

An Extended Review of the X11ARIMA Seasonal Adjustment Package

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Abstract.

The revised version of X11ARIMA, Statistics Canada's seasonal adjustment package, is reviewed. The 1988 package, available for PC's as well as mainframes, is easy to use and more flexible than the 1980 version. New features reflecting research by Estela Dagum and her colleagues are highlighted. Comparisons are made with some other available X-11 programs.

Keywords: X-11, ARIMA models, Extrapolation

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International Journal of Forecasting 8 (1992), 627-633

The views expressed are those of the author and do not represent official positions of BLS.

1. Introduction

This paper reviews X11ARIMA/88, the revised version of probably the most widely used, currently maintained seasonal adjustment package. It is small and simple enough for anyone interested in applying seasonal adjustment, handling monthly and quarterly data. Estela Dagum, the developer, and her associates at Statistics Canada have advanced the practice of seasonal adjustment through a stream of research studies, with many of the results reflected in the package.

The new version, which will be called X88 for short, is available both for mainframes and PC's. Alternative packages include the original version, released in 1980, the U. S. Bureau of the Census package X-11.2, and SAS's PROC X11. This review will discuss various features of the package, emphasizing differences from the original version, denoted X80, and PC aspects, followed by a brief description of the other packages mentioned above, which will be denoted X2 and XSAS, respectively. Some comparisons based on runs with U.S. Bureau of Labor Statistics time series will be presented.

All these programs are based on Julius Shiskin's X-11 method developed at Census. In modern statistical terms, it is a nonparametric, robust procedure for decomposing a time series into trend-cycle, seasonal, and irregular components. Another program in this spirit is STL (Cleveland et al, 1990), but initial comparisons with X-11 were not that favorable. Model-based methods are not widely used by statistical agencies, because (1) they require care and labor in identifying models, (2) they are somewhat subjective, and (3) many series behave too erratically to be described well by simple univariate time series models.

2. Program features

ARIMA extrapolation

This feature is the major innovation introduced by Dagum: extending the series with forecasts to lessen the use of X-11's asymmetric filters. Dagum (1982) gives some measures of potential (theoretical) reduction in revisions and refers to empirical studies by herself and others.

The principal changes from X80 are a new set of ARIMA models for the automatic forecasting option, a relaxing of criteria for fitting and forecasting, and changes in the program options. The default is the automatic option, while in X80 the default is no extrapolation. Two new models have been added to the three available in X80, based on an empirical study by Chiu et al (1985). Huot et al (1986) describe

sets in the parameter space for each model in which improvement from extrapolation can be expected.

The criteria for accepting a model under the automatic option are relaxed by adopting a p-value of .05, rather than .10, as the critical value of the Ljung-Box statistic and permitting mean absolute percentage forecasting error as high as 15%, rather than 12%. This means that the chances are greater that some model will be accepted and, additionally, that the first model, the airline model, will be selected.

The new version has an option for forecast horizon, allowing forecasts up to three years ahead. Theoretical results by Pierce (1980) suggest "full forecasting," i.e., extending the series with enough forecasts that the symmetric filters will be applied at the most current time point, approximated by 36-42 months of forecasts with the 3x5 seasonal filter and 60-66 months with the 3x9. Huot et al (1986) tend to recommend one or two years of forecasts. Bobbitt and Otto (1990) and Buszuwski (1987) suggest full forecasting. The default is 1 year, the only value in X80.

Another option permits zero estimation iterations for ARIMA parameters, so that the user can fully specify a model and the parameter values to be used. This is especially helpful, since the program's method of estimation is conditional least squares, faster to compute, but less accurate than maximum or exact likelihood methods. (See empirical comparisons below).

These days structural models with Kalman filter estimation are popular, but Findley (1990) gives empirical evidence of ARIMA models performing better than structural models. At least for now, X88's use of ARIMA models seems appropriate.

The one serious bug I found has been corrected; it affects only PC versions released prior to February 1992. When "no extrapolation" is selected, extrapolation option 1, the forecast seasonal factors repeated the last year's. They should be computed as last year's, plus half the difference between a month's factors for the last two years.

Composition or aggregation

X-11 is not an additive process, i.e., the seasonally adjusted sum is not the sum of seasonally adjusted components. While X-11 is composed of linear filters, the replacement of extremes in the program destroys the additivity. The composite run feature carries out "indirect adjustment" of an aggregate series by adding up the seasonally adjusted components. It also computes a direct adjustment of the aggregate, and provides diagnostic statistics for comparing the two. Where practicable, government agencies often opt for indirect adjustment for consistency. For instance, the 12 major U.S. labor force series are adjusted directly, and then all series derived from them are adjusted indirectly.

A shortcoming of the program is the limitation to a single set of weights for computing aggregates. Variable weights have several applications. In computing an indirect adjustment of quarterly average household spending from age group components, one needs to weight these components by their share of the population. Since the population estimates shift somewhat every quarter, separate weighting of components is appropriate for each time period. Weighting is always required in aggregation for indexes, and for non-Laspeyres formulations, there will be variable weighting. Even for Laspeyres indexes, the weights change periodically. This can be due to a weights revision or to a new definition of the components of the aggregate. BLS has a modified version which permits this.

Other basic options

(1). Seasonal filter

X88 implements automatic selection of the seasonal filter based on the global I/S ratio and an empirical study by Lothian (1984). Somewhat more conservative than Lothian in departing from the former default 3x5 filter, the program has three intervals for accepting a 3x3, 3x5, or 3x9 filter. If the value falls in a "gray area" on either side of the central interval accepting 3x5, data for one year are dropped and the ratio re-computed. While automatic selection is the default, the user can specify a seasonal filter, including stable estimation of seasonal factors.

(2) Easter option

The program can estimate and adjust for simple Easter effects, where the effect is principally a function of Easter's falling in March or April. Often, this simple model is not adequate. Different holiday procedures are described in Monsell (1989), available in X-11.2; McIntire (1990); and, Dagum, Huot, and Morry (1988).

Diagnostics

Dagum and her colleagues deserve praise for stressing the need to check whether a seasonal adjustment is adequate. Based on 11 "quality control" measures, labeled M1-M11, and an summary weighted average Q, the program states whether or not (1) seasonality is "identifiable" and (2) the seasonal adjustment is "accepted" or "rejected." These measures can be roughly separated into measures directly related to the seasonal component (M6-M11), measures related to the seasonally adjusted series (M1-M3, M5), and a test of randomness of the irregular component (M4). Analysts usually want to see the ANOVA-style F test for seasonality used by Shiskin in X-11, which is included in the output and reflected in the most heavily weighted measure M7. Some of the other statistics are related to Shiskin's concept of months for cyclical dominance (MCD). Not strict statistical tests, except for M4, the passing scores for these statistics were derived from a large-scale empirical study.

Ease of use; input/output

The new version has two executable modules, one for processing the input data and control information (program options) and one for carrying out one or more seasonal adjustments. The first step uses NAMELIST-style control input. The information is placed in SAS-style statements, with command name, options, and final semi-colon. These statements can either be entered interactively or, my preference, by specifying a file containing these statements. The user names the input data set and specifies its format or one of several "traditional" year \times month table formats. The PUNCH option, the counterpart to "special output" in X80, permits saving output, such as seasonal factors. For a bad statement, such as one not issued upper case, the program returns "ERRONEOUS;" if there is a mistake or mismatch between control information and input data, the program prints an error message. With preprocessing done, the user types "XA88" for actual program execution, and is prompted for a file for placement of the program printout.

All these features make the program easy to use for either a casual or experienced user. As mentioned above, the syntax is straightforward, and input/output is fairly flexible. In typical multiple runs, it is an advantage to place all data in a single data set. On the other hand, this requires all data, including any prior adjustment factors, to have the same format.

Documentation

The thorough documentation is divided into two major parts, technical description of the program and a users manual. The main users manual has 37 pages of instruction and another 37 pages with a full seasonal adjustment printout. A separate 8-page guide goes over installation and execution of the PC version.

I would urge some improvements in the documentation to help the beginner. To improve the presentation, I would suggest grouping options under headings to reflect explicitly the program syntax, similar to SAS manuals. For example, all the appropriate options could be grouped under a heading "SA Command Options." Furthermore, a couple of examples of an entire set of command statements are needed. Only the PC guide has any full examples, and its examples are fairly limited.

The technical description repeats the old manual, after conveniently collecting the new features in the first seven pages. The material repeated, highly useful, includes brief rationales for seasonal adjustment and aspects of the methodology and a 32-page layout of the iterative steps of the program.

In addition to the two executable modules and a help function, the diskette for the PC contains an example, including the input data, command statements, and a printout. The source code (FORTRAN) does not come with the PC version, but may be available from Statistics Canada.

3. Other Packages

Census X-11.2

X-11.2 (X2 for short) lacks (1) the extrapolation option of X88 and (2) composite adjustment. Otherwise, it has most of X88's features, including the diagnostic statistics M1-M11 and Q. Like X80 and XSAS, the default seasonal filter is 3x3, then 3x5. However, the program prints an alternate filter recommendation based on the same criterion from Lothian (1984) that X88's variable filter option is based on.

The principal X2 feature not found in X88 is the sliding spans analysis (Findley et al, 1990). More direct and intuitive than M1-M11, sliding spans statistics seem to me a highly useful diagnostic. They check for stability of factors, seasonally adjusted values, and change estimates, usually across three or four spans, formed by adding a new year and dropping an old one. I find the sliding spans more informative for comparing direct and indirect adjustment than the smoothness measures of X80 and X88, which are somewhat difficult to interpret. X2 has a couple of spectrum plots. This is a tool I've also found very useful, but I haven't tried X2's routine. A holiday adjustment method, somewhat more elaborate than X88's, permits special treatment when Easter, Labor Day, or Thanksgiving affects a series.

Input/output involves NAMELIST input, and is neatly organized. X2 is more flexible than X88 in expecting separate files and format specifications for each input series, including series of prior adjustments factors. This flexibility must be weighed against the proliferation of input and output files in multiple runs.

Census continues to develop "X12ARIMA" (Findley et al, 1988). This package potentially offers many desirable features, including a superior estimation package, composite adjustment, and a flexible routine for treating outliers and interventions. Test versions, however, have been too large to adopt easily to PC's.

X2 takes about 530K of memory on my machine, more than X88. Unlike X88, source code is supplied, an advantage if you have a FORTRAN compiler and you would like to modify something for your application .

SAS PROC X11

SAS PROC X11 (or XSAS for short), as one might expect, is an adequate, but less complete version of X-11 than the others. It lacks ARIMA extrapolation or composite adjustment. It has the MCD, the basic F test for stable seasonality, and several summary measures tables, but not M1-M11 or sliding spans. It is easy to use, and has many of the program options, including prior adjustment and trading day adjustment; it outputs specified tables as SAS data sets.

XSAS apparently is an older Census program, modified only for interface with the SAS language and data sets. Specialists will want one of the other programs, but, as a "free" program within SAS ETS, XSAS is quite usable, and, for basic X-11, appears to give results very similar to the others, especially X2.

4. Empirical Comparisons

Basic X-11

Choosing the "no extrapolation" option in X11ARIMA reduces the methodology to "basic X-11." Different versions introduce modifications from the original program, such as X88's variable seasonal filter selection and improved accuracy of asymmetric Henderson filter weights. Both X80 and X88 appear to use single precision, while X2 has double precision.

As a small test for differences among these programs, the 12 major U.S. labor force series are run with X88, X80, X2, and XSAS with default options (except "no extrapolation" for X88). The time series, identified below the exhibits, are available from both the author and this journal. Exhibit 1 shows pairwise summary difference statistics. These are reported separately for 1981-90, the data input span, and for 1991, the year of projected seasonal factors. The two left-hand columns are mean median absolute differences, based first on computing median absolute differences across time spans for each series, and then averaging these medians across series. For the right-hand columns, the maximum absolute difference is computed for each series and then the median value computed across the twelve maxima. This choice of statistics depicts typical differences better than taking means of mean absolute differences and means of maximum absolute differences, both of which are influenced more by a few large values. The pairs are listed by increasing size of differences.

It is perhaps surprising that differences are this large for the same basic methodology: over half the time X88's within-span factors differ from the other programs by more than .05 and its projected factors by more than .20. All pairs show differences greater than 0.10 for most series. Many of these differences are nontrivial.

It is in the more volatile teenage series that we find most of the large differences, with the smallest within-span maximum being .45 for YMU. Exhibit 2 gives maximum absolute differences for each pair of methods for the 6 teenage series for the within-span period.

X88 chooses the 3x9 filter for three of these series, YMN, YWN, and YWU, reflected in larger pairwise differences with this method, especially for YWN and YWU. A detailed examination of YWU shows that, as expected, the 3x9 gives a smoother, more moderate seasonal pattern for X88. Across the ten years, July factors vary from 119.0 to 123.6 for X88, a range of 4.6 compared to 6.7 or 6.8 for the other methods. X2, while using the 3x5, recommends trying the stable filter option, based on a large I/S ratio.

For YWA, Exhibit 2 shows the largest differences across 1981-90 come from X80. The 7/81 factor for X80 is 200.6 while the other methods yield values between 206.4 and 207.9. (Seeing the size of these multiplicative factors for YWA suggests that the differences are not as severe as they might appear at first). The differences for July might be attributed to replacement values for extreme SI ratios. X80 computes substantially smaller replacement values in Table D9 for 7/81 and 7/83.

Summarizing, all four versions of X-11 give very similar seasonal patterns, but nontrivial differences occur. When one method is

different from the others, sometimes it appears to be better, as when X88 applies a 3x9 seasonal filter for YWU or when X80 apparently computes better replacement SI ratios for YWA. X2 and XSAS tend to give the most similar results. Incidentally, for X88, PC and mainframe seasonal factors agree to two decimal places.

ARIMA Modeling

As a check on the extrapolation portion of X88, a comparison was made with other modeling programs. The models and transformations selected by BLS for the official seasonal adjustment of the twelve labor force series are estimated by SAS PROC ARIMA with both conditional least squares (CLS) and maximum likelihood (ML) options, and by a modeling and signal extraction program written by Peter Burman (1980). Perhaps surprisingly, the airline model is used for none of the series. All include a single seasonal moving average parameter. Eight involve 2-4 moving average parameters, three have AR parameters, and one is the problematic (212),(011)₁₂ model.

X88 uses conditional least squares estimation, confirmed by close agreement with PROC ARIMA's CLS option on all but one series. Burman's exact likelihood results are close to SAS's ML option, so further comparisons will be between the latter and X88. The most significant differences in parameter estimates are for the seasonal moving average parameter, with the ML estimates always higher, and for half the series substantially higher. Turning to the 12 forecast values produced by each method, six series have fairly large differences during the latter half of the year, the longer-range forecasts. Four of these have large differences in seasonal MA parameters. For two of these, the shape of the forecasts appears appreciably different.

Summarizing these results, CLS and ML parameter estimates may differ quite a bit for seasonal models. As well as modeling the series outside X88, one may benefit from specifying the parameters estimated externally and applying X88's "no iterations" option. Still, in most cases in this small empirical comparison, CLS and ML forecast patterns are similar.

Conclusion

X11ARIMA/88 stands as the most complete, general purpose seasonal adjustment program. The revision adds flexibility and more user-friendly input/output. With correction for one significant bug (discussed in 2a. above), the PC version works easily and about as well as the mainframe version without excessive space requirements. Minor changes to the documentation would clarify the syntax for input.

Appendix. Program Information and System Requirements

The X11ARIMA/88 Seasonal Adjustment Method, Estela Bee Dagum, 7-E R. H. Coats Building, Statistics Canada, Ottawa, CANADA K1A 0T6, 613/951-9876; PC version in the U.S.: Levenbach Associates, 103 Washington Street, Suite 348, Morristown, NJ 07960, 201/285-9248. List price: Mainframe, \$900; PC, \$450 academic, \$650 government, \$895 commercial.

PC requirements are stated as the following or better: 8086 microprocessor, DOS 3.1, 8087 math co-processor, and 640K memory; either one hard disk and one floppy disk drive or two floppy drives. The program executes easily and quickly on my GRID 386, needing under 450K of memory.

Acknowledgments.

The author is grateful to George Methee for providing the labor force data and for help in examining and running the programs, and to James Buszuwski and Robert McIntire for helpful comments.

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Exhibit 1. Pairwise Absolute Differences in Seasonal Factors Between X-11 Programs Across 12 Labor Force Series

Program Pairs	Mean		Median	
	Maximum Absolute Difference		Maximum Absolute Difference	
	1981-90	1991	1981-90	1991
X2-XSAS	.02	.03	.15	.15
X2-X80	.03	.04	.20	.14
X80-XSAS	.04	.04	.25	.19
X88-XSAS	.08	.21	.25	.34
X2-X88	.07	.22	.30	.38
X80-X88	.07	.21	.38	.40

Exhibit 2. Maximum Absolute Differences, 1981-90, for Teenage Series

Program Pairs	YMU	YWU	YMA	YWA	YMN	YWN
X2-XSAS	.26	.42	.53	.60	.19	.13
X2-X80	.38	.11	.88	6.34	.55	.13
X80-XSAS	.14	.43	.88	5.86	.36	.14
X88-XSAS	.19	1.84	.92	1.51	.57	.58
X2-X88	.45	1.82	.92	1.03	.56	.62
X80-X88	.23	1.85	.45	7.37	.57	.61

Guide to series:

- YMU - Unemployment, teenage men
- YWU - Unemployment, teenage women
- AMU - Unemployment, adult men
- AWU - Unemployment, adult women
- YMA - Agricultural employment, teenage men
- YWA - Agricultural employment, teenage women
- AMA - Agricultural employment, adult men
- AWA - Agricultural employment, adult women
- YMN - Nonagricultural employment, teenage men
- YWN - Nonagricultural employment, teenage women
- AMN - Nonagricultural employment, adult men
- AWN - Nonagricultural employment, adult women