RESENHA DE SOFTWARE

X-11 SEASONAL ADJUSTMENT PROGRAM OPTIONS

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Resumo

Os programas X-11 e X-11-ARIMA são amplamente utilizados para realizar ajuste sazonal de séries temporais. Um dos principais motivos por esse sucesso é a aplicação quase que automática do programa. O artigo mostra, entretanto, que uma utilização mais cuidadosa das várias opções disponíveis pode melhorar consideravelmente a qualidade do ajuste.

de algumas das opções disponíveis são estudados através da aplicação do programa X-11 a uma série empírica que exibe fortes mudanças estruturais na estrutura de tendência e sazonalidade.

Abstract

X-11 and X-11-ARIMA programs are widely used in seasonal adjustment. One of the reasons for their success is the almost automatic application of the methods. The paper shows, however, that an appropriate use of the options available can improve considerably the performance of the programs. The effects and power of some options are analyzed through the application of the X-11-ARIMA program to an empirical series which presents strong both trend and seasonal structural change.

Keywords and phrases: Seasonal adjustment, X11/X11-ARIMA programs, X-11/X11-ARIMA options, X11/X11-ARIMA filters.

1. Introduction.

The first method widely accepted for seasonal adjustment was the U.S. Bureau of the Census X-11 Method (Shiskin *et. al*, 1967), mainly due to its almost automatic application and to the good results generally obtained (Dagum, 1978; Pierce, 1980; Hillmer and Tiao, 1982). This method and its variant, the X-11-ARIMA, developed by Statistics Canada (Dagum, 1980), are nowadays closely linked to seasonal adjustment, and available in many statistical packages.

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These programs have been criticized, however, because of their empirical nature (Hillmer and Tiao, 1982), the seasonal factors sensitivity to revision (Dagum, 1978, 1982), correlation of the residuals (Cleveland and Tiao, 1976), and the difficulty in assessing the effects of the options in the results (Akaike, 1980). This work shows that an efficient use of the options can attenuate the problem of the revisions and of the correlation of the residuals, improving considerably the quality of the adjustment. The quality of the adjustment can be monitored by the set of quality control statistics (Lothian and Morry, 1978) which are given at the end of the output of the X-11/X-11-ARIMA programs.

Another important aspect in seasonal adjustment is to decide whether a series should be adjusted. Recently, Findley and collaborators introduced the sliding spans technique (Findley and Monsell, 1986; Findley *et al*, 1988, 1990). They define some statistics which were mainly function of the size and implications of the revisions and were meant to measure the reliability of the adjustment. However, the M-statistics and the sliding spans technique can only be used to decide whether

if the adjustment is done with the right option. Thus, a clear understanding of the options and their power is important, but the options are not fully understood (Akaike, 1980), neither fully explored. This paper tries to contribute to the elucidation of the problem showing empirically how an appropriate choice of the options can improve considerably the quality of the adjustment. This is done comparing the M-statistics using the automatic adjustment and other options. Section 2 gives a short discussion of the options used and lists the options not used here. The São Paulo State infant mortality rate series which is used in the paper is described in Section 3 and the application of the options is shown in Section 4. Final comments are given in Section 5.

2. The X-11 ARIMA Program Options.

This section gives a brief description of the options available in the X-11-ARIMA program (1978 version) which are used in this work. A complete description of the options can be found in the program user's manual (Dagum, 1980). The options not discussed here are listed at the end of the section. The choice of the options in the X-11-AROMA is done through one card. One can use the

program standard option leaving all the columns in blank; leaving the decision to the program (automatic option), or choosing the option himself/herself. In the following description of the options the standard option will be designated by "S" and the automatic decision by "A". When there are two automatic options, both are denoted by "A". When the automatic and standard options are the same they will be denoted as "S" option. The rationale used by the program is given without details.

a. Lower and Upper Sigma Limit for Graduating Extreme Values in Estimating Seasonal and Trend Cycle Components.

S - Assign full weight to irregular values within 1.5σ and zero weight to irregular values outside 2.5σ .

- Enter the lower and upper sigma limit values.

Scott (1987) already studied the effects of the outliers, so this problem is not fully explored here.

b. Moving Averages for Seasonal Factor Filters

The program provides 8 options: the filters are fixed a priori in 6 options and In the other two the program chooses automatically the appropriate average.

S - Select a 3×3 for the first estimates of the seasonal in each iteration and a 3×5 in the final estimate.

- Select one of the following: a 3-term, a 3×3 , a 3×5 , or a 3×9 moving average.

- Select a stable seasonal (average of all values for the month).

A - The program selects a different moving average for each month.

A - The program selects a moving average, but must be the same for all months.

The choice of the average depends upon the data and the type of adjustment required. A short filter will be more dependent on the outliers but will be quicker in detecting structural changes. The appropriate choice will generally reflect a trade-off, especially because large irregular components come normally with structural changes.

c. Moving Average for Variable Trend-Cycle Routine.

The options available are:

- The user selects a 9, or 13, or 23-term Henderson filter.

S - The program selects one of the moving average listed above. The choice is based on the same rationale as in the previous item.

d. One Year Ahead Forecasts using Box-Jenkins ARIMA Forecasting Routine.

This option is only available in the X-11-ARIMA program. It fits an ARIMA model to the data and produces one year ahead forecast values. These values are added to the original series and used to estimate the seasonal factors. The options are:

S - No forecasts.

A - The program selects the model with produces the smallest forecast errors among a group of possible models. If this model gives forecast errors larger than a fixed threshold value this option is not used.

- The user enters with the model.

The following options are also available in the X-11-ARIMA program, but are not used in Section 4:

-Type of adjustment (Multiplicative, additive or logarithmic).

-Adjustment of Yearly total (Y/N).

-Type of program (Seasonal adjustment or estimates of trend-cycle, irregular, I/C, MCD and residual trading-day and seasonal variation from seasonally adjusted input).

-Adjustment of trend-cycle for strikes (Y/N).

-Prior monthly adjustment factor (Y/N).

-Prior daily weights (Y/N).

-Length-of-months allowance (Y/N).

-Trading-day regression (Y/N).

-Starting date for computing trading-day regression.

-Starting date for applying trading-day regression.

3. São Paulo State Infant Mortality Rate Series.

The monthly São Paulo State (Brazil) Infant Mortality Rate (aged 0-1) series, from 1933 to 1985, is used throughout this work. The series is not complete because the 1949 data are missing. This series was chosen because it embodies most of the good and bad features expected to be found in seasonal adjustment practice. For example, the series has a strong seasonality which makes it very appealing for seasonal adjustment, but at the same time it has

Figure 1.
São Paulo State Infant Mortality Rate (aged 0-1)
from 1933 to 1985

strong shortcomings, as structural changes in trend and seasonality. There are periods with stable trend, or with quick decrease and even increase in the trend (see Figure 1 and the complete data set in Appendix I). Simultaneously the seasonal factors decrease considerably and their pattern changes throughout the period.

The analysis of Figure 1 shows almost a constant trend until 1940, a decrease until around 1964, another increase until around 1983 followed by a decrease. The seasonal factors also decreased drastically until 1960, then increased simultaneously with trend, possibly indicating a multiplicative seasonality.

There were also changes in the seasonal structure. At the be-

ginning, the mortality is relatively higher during summer. When the trend level reaches lower values the series reaches its peaks during the winter months.

Studying the same series during the 1930-1979 period Ortiz (1982) found out that endogenous diseases (nonseasonal) accounted for 10% of the deaths in 1975 and increased to 42% in 1979. Simultaneously the infectious diseases importance decreased in the same period from 38% to 25% and the deaths from respiratory related problems increased from 10% to 17%. It must be noted that respiratory problems occurred mainly during the cold season.

4. The Performance of the Automatic Option and the Power of the Options.

This section examines the performance of the automatic option, and shows that an appropriate choice of the options available can improve considerably the quality of the adjustment. Although there are more recent versions of the X-11-ARIMA program the analysis presented here was carried out using the 1978 version. In this version the multiplicative seasonal models entertained in the automatic option are: $(0, 1, 1)_{\text{times}}(0, 1, 1)_s$, $(0, 2, 2)(0, 1, 1)_s$ and $(2, 1, 2) \times (0, 1, 1)_s$, where s is the period of seasonality.

The program will be applied to several periods of the series, each one having different characteristics. This will enable us to analyze the performance of the program's options in different situations. The quality of the adjustment will be based on the M-Statistics (see Appendix II) and the total quality control statistics provided by the program.

The 1949 year data are completely missing. Since in the 1933/1948 period (this period will be denoted by S3348) there are two sharp decreases in the trend around 1942/44 and 1946/48, this period can be used to test the influence of the options on the revisions in the presence of quick sudden change in the trend level.

The seasonal structure from 1933 to 1945 is stable (see Figure 2): the series presents its maximums (within a year) around December (2 in November, 9 in December and 2 in January) and decreases until the middle of the year; the minimums occur in June or August, except for one year, when it was in September. The level of the series in the first part is almost constant, but at

the end of 1940 and beginning of 1941 there is a large increase followed by a quick decrease to a lower level than before the increase. The series remains around this level until 1944 when the trend decreases to a still lower level. This part of the series will be appropriate to study the performance of the program when the seasonal component is well behaved but there are quick modifications on the trend.

The results of the application of the automatic option to the series S3340 and S3348 are shown in Table 1. Notice that the series S3340 does not present any marked change in the trend while the series S3348 includes two modifications.

As expected, the automatic option gives a better performance for shorter series. For instance, in the test of the auto correlation of the residuals the null hypothesis (residuals not correlated) is not rejected for any lag (from lag 1 to 12) for the short series, and rejected at lags 2, 3 and 9 at the 0.05 level of significance for the S3348 series (the upper limit used in the test was the value $2\sqrt{n}$ — see, however, that the power in the two tests is not the same). Similar result was found by the Kolmogorov-Smirnov test of the periodogram. The M-statistics and the total quality control statistics are not completely bad (see table 1), but the problem of the autocorrelation of the residuals is detected ($M_4 > 1$).

The problem of the autocorrelation of the residuals could be due to the change in the trend level. The use of large filters by the automatic option does not allow the adjustment to adapt quickly to the change of the trend. After a change in the filters (3×3 for the seasonal component and 9-H for the trend component, instead of the longer filters used by the automatic option), the null hypothesis of no correlation of the residuals is rejected at 5% level only at lag 2. This improvement can also be noted by the M-statistics (see table 1); see that all the M-statistics are smaller than 1 and the total quality control statistics decreased from 0.50 to 0.38. The analysis of the results of table 1 also shows that the effect of the trend filter alone is more important than the modification of the seasonal filter (compare the M-statistics from the 3×3 option with the 3×5 and 9-H options). However, the best performance was with the simultaneous application of these shorter filters (3×3 , 9-H). Hereafter this option will be called short filter and/or optimal option.

Although the option (3×3 , 9-H) with shorter filter produces

Figure 2.

Seasonal adjustment of the São Paulo State infant mortality rate series from 1933 to 1948 (S3348) using automatic and (3×3 , 9-H) filters as options. a) original and trend components, b) seasonal component, c) irregular component.

Table 1.

Quality statistics of the seasonal adjustment of the series S3340 and S3348 for the different options. * larger than 1

Statistics	S3340	S3348			
		automatic	3 x 3	3 x 5,9-H	3 x 3,9-H
M1	0.27	0.35	0.28	0.23	0.20
M2	0.48	0.40	0.34	0.29	0.26
M3	0.48	0.68	0.45	0.38	0.35
M4	0.35	1.31*	1.18*	1.05*	0.78
M5	0.84	0.77	0.68	0.45	0.45
M6	0.01	0.03	0.07	0.24	0.33
M7	0.18	0.21	0.21	0.17	0.20
M8	0.23	0.34	0.52	0.32	0.52
M9	0.20	0.17	0.20	0.16	0.21
M10	0.31	0.52	0.67	0.51	0.72
M11	0.31	0.52	0.65	0.51	0.70
Q	0.37	0.50	0.47	0.36	0.38
# fails	0	1	1	1	0

a better quality statistics, its revisions could be larger than those of the automatic option.

Revisions in general are stronger in the presence of trend and/or seasonal structural change. At the end of 1940 and beginning of 1941 there is a sharp increase of the trend followed by a sharp decrease. An analysis of the revisions could be done by comparing the preliminary adjustment using data up to 1940 and using all the data (S3348). The adjustment of the series S3348 uses all the information available and could be considered as the final adjustment, at least for the 1940 and 1941 years. Both adjustments are given in Figure 3. The short term filters adjust-

Figure 3.

Comparison of the revisions between the preliminary (adjustment of the series S3340) and the final adjustment (adjustment of the series S3348), using the automatic and optimal options.

ments has larger variation than the automatic filter and is less influenced by further data, and probably for this reason presents smaller revisions.

Both preliminary adjustments give the same month as the beginning of the upward trend. However, for the final adjustment the automatic adjustment indicates an earlier turning point. Probably the optimal filter adjustment result is correct; the trend started to go up earlier in the automatic adjustment because the longer filter spreads the influence of the future large peak.

Another important problem in analysis of time series is to detect the turning points as quick as possible. This is analyzed through Figures 4a,b which show the adjustment using data up to March 1941, up to April 1941 and up to December 1948. Both final adjustments agree that in January the trend was reaching the turning point. The optimal adjustment in March already detected

Figure 4.

Comparison of the breakpoints through the preliminary adjustment (January 1933 to March 1941, January 1933 to April 1941, and the final adjustment — S3348) using: a) 3×3 and 9-H filters and b) the automatic option.

a change in February, and in April pointed out a turning point in February. At the same time the automatic option in April was not able to detect any change. The analysis also shows that the revisions are not larger for the short filters.

The results given above showed that the adjustment with shorter filters detected the turning points earlier, as expected, but did not necessarily produce larger revisions. Besides, when the researcher is only interested in detecting the turning points and is not publishing the adjusted series the problem of the revisions becomes secondary.

Similar result appears when the program is applied to the series S3346 and S3348 to study the revisions during 1946 (see Figure 5).

The second part of the series, from 1950 to 1985, will be used to test the influence of the options under change in the trend and seasonal pattern. The series is divided into three periods: a) From 1950 to 1965 which includes a period (end of the fifties and

Figure 5.

Comparison of the revisions between the preliminary (adjustment of the series S3346) and the final adjustment (adjustment of the series S3348).

beginning of the sixties) with sharp decrease in the seasonal factors and trend, but keeping the same seasonal pattern; b) From 1960 to 1975 which includes the sixties with almost stable trend and seasonal structure and the seventies with increase in the trend; c) From 1970 to 1985 where the seasonality is not too strong and there are structural changes in the seasonal pattern, with the maximums of the mortality rate series, in some years, happening during the cold season.

As before, the automatic option is used, the short comes analyzed and the best choice of options looked for. Table 2 presents a summary of the quality of the adjustment using the automatic option and the optimal options.

The main features of the series, the problems found in the automatic option and the effects of the options are:

S5065: During this period the trend and the seasonal components

Table 2.

Quality statistics of the seasonal adjustment of the series SS065, S6075 and S7085 for different options. with outlier control, larger than 1.

Statistics	S5065		S6075		S7085	
	automatic $3 \times 9, 9-H$ automatic		$3 \times 9, 9-H$		automatic $3 \times 9, 9-H$	
M1	0.70	0.50	1.27*	0.85	1.46*	0.96
M2	1.04*	0.86	1.17*	0.95	1.10*	0.80
M3	0.96	0.68	0.84	0.67	0.64	0.14
M4	0.38	0.11	0.25	0.69	0.78	0.02
M5	0.94	0.47	0.85	0.44	0.62	0.39
M6	0.02	0.25	0.20	0.07	1.14*	0.75
M7	0.42	0.35	0.46	0.38	0.38	0.24
M8	0.57	0.37	0.70	0.51	0.40	0.26
M9	0.39	0.31	0.50	0.47	0.09	0.22
M10	0.38	0.31	0.83	0.55	0.26	0.31
M11	0.37	0.31	0.74	0.55	0.22	0.31
Q	0.65	0.45	0.76	0.60	0.67	0.38
# fails	1	0	2	0	3	0

decrease continually but without any sudden change. Although the seasonal factors decrease in amplitude, their pattern remain almost the same.

The automatic option gives a reasonable performance, but the size of the irregular component is high ($M2 > 1$, and $M3$ and $M5$ almost equal to 1.0). The test of the auto correlation of the residuals (lags 1 to 12) is significant at 5% level only at lag 2.

The irregular component influence could be controlled using the outlier control option and/or appropriate filters. Controlling the irregular component through the outlier control option did not produce good result because it introduced correlation of order 12 in the irregular component. A short trend-cycle filter gave a better result because the adjustment was able to follow the trend level change. However, the short seasonal filter introduced auto correlation in the irregular component, probably because the seasonal factors estimate became too much dependent on the outliers. The best combination of filters, which turned out to be $(3 \times 9, 9-H)$,

decreased considerably the relative contribution of the irregular component, but the correlation of order 2 of the irregular component remained.

S6075: In the first 5 years of the series the maximums occur mainly in December with relative maximums at May or June, and absolute minimums at July or August. After 1966 the seasonal pattern starts to modify: the absolute maximums occur more often in February, the minimums in September and the relative minimums and maximums become more important. 1970 is an atypical year with its absolute maximums in September.

The automatic option fails at Statistics M1 and M2 showing that the irregular component is too high. The test of the autocorrelations of the residuals, from lag 1 to 12, is significant at 5% level at lags 3, 9 and 12, showing a residual seasonality.

The influence of the alternative options was similar to the previous series: the shorter seasonal filter accommodated better the moving seasonality but was more dependent on the irregularities of the component. In this trade-off the control of the irregularities showed to be more important with the filters (3 x 9, 9-H) giving the best overall performance. The residual component still presented significant autocorrelation at lags 1 and 9, but not at lag 12.

S7085: The seasonal pattern change is accelerated in this period. After the middle of this period the absolute maximums occur sometime in the middle of the year (1978, 1979, 1984, 1985). In fact, there is no increase of the mortality rate during the winter, but a decrease in the trend, with a higher decrease of the mortality during the summer.

During this period the automatic option produced the worst performance, failing in the statistics M1, M2 and M6, showing that the irregular component is too high. The irregular component is autocorrelated (significant autocorrelation at 5% level at lags 1, 2, 9 and 12).

The performance of the options in this period was similar to the series S6075. The use of larger seasonal filter was more important because of the large variance of the irregular component. In this case the control of the outliers improved the performance. All M-statistics gave values less than one, and the irregular component showed a significant (5% level) correlation only at lags 1 and 2. Observe that although the irregular component showed auto-

correlation after the application of the best options in the three series there was no significant autocorrelation at lag 12 in any of them.

5. Conclusions.

Although the X-11 and X-11-ARIMA programs have been used successfully by many official agencies, there is a lot of research and improvements going on as indicated by the papers by Dagum *et al* (1988) and Findley *et al* (1988). Both papers point problems and indicate (possible) solutions and modifications in the programs. All these future improvements will make the program more power full and will introduce more options. The automatic option is expected to perform better than now, but a better comprehension of the options will be more valuable. In this sense the empirical examples presented in this paper show us how the already available options can improve considerably the quality of the adjustment. They probably do not give the final and complete answer but help to shed some light on the problem.

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APPENDIX I

São Paulo Infant mortality rate (death/thousands aged 0-1)

Year	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Agu	Sep	Oct	Nov	Dec	Average
1933	192	175	151	142	141	155	145	138	150	219	302	297	184
1934	248	235	185	164	149	135	131	128	137	174	229	248	178
1935	212	203	197	160	145	139	147	140	141	158	212	263	175
1936	219	193	172	162	150	146	146	145	143	230	287	290	188
1937	215	178	164	143	145	129	128	135	136	182	267	249	172
1938	177	175	147	141	138	133	136	127	131	181	253	260	167
1939	190	160	147	135	136	144	140	134	143	188	246	290	171
1940	238	180	146	148	132	135	129	143	139	169	247	352	178
1941	263	231	171	139	150	128	128	132	156	168	214	232	175
1942	177	153	135	123	115	118	115	107	119	171	207	218	145
1943	185	171	145	126	107	111	112	115	112	132	204	204	143
1944	169	160	149	133	114	110	110	111	111	157	222	251	149
1945	185	164	140	123	117	105	101	108	118	128	145	160	133
1946	120	132	109	97	91	98	95	84	90	113	140	156	110
1947	122	127	111	100	95	89	93	90	90	108	121	140	107
1948	125	133	120	107	99	91	93	96	102	118	151	179	117
1950	147	129	114	97	96	97	96	96	101	108	155	171	116
1951	126	117	102	92	90	95	99	91	94	125	172	172	114
1952	138	116	101	95	94	94	83	84	94	98	132	129	104
1953	108	101	96	91	83	89	91	81	88	134	142	146	104
1954	115	100	80	95	92	89	80	77	81	93	126	125	95
1955	120	129	99	91	93	84	82	82	81	102	123	147	102
1956	195	129	99	103	96	83	73	68	65	93	104	111	99
1957	110	104	102	85	81	78	78	68	76	96	102	119	91
1958	119	104	93	86	81	84	74	72	75	79	96	102	89

**São Paulo Infant mortality rate
(death/thousands aged 0-1)**

Year	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Agu	Sep	Oct	Nov	Dec	Average
1959	92	88	82	78	83	80	66	71	71	86	92	104	82
1960	93	90	80	75	79	69	62	60	62	70	90	94	77
1961	90	83	80	72	75	75	65	66	70	72	85	90	77
1962	87	78	73	73	76	84	71	64	65	74	84	86	76
1963	82	86	86	71	76	71	62	67	68	80	98	98	79
1964	82	83	73	71	74	72	69	57	60	61	74	75	71
1965	77	73	68	70	67	69	74	70	67	70	77	90	73
1966	88	83	73	71	76	75	71	69	69	69	80	88	76
1967	79	85	82	74	73	80	70	67	70	68	78	81	75
1968	77	69	68	72	75	71	70	66	65	71	84	97	74
1969	96	99	91	85	83	76	78	75	73	79	84	88	84
1970	83	82	83	84	89	91	89	80	77	77	89	87	84
1971	102	101	90	91	90	99	92	82	74	81	88	86	89
1972	96	92	92	92	81	86	85	77	77	79	84	101	86
1973	106	109	107	98	98	91	80	84	76	69	75	80	89
1974	85	95	88	87	82	91	80	77	68	70	83	93	83
1975	94	96	102	84	84	77	86	69	71	75	94	103	86
1976	115	105	92	82	73	74	77	67	64	63	63	76	79
1977	91	97	85	78	76	67	62	57	54	53	58	66	70
1978	70	66	66	71	70	73	75	70	55	52	61	63	66
1979	64	64	53	61	60	69	65	53	58	58	56	57	59
1980	58	63	62	59	54	55	47	46	42	40	45	50	52
1981	59	67	64	50	46	48	46	39	38	44	48	55	50
1982	60	58	50	55	54	48	47	43	40	39	40	44	48
1983	49	52	48	47	41	41	41	35	32	36	37	41	42
1984	48	50	48	43	44	51	57	47	37	35	39	43	45
1985	41	42	41	43	41	42	34	29	29	29	32	36	37

APPENDIX II

The m-statistics quality control

The eleven M-statistics are:

- M1 - Tl-erelative contributon of the Irregulars over three months span.
- M2 - The relative contribution of the irregular component to the

variance of the stationary portion of the series.

- M3 - The amount of month-to-month change in the irregular as compared to the amount of month-to-month change in the trend-cycle.
- M4 - The amount of the autocorrelation in the irregular as described by the average duration of the run.
- M5 - The months (quarter) for cyclical dominance statistic.
- M6 - The amount of year-to-year change in the irregular as compared to the amount of year-to-year change in the seasonal.
- M7 - The amount of stable seasonality present relative to the amount of moving seasonality.
- M8 - The size of the fluctuations in the seasonal component throughout the whole series.
- M9 - The average linear movement in the seasonal component throughout the whole series.
- M10 - The size of the seasonal component fluctuations in the recent years.
- M11 - The average linear movement in the seasonal component in recent years.