seasonal adjustment program of the US Bureau of the Census. The program is available free of charge from the Bureau of the Census (http://www.census.gov/).

As regards content, X-12-ARIMA consists of three parts. The first part offers to its users an entirely new range of outlier and calendar adjustment capabilities on the basis of regression models with ARIMA errors. Besides, it is possible to make forecasts aimed at stabilising the seasonally adjusted values at the end of the period under analysis.

Except for a few supplements, the central part of the procedure used for seasonal adjustment is identical to the former X-11 procedure of 1965. This means in particular that the seasonal adjustment is based on the iterative application of various moving averages. The user may choose among numerous options regarding the length of the averages used. Also, users must choose between an additive and a multiplicative combination of the time series components.

To obtain high-quality results, X-12-ARIMA requires the user to make a well thought-out selection from among a multitude of options. To this end, the third part of the program offers a number of diagnostic instruments which are intended to help the user check the adequacy of the options selected.

For further information on time series analysis, please contact: bv4.1@destatis.de.