Some Issues in Seasonal Adjustment When Modeling Interventions

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1. Introduction

This paper presents examples to illustrate that intervention analysis, while beneficial to seasonal adjustment, raises statistical issues deserving further attention. As described in Buszuwski and Scott (1988), a sharp drop in prices in early 1986 distorted seasonal adjustment of the U.S. Producer Price Index (PPI) for Gasoline. Modeling a ramp intervention across a three-month period, plus other intervention effects, led to a seasonal adjustment which (1) showed improved diagnostics and (2) gave seasonal factors more in accord with past history and analysts' expectations. Since its first use in energy series in January 1988, X-11 seasonal adjustment with intervention analysis has expanded to about 20 Producer Price Index series and 30 Consumer Price Index series in the areas of energy, transportation, apparel, and tobacco. In turn, these series affect many indexes at higher levels of aggregation, where indirect seasonal adjustments are calculated.

The types of interventions we consider are additive outlier (AO), level shift (LS), ramp (level shift spread linearly across two or more months), and Burman's seasonal shift (SS). Software developed at BLS (Buszuwski, 1989), to support these activities, utilizes the program developed by Burman (1980) for estimating seasonal ARIMA models with interventions. The intervention effects from the model are used to compute prior adjustment factors for seasonal adjustment with the 1980 version of X-11-ARIMA for seasonal adjustment.

Findley et al (1988) and Bruce and Jurke (1992) have also found benefits in applying intervention analysis to seasonal adjustment with preliminary versions of Census' X-12-ARIMA. This software is convenient and flexible for modeling interventions, and can identify and estimate intervention effects in an automatic mode. Burman and Otto (1988) found only small gains from intervention analysis, but stimulated subsequent work at Census and the Bureau of Labor Statistics.

After six years of experience, we still find that difficulties arise in the process. Examples show that many intervention effects may be needed for a single series, a departure from usual notions of desired parsimony. Choosing a set of interventions can be labor intensive and somewhat subjective. Caution is warranted in modeling interventions near the end of a series, since a wrong decision can lead to a poor seasonal adjustment. It is hoped that the examples will stimulate more work on intervention analysis in the context of seasonal decomposition.

2. Parsimony

The issues will be illustrated with three series, beginning with PPI Unleaded Gasoline (057104), shown in Figure. 1. Part of the reason that difficulties arise is the fact that many price index series have mild seasonality, which can be overshadowed by large trend or irregular movements. PPI gasoline prices, like consumer gasoline prices, tend to rise during spring, level off through summer and fall, and decline in winter. While most might agree that seasonality is present in the series, some might reasonably question whether the seasonality is identifiable, i.e., can be estimated reliably.

FIGURE 1

FIGURE 2

Figure 2 is a spectral plot of (1) B01, the prior adjusted series, divided by D12, the trend estimate from X-11's decomposition, vs. (2) D13, the irregular from X-11's decomposition. This graph indicates that seasonality is present, and that it is effectively removed by X-11-ARIMA. Figure 3 compares the official seasonal factors for 1992 to those with no prior adjustment. The pattern without prior adjustment is quite different and not in accord with analysts' notions of seasonality in the series. We take the position that with intervention analysis, X-11 seasonal adjustment is satisfactory, but without it it is not.

FIGURE 3

FIGURE 4

Returning to Figure 1, the most prominent features are trend movements, the sharp decline in early 1986, an exceptional rise and fall during the latter half of 1990 and early 1991, and, to a lesser extent, another rise and fall in 1989. These three behaviors correspond to, respectively, (1) increased production following a dispute among oil-producing nations, (2) the Persian Gulf war, and (3) the Alaskan oil spill. Also unusual are (1) very low values in July and August, 1986 and (2) a sharp January increase in 1990. These are more evident from a graph of first differences, grouped by month.

Intervention treatment greatly improves stationarity, as seen in the prior adjusted series in Figure 1. In all, for the eight-year span, 1983-90, the set of interventions used for official adjustment of this series consists of four ramps, (1/86-4/86, 12/86-2/87, 6/89-8/89, and 7/90-10/90), one level shift (4/89), and five AO's (7/86, 8/86, 3/89, 10/89, and 12/90). Modeling diagnostics with a (310) $(011)_{12}$ seasonal model are acceptable; t-statistics for intervention parameters are above 3, except for one 2.4 value. Stable F and Q values from X-11-ARIMA are 17.0 and .79.

The intervention model uses 14 parameters and affects 16 out of 96 points. This does not appear to be parsimonious. Is there a simpler set of interventions which might be used? After some experimentation, a simpler model was tried with 2 ramps and 4 AO's involving 10 out of 96 points. The parameter estimates and the common intervention effects are very similar to the official model. One of the omitted ramps has little impact, since X-11-ARIMA adjusts both months in the ramp in the same direction as the intervention analysis. The major omission is treatment of the oil spill in mid-1989. X-11 recognizes May, 1989 as an extreme value both in Table C17 (Irregular Component) and Table D9 (extreme SI ratio replacement). In spite of this, the seasonal pattern is magnified, as seen in Figure 4. The peak shifts toward May and June. In particular, June values for 1989 and 1990 are 105.5, compared to 102.0 and 102.1 in the official adjustment. A moving-F statistic of 4.6 also argues against the quality of this seasonal adjustment. The oil spill appears to affect seasonal adjustment with the simple model more than we might prefer.

3. Sensitivity

For nonseasonal models, it is sometimes said that outliers are unlikely to have great impact, except near the end of the series. Many points are near the ends of monthly subseries. Our feeling is that seasonal decomposition is much more sensitive.

3.1 Different ramp start

The price decline in early 1986 shows the persistent effects of a trend intervention. Excluding a single month from a ramp can impact estimation of the seasonal component. The series moves downward after December, 1985. Since the January decrease is not very different from usual behavior, the official adjustment uses a ramp from 1/86 to 4/86. Like level shifts, ramp effects are considered part of the trend-cycle component. Starting the ramp in December, i.e., including January as part of the intervention period, makes a difference. The modeling deteriorates, shrinking to a (210) $(000)_{12}$, with a failing Box-Ljung statistic. This exhibits sensitivity in the sense that a complex set of interventions can be very close to satisfactory without the diagnostics giving positive indications. It helps explain that we find ourselves going through numerous iterations before settling on an intervention set. In this case, as well as affecting the modeling, the December start impacts the seasonal adjustment. The chart compares January seasonal factors.

	January	
	1986	1990
Official	96.0	96.7
Dec start	98.3	97.6

The 1986 value increases by 2.3. By 1990, the two patterns are similar, although the difference for January is nearly 1. Thus, treating one month differently has a measurable effect on the seasonal adjustment.

3.2. Extra level shift

A second example involves an upward level shift in January, 1990. This is part of the officially selected set of interventions for the 1984-91 and 1985-92 spans. However, it was initially discarded for 1983-90, due to poor modeling results. The AR parameter estimates are very similar, but the model shrinks to a monthly means model and has a failing Box-Ljung statistic (33.5).

Somewhat surprisingly, the official factor for January 1990 is lower. What brings them together is that X-11-ARIMA replaces the 1/90 unmodified SI ratio of 103.2 with 97.2. This again suggests that the extra January shift is justified. Thus, the modeling results more favorable to omitting this level shift are puzzling. Perhaps, we simply haven't found quite the right combination of interventions. In any case, this illustrates sensitivity on the modeling side, and inconsistency between modeling and X-11-ARIMA results.

3.3. Dropping marginal AO

Another illustration of sensitivity comes from dropping one of the AO's, October 1989, which from the graphs appears only marginally atypical. The X-11-ARIMA statistics and the seasonal adjusment are very similar, although October moves 0.3 in the expected direction. The impact on modeling, however, is significant. The model shrinks to a (210) $(011)_{12}$, with a failing Box-Ljung value (39.8). In this case, the sensitivity lies in the modeling more than in the X-11 adjustment.

Unleaded Gasoline illustrates that series with mild seasonality and volatile movements may require substantial treatment for interventions, leading us away from usual notions of parsimony. Both the modeling and the seasonal adjustment results may be sensitive to intervention specifications.

4. Seasonal Change Identification

In this section we discuss the benefits and pitfalls in modeling interventions for the seasonal component of a time series. An example of this type of intervention is the Consumer Price Index (CPI) series for Women's Separates and Sportswear (CUUR0000SE3803). A two-cycle seasonal pattern that corresponds to the spring-summer and fall-winter fashion seasons characterizes this and several other apparel series (see Figure 5).

Pitfalls arise when an intervention may seem to be associated with the seasonal component, but is more appropriately modeled by a few additive outliers. An example of this is the Producer Price Index (PPI) series for Passenger Cars (141101) which is discussed in section 4.2.

4.1 Modeling Alternative Intervention Specifications

The major intervention affecting the Separates series corresponds to a change in CPI data collection methodology. This change, introduced in 1990, permitted earlier pricing of spring season items, in response to earlier introduction of these items in stores. As Figure 5 shows, February is a trough in the seasonal pattern (with January nearby) for most years in the sample up to 1989. The effect of the change in data collection methodology is clear in the graph, when beginning in 1990, January becomes a distinct trough in the seasonal pattern. Thus, this series contains an abrupt change in the seasonal pattern that becomes permanent. The CPI currently models this as a negative seasonal shift at 1/90. January's seasonal factor decreases relative to February's factor. (The seasonal change model appearing in Bell (1983) works nearly as well for this intervention).

FIGURE 5

In the case of the Separates series, CPI analysts had good information concerning the nature and timing of the seasonal shift intervention. Unfortunately, the analyst does not usually have such exact information available and a considerable amount of speculation often enters the analysis. Depending on the nature of the available information, and how the analyst weighs this information, the analysis may proceed in alternative directions.

For instance, if we envision ourselves as conducting the analysis for the 1983-90 data span, and we see the atypical winter trough for 1990, we might decide that 2/90 represents an additive outlier. Estimation of the intervention in the modeling stage of the analysis would produce a negative adjustment to the observed value for 2/90. The 1990 winter trough would then appear similar to those of previous years. In this case the analyst is maintaining the historical seasonal pattern in the data.

Situations can arise where the analyst is uncertain as to how to model an apparent intervention. Prior information concerning the series may be unavailable or unreliable. A conservative approach to modeling under this type of uncertainty is *not* modeling the intervention until future data reveals its true nature. For instance, if in the winter of 1991 the seasonal pattern reverts to its old behavior then the analyst can be confident that 2/90 is an isolated incident and therefore an additive outlier.

The advantage that not modeling the suspected intervention offers is that the resulting seasonal factors partially adapt. Often, seasonal factors are estimated that are intermediate to those obtained by the seasonal shift and additive outlier scenarios. The estimates of the seasonal factors will not be optimal in this case. However, "doing nothing" (DN) is less susceptible to the large revisions liable to occur when an intervention is modeled one way the first year and another way the next year.

Continuing with the CPI's Separates series we model each of the three alternative approaches to the winter 1990 intervention. Three 8-year spans of data are used for the analysis. Table 1 defines the alternative intervention sets and presents modeling and seasonal adjustment results.

Model parameter estimates have significant t-statistics, Box-Ljung statistics are acceptable for all three approaches. AIC values are similar for SS and AO and slightly worse for DN. However, without prior information concerning the nature of the intervention, it would be difficult to choose among the alternative approaches.

X-11ARIMA quality control statistics for the "No Prior" (NP) seasonal adjustments are also included in Table 1. The quality control statistics improve for the three cases where interventions are modeled relative to the case where they are not modeled (NP). Among the three cases where the interventions are modeled the analyst would have a difficult time making a selection based on these statistics.

Figure 6 illustrates the differences in seasonal factor estimates associated with the alternative ways of modeling the winter 1990 intervention in the Separates series. As can be seen the January factors adapt immediately to the seasonal shift for the SS case for all three spans. The corresponding factors for the AO case tend to follow the pre-1990 trend. In the first span, the DN January factor is almost identical to the AO case, but in subsequent spans the DN factors are between the AO and SS estimates for recent years.

For the February factors the differences between SS and AO are more strongly defined. It is interesting to note that the DN factors adapt to the seasonal shift immediately as it occurs in all three spans. However, there are substantial differences between DN and SS prior to 1990.

By 1992, the earlier February pricing of seasonal items has been in effect for three years. Even without intervention treatment, X-11 is evolving to the new seasonal pattern. The data for these three years are in agreement with the prior information of a seasonal change.

4.2 The Passenger Cars Case

Seasonality in this series centers on the industry convention of a "model year". End-of-model-year incentives to dealers lower prices in September and new model introductions in October raise them. During the mid-1980's the sharpness of the September trough was moderated by earlier end-of-model-year incentives to dealers, mostly August but sometimes as early as July. At the same time October evolved as a sharp peak in the seasonal factor pattern. To model this, the official set of interventions for the series contains seasonal shifts beginning in 9/85 and 8/86. Other interventions include 4/89 as an additive outlier and four ramps: 1) 12/84-1/85, 2) 9/86-10/86, 3) 1/87-2/87 and 4) 2/89-3/89. The ARIMA model is L110011.

FIGURE 7

However, our discussion here focuses on the Septembers of 1989 and 1990. In these years, most of the decline occurs before September. The official adjustments treat these Septembers as AO's, which reinforces September as the trough. For 1991 and 1992 (not shown in Figure 7) the September trough clearly returns. Thus the seasonal shift approach would have been an error.

Table 2 presents the X-11ARIMA quality control statistics for the alternative modeling approaches for the span 1/83-12/90. The SS approach models a positive seasonal shift at 9/89. As can be seen the quality control statistics improve for the three cases where interventions are modeled relative to the case where they are not modeled (NP). However the AO case, corresponding to the official seasonal adjustment, appears to be best.

Table 2 X-11ARIMA Quality Control Statistics for the Passenger Cars Series, 1/83-12/90

TYPE	FS	FM	M7	Q
NP	34.0	2.8	0.48	0.62
SS	65.0	1.7	0.30	0.41
AO	113.1	1.9	0.24	0.45
DN	81.8	0.7	0.23	0.36

Table 3 presents seasonal factors for the important months of September and October for the last five years in the data span. The differences between the SS and AO cases are significant. The DN factors are intermediate for the Septembers of recent years. On the other hand, the October factors for DN are very close to those from AO.

Table 3 Alternative Seasonal Factor Estimates for the Passenger Cars Series

	SEPTEMBER			OCTOBER		
	SS	AO	DN	SS	AO	DN
1986	95.3	94.9	95.4	103.6	103.6	103.7
1987	95.4	95.0	95.6	103.7	103.7	103.8
1988	95.5	95.0	95.7	103.9	103.8	104.0
1989	96.8	95.0	95.8	102.7	103.9	104.1
1990	96.8	95.1	95.9	102.8	104.0	104.2

The point of these exercises is that strict adherence to modeling and seasonal adjustment quality control statistics is not advised in deciding whether or not an intervention represents a seasonal shift or a string of outliers. Rather prior information is often crucial in identifying the nature of a suspected intervention. For instance, an abrupt change in the conventions and practices of an industry could be the basis of a seasonal shift. Unfortunately, information on such changes in industry behavior may not be timely or the changes may or may not be permanent, depending on many factors in the marketplace.

5. Summary

This paper has emphasized technical points in applying intervention analysis to seasonal adjustment. Additional issues for a statistical agency include openness to public scrutiny, reproducibility, and objectivity. Since our methods are labor-intensive, resources are also an issue. This means that at present only series important in their own right or as key components to important aggregates receive intervention treatment.

Summarizing the results of the paper, our examples illustrate the following points:

- contrary to usual notions of parsimony, many interventions may be needed for an effective seasonal adjustment

- summary diagnostics are not enough; it is important to keep track of how the seasonal pattern is affected

- small changes in the intervention set can significantly effect the modeling, the seasonal adjustment, or both

- when alternate treatment interventions move the seasonal factors in opposite directions, one of them must be inferior; yet both can yield better modeling and X-11 diagnostics than "doing nothing"; economic knowledge of the series and its seasonal pattern is needed.

6. References

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Table 1 Results for the Separates Series

TYPE	MA1	MA2	SMA1	L-B	AIC	FS	FM	M7	Q
1/83-12/90									
NP						43.0	1.8	0.379	0.60
SS	-0.28		0.41	17.2	-775	51.1	1.4	0.332	0.57
AO	-0.28		0.40	16.2	-774	49.8	1.6	0.343	0.56
DN	-0.26		0.45	17.2	-771	49.2	1.4	0.335	0.57
1/84-12/91									
NP						42.4	1.9	0.386	0.59
SS	-0.17	0.34	0.31	24.3	-797	60.1	1.8	0.319	0.51
AO	-0.19	0.34	0.30	19.8	-800	61.1	1.7	0.313	0.51
DN	-0.08	0.29	0.25	25.0	-787	57.7	1.7	0.324	0.52
1/85-12/92									
NP						57.6	2.7	0.362	0.53
SS	-0.22	0.35	0.35	23.9	-800	66.5	2.3	0.324	0.46
AO	-0.25	0.34	0.31	19.0	-801	69.3	2.1	0.311	0.46
DN	-0.12	0.29	0.27	23.3	-789	64.5	2.2	0.325	0.50

SS: DN plus 1/90(-SS)
AO: DN plus 2/90 2/91 2/92
DN: 1/84 2/84 8/89 4/92 9/92