Seasonal Adjustment of Hybrid Economic Time Series

Stuart Scott, George Stamas, Thomas J. Sullivan, and Paul Chester, U.S. Bureau of Labor Statistics
Stuart Scott, 2 Massachusetts Ave., NE, Rm. 4915, Washington, DC 20212

Key Words: Employment statistics, revisions, X-11-ARIMA, smoothness

1. Introduction

State industry employment is estimated monthly from the Current Employment Statistics survey, a sample of about 380,000 employers, and seasonally adjusted with X-11-ARIMA. An annual benchmarking process revises estimates to reflect universe counts available from administrative records of the Unemployment Insurance (UI) programs of each state. At any point in time, the current series consists of universe data through the latest benchmark month followed by sample data up to the current month. A straightforward application of X-11-ARIMA to this hybrid series gives projected seasonal factors which are heavily influenced by the universe data, but which are applied to sample data. Distortions can occur, because the two data sources historically have displayed different seasonal patterns.

Beginning with January 1994 data, the U.S. Bureau of Labor Statistics (BLS) implemented an alternative method that separately adjusts each part of the series, an approach first carried out by Berger and Phillips (1993). The decision to implement the alternative method, which we refer to as the two-step method, was based on the evaluation reported in this paper.

The major users of the employment statistics include the Federal Reserve Board, the President's Council of Economic Advisors, the Joint Economic Committee of Congress, and various other policy-oriented groups. Where economic statistics are used as the basis for their policy analysis, it is important that the preliminary estimates be accurate and that the economic information found in these data be discernible. Highly variable economic series make the interpretation of such data difficult. Furthermore, large annual revisions to the data may also impact the validity of policy analysis conducted on the original estimates, as Berger and Phillips (1994) suggest.

Our analysis of the seasonal adjustment of state industry employment statistics compares the two-step method with the combined method formerly used (Shipp and Sullivan, 1992), i.e., a basic application of X-11-ARIMA to the hybrid series. Our findings are:

- there are meaningful differences between universe and sample seasonal patterns,
- the two-step method produces smoother seasonal adjustments, and
- the two-step method results in smaller revisions to the seasonally adjusted data and one- and 12-month change estimates.

We feel these attributes improve the economic interpretation of the data.

2. The Current Employment Statistics Survey

The time series from the Current Employment Statistics survey combine available universe employment data with ratio estimates of sample employment. For the period for which the Unemployment Insurance (UI) data are available, the universe value is the time series value, AE_t (t= 1, 2, ..., T) where AE_t is the all employees count in month t and month T represents the latest benchmark. In the post-benchmark period (t > T) , for which only sample data are available, a ratio of the sample count in the current month divided by the sample count in the previous month is multiplied by the previous month's employment estimate. Only "matched" reporters are used, i.e., a sample unit's values are used in the ratio only if it reports in the two adjacent months. For k>0,

$$AE_{T+k} = AE_T \cdot \prod_{j=1}^{k} \frac{ae_{T+j}}{ae_{T+j-1}}$$

where ae_{T+j} = the sample employee count in month T+j summed over all matched units. Each year, in the annual benchmark process, the value of T increases by 12 months as universe values replace sample values..

Statistics Canada's X-11-ARIMA program (Dagum, 1980) is applied to state industry employment series as follows:

- The 1980 version of the program is used, with the automatic option for ARIMA extrapolation.
- Data are adjusted either additively or multiplicatively, depending on which form has better diagnostics.
- Prior adjustments are made for strikes and other atypical employment-related activity.
- Series are adjusted directly at the major industry division levels and indirectly for higher aggregates, by adding seasonally adjusted components.
- Twelve-month-ahead projected seasonal factors are used.

3. Seasonal Differences between Universe and Sample

In order to compare seasonality in sample and universe data, a time series from each source is needed. A sample link L_t is computed as the ratio of the sample estimate for month *t* divided by the sample estimate for month *t-1*. To form a sample series on a common benchmark, say AE_t, the links can be applied forward and backward, starting with

$$AE_{T-1} = AE_T/L_T\ ,\ AE_{T+1} = AE_T \bullet L_{T+1}$$

Figure 1. Mean Seasonal Factors, Texas

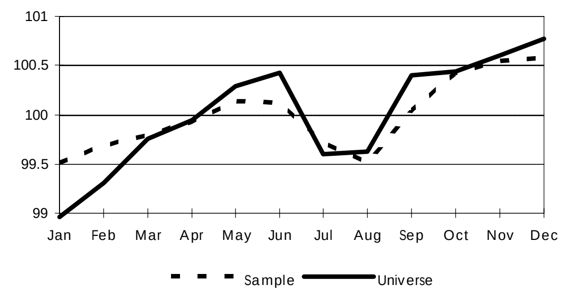


Figure 1 compares eight-year average seasonal factors for Texas for pure sample and universe data. There are noticeable differences in the factors, with the most pronounced difference in January. When the universe factor is more extreme, it will tend to over-adjust a sample estimate. For January, the universe factor, based on larger universe declines, will turn a typical sample decline into an increase. The combined method, as seen in Figure 2, estimates the change in January, 1993 as over 90,000. Summing up change in January across states yields a change over 600,000. That most of this change is spurious is supported by the national January change estimate of about 180,000, derived in a different way from the same data.

Table 1 exhibits mean absolute differences in seasonal factors for eight states. January differences range from 0.29 in New York to 0.58 in Texas. Other months with appreciable differences in several states are February and September.

4. Analysis

To evaluate the alternative seasonal adjustment methods, data are examined for the eight states listed in Table 1. By including one state from each BLS region, geographic diversity is achieved and any region-specific benchmarking activities can be at least partially examined. Revision and smoothness statistics are used.

<u>Revisions</u>

One measure used for evaluation is mean absolute revision, used in many seasonal adjustment papers, e.g., McKenzie (1984). Revision in one-month per cent change is defined as

$$R = \frac{A_t^{(f)} - A_{t-1}^{(f)}}{A_{t-1}^{(f)}} \cdot 100\% - \frac{A_t^{(i)} - A_{t-1}^{(i)}}{A_{t-1}^{(i)}} \cdot 100\%$$

where A_t denotes the seasonally adjusted value in month t, (i) the initial value, and (f) the final value. Revisions are also computed for seasonally adjusted values and for 12-month % change.

Figure 2. One-Month Change, Texas, 1993 (in 1000's)

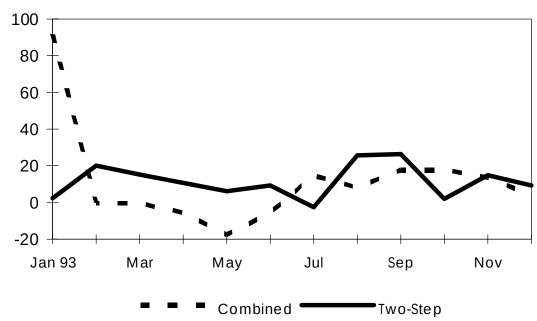
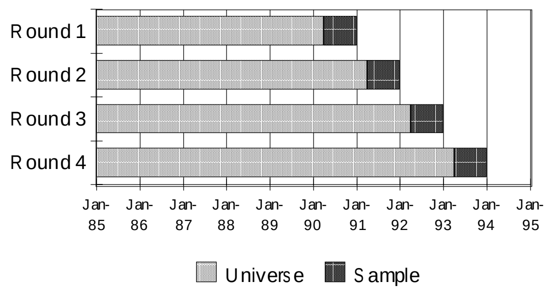


Table 1. Mean Absolute Difference in Seasonal Factors

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Colorado	0.52	0.58	0.25	0.33	0.27	0.35	0.41	0.54	0.43	0.06	0.08	0.35
Florida	0.36	0.22	0.02	0.14	0.02	0.19	0.22	0.15	0.17	0.07	0.14	0.24
Massachusetts	0.53	0.49	0.30	0.23	0.08	0.32	0.29	0.40	0.58	0.02	0.00	0.12
Michigan	0.52	0.33	0.22	0.20	0.09	0.11	0.20	0.32	0.31	0.18	0.14	0.08
New York	0.29	0.20	0.04	0.16	0.01	0.16	0.04	0.03	0.14	0.04	0.16	0.22
Oregon	0.44	0.49	0.35	0.20	0.10	0.07	0.15	0.24	0.37	0.19	0.28	0.33
Pennsylvania	0.30	0.31	0.06	0.04	0.08	0.11	0.16	0.16	0.28	0.12	0.03	0.03
Texas	0.58	0.40	0.04	0.01	0.15	0.30	0.12	0.11	0.36	0.02	0.05	0.19

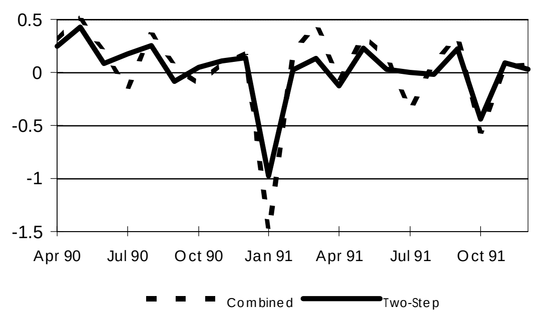
Figure 3. Experimental Design



Sliding span statistics developed by Findley et al (1988) are not necessarily applicable, since they measure stability in seasonal factors, seasonally adjusted values or seasonally adjusted change. The two-step method, by definition, implies advantages for changes between the initial and final values of the seasonal factor for a given month. Going from sample to universe data with benchmarking affects the level of the series, as well as the seasonality, contributing to a departure from stability in seasonally adjusted values. Revision statistics are also subject to this latter problem. Our initial thinking was that focusing on one-month change revision might largely eliminate the effects of changes in level, but the revisions in level are not constant across months. This leads us to attempt below a decomposition of total revision into seasonal and level components. Finally, revision statistics focus on behavior at the end of the series, where the difficulties lie in this application.

Figure 3 shows four spans of data used as input to seasonal adjustment, intended to follow current practice for official seasonal adjustment. For Round 1, the input data are the years 1985-90. We would go back further, except that sample data are readily available only back to 3/85. Having earlier universe data, for the combined method we actually use universe data from 1/84-3/90 and sample data for the remainder of 1990. For the two-step method, universe seasonal adjustment uses input data 1/84-3/90 and sample seasonal adjustment uses data 3/85-12/90. Seasonal factors for each method are applied to sample values for the last nine months of 1990 and for all of 1991, the projection period. These factors come entirely from the sample seasonal adjustment for the two-step method and, of course, from the one seasonal adjustment based on the hybrid series for the combined method. Each successive round appends an additional year of universe data, and then extends the series through the last nine months of the year with sample data. The sample periods from Rounds 1 and 2 are used as the evaluation periods, and values from Round 4 are used as the "final" values. While the latter are not truly final for these evaluation periods, they should be reasonably close to final, especially for the sample period 4/90-12/91 in Round 1.

Figure 4. Total Revisions in One-Month % Change, Texas



One-month change revisions for Texas appear in Figure 4. The two-step method has a smaller absolute revision in 1/91 and in some other months. Still, after studying the results, we felt these statistics were not fully satisfying. As mentioned above, benchmarking changes the levels in the series, so the revisions in level contribute to the overall revisions. To separate revision effects, we introduce the concept of a "corrected" observed sample value, corrected in the sense of correcting the level to be the universe level.

$$O_S^* = (O_U / S_U) \bullet S_S$$

Dividing the observed universe value for a particular month by a universe seasonal factor gives a pure seasonally adjusted value. Multiplying by a sample seasonal factor yields an observed sample value, but now at the universe level. These values are computed for the period 4/90-12/92. We use the best seasonal factors available for this correction, namely factors from Round 4. In the simplest case, adding and subtracting O^* gives the kind of decomposition we seek for a seasonally adjusted value. We have

$$R = A_4 - A_1$$

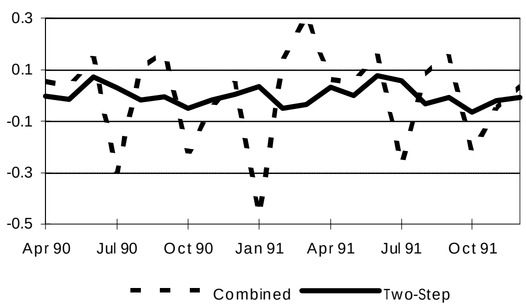
$$= (A_4 - \frac{O^*}{S_1}) + \frac{(O^* - O_1)}{S_1} = R_S + R_L$$

the terms on the right being the seasonal revision and the revision in level. Similarly, O^* can be used to obtain decompositions for one- and 12-month change. We call the seasonal revision component the "adjusted" revision, and focus most of our analysis on it. Figure 5 shows adjusted revisions for Round 1 for Texas. Now, revisions are uniformly lower with the two-step method. While some of the strongest results are for Texas, the two-step method gives an improvement in all eight states. Table 2 shows mean absolute adjusted revisions for Round 1. In most states, the statistics are about half or less with the two-step method. The table shows that total revisions are also lower on average (but to a lesser degree) in all states. Similar to results for one-month change, the two-step method reduces revisions to 12-month change estimates. Section 5 contains more on 12-month change.

Table 2. Mean Absolute Revisions to One-Month % Change

State	Total: Combined	Total: Two-Step	Adjusted: Combined	Adjusted: Two-Step
Colorado	0.33	0.18	0.22	0.08
Florida	0.29	0.22	0.16	0.04
Massachusetts	0.33	0.21	0.19	0.10
Michigan	0.32	0.25	0.22	0.13
New York	0.17	0.15	0.10	0.06
Oregon	0.27	0.23	0.16	0.11
Pennsylvania	0.16	0.14	0.13	0.07
Texas	0.30	0.19	0.15	0.03

Figure 5. Adjusted Revisions in One-Month % Change, Texas



One check on the revisions decomposition has been carried out. Given that the level revision is not intrinsically linked to a seasonal adjustment method, this revision component has been compared for the two methods. For Rounds 1 and 2, estimates for mean absolute % revision in level, which ranges from .15% to .23% across the states, never differ more than .01% for the two methods. These positive results support the use of the adjusted revisions.

<u>Smoothness</u>

Application of the two-step method to the Texas data in Figure 2 shows a marked improvement in the smoothness of the seasonally adjusted series. The large upward spike (90,900 employees) in the December 1992-January 1993 one-month change under the combined method has been replaced by a less significant level change under the two-step method (2,300). More stability is seen in Figure 6 for one-month % change in Texas in Round 1.

The departure from smoothness of the series, measured by the sum of squared first differences, is much less in the two-step method than the combined method. Table 3 below contains the ratio x 100 (two-step divided by combined) for the eight states. The relative smoothness was computed for the latter part of the series for Rounds 1 and 2.

Table 3. Relative Smoothness of the Two-Step Method

State	Round 1	Round 2
Colorado	61	94
Florida	82	73
Massachusetts	88	70
Michigan	91	104
New York	120	92
Oregon	79	79
Pennsylvania	88	94
Texas	65	65

5. Analysis of Twelve-Month Change

Recently, BLS began using seasonally adjusted data for estimating 12-month change in all its employment and unemployment statistics. Unadjusted estimates at first seem natural and preferable for at least two reasons:

- "by definition," a 12-month change should contain no seasonality;
- as an imperfect process, seasonal adjustment may introduce error into the estimate.

Arguments for using adjusted estimates include:

- their use is consistent with the use of seasonally adjusted values for other comparisons across months;
- in presence of moving seasonality, unadjusted estimates will contain residual seasonality.

In most situations, the differences are small. In this setting, we can expect that the two-step method will perform better, since residual seasonality from unadjusted estimates is likely for certain months. For Round 1, 12-month change estimates for 4/90-3/91 will involve subtracting a universe value from a sample value. For 3/90 and earlier months, the subtraction involves two universe values; from 4/91 on, it involves two sample values. Figure 7 shows Round 1 results for 1990-91; clearly, the two-step method is smoother. Table 4 gives mean absolute revisions for the eight states for the 12-month period 4/90-3/91 for Round 1. For all states except

Michigan, the statistic is at least twice as large with unadjusted estimates.

For Texas, January has adjusted revisions -.82% and -.84%, the largest revisions for the unadjusted data, compared to -.28% and -.02% with the two-step method. The latter method has only three revisions out of the 24 larger than 0.15%, while 17 revisions exceed .15% for the unadjusted estimates. Another way of expressing this result is that, with the two-step method, the initial rounded estimate is rarely off by more than 0.1% while the unadjusted estimate differs by .2% or more two-thirds of the time.

Figure 6. One-Month % Change, Texas, Round 1

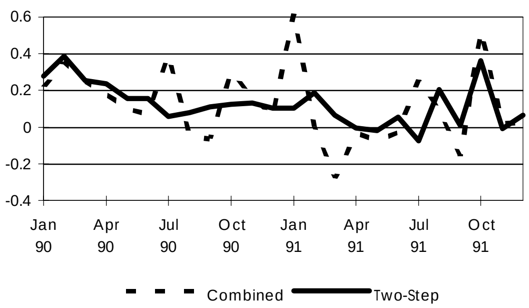


Figure 7. 12-Month Change, Round 1 (in 1000's)

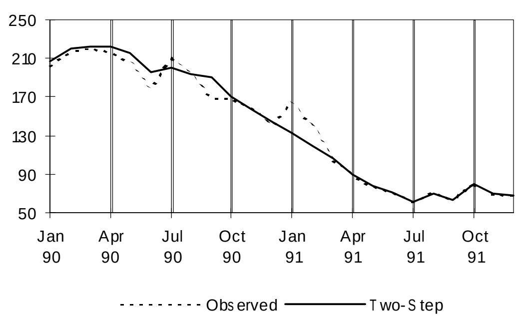


Table 4. Mean Absolute Revisions to 12-Month % Employment Change

	Total		Adjusted	
State	Unadjusted	Two-Step	Unadjusted	Two-Step
Colorado	0.39	0.18	0.28	0.12
Florida	1.01	1.01	0.18	0.06
Massachusetts	0.54	0.31	0.31	0.08
Michigan	0.50	0.36	0.29	0.16
New York	0.32	0.26	0.13	0.05
Oregon	0.82	0.62	0.28	0.09
Pennsylvania	0.50	0.39	0.15	0.06
Texas	1.10	1.06	0.29	0.13

6. Issues and Limitations

With the two-step method, there is always one calendar year with a mixture of universe and sample seasonal factors. For Round 1, 1990 has universe factors for the first three months and sample factors for the rest of the year. Even with a standard application of X-11, the seasonal factors need not average to 100, unless that X-11 program option is selected, but, with independent seasonal adjustments, the differences may be greater. To check whether the two-step method appreciably affects the level of the series, adjusted and unadjusted monthly employment averages are compared in Table 5.

Table 5. Unadjusted and Seasonally Adjusted Monthly Averages Round 1, 1990 (in 1000's)

State	Unadjusted	Combined	Two-Step
Colorado	1517.8	1517.7	1519.4
Florida	5416.0	5416.1	5417.7
Massachusetts	2983.7	2983.7	2986.5
Michigan	3954.3	3954.6	3957.5
New York	8205.4	8206.4	8209.0
Oregon	1246.0	1245.9	1247.1
Pennsylvania	5171.2	5171.2	5175.2
Texas	7030.2	7030.0	7034.4

For both rounds, the difference from the unadjusted average is less than 1,000 for the combined method, while it always exceeds 1,000 for the two-step method. For the two-step method, the maximum per cent difference is .10% in Round 1 and .15% in Round 2. The amounts for Texas are 4,300 and 9,800, or .06% and .14%, respectively. Furthermore, the difference is always in the same direction, with the two-step average being higher, so there can possibly be some accumulation across the states. For some detailed industries, the differences are larger. Still, with differences in the neighborhood of .10%, the discrepancies for total employment are fairly small, and they occur only in the just-concluded year, not the year using projected factors.

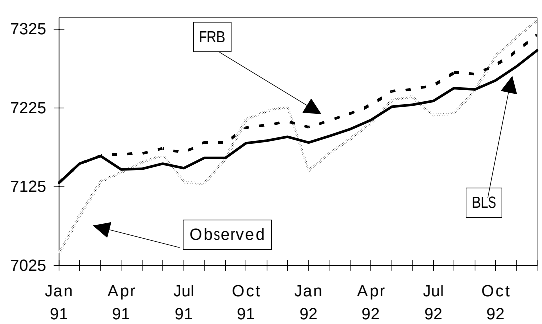
A second question is whether comparisons across the seam month, March for our data, are distorted. Berger & Phillips (1994) present another version of the two-step method intended to avoid such occurrences. For $t>T$, the last seam month, they compute an adjusted seasonal factor

$$S_S^*(t)=k{\cdot}S_S(t), \quad \text{with } k=S_U(T)/S_S(T),$$

where S_S and S_U denote sample and universe seasonal factors. This has the appealing property that successive ratios of seasonal factors are natural ratios, i.e., ratios of seasonal factors from one seasonal adjustment. On the other hand, the factor k will consistently move the seasonally adjusted series up or down, according as k<1 or k>1. Figure 7 for Texas illustrates the bias in the Berger-Phillips version of the two-step method. Visually, the BLS values appear to "go through" the data, while the Berger-Phillips values nearly all lie above the unadjusted values. For all the months where the Berger-Phillips values are above the unadjusted values and the BLS values are below, the seasonal factor has changed directions, i.e., moved from above 100 to below.

Examining monthly averages as above, their variant gives differences over .50%; moreover, these differences occur through both the previous year and the projection year. We feel that the potential for distortions across the seam deserves more study, but that the bias in the Berger-Phillips formula is unacceptable.

Figure 8. Unadjusted and Seasonally Adjusted Employment, Round 1, Texas



Care is required in application of the two-step method, due to state variations in data handling. In our eight-state experiment, universe replacement was controlled with the seam in March. With speedier processing of universe data, most states now can use universe data through June; others are able to make September the seam month. Other special situations arise which require monitoring and communication with the states.

A different approach to the overall problem is to predict universe values from sample values. Stamas, Kratzke and Mueller (1993), for instance, formulate a structural time series model for this purpose. This would provide a more consistent seasonal pattern, and eliminate the need for a two-step method. No definitive results have been obtained yet. Which seasonal pattern is more accurate is not known, but that is not an issue with the two-step method.

A more fundamental solution is to examine measurement error and coverage issues. A large response analysis survey now in progress may shed some light on error sources. The CES survey is presently embarking on an effort to put in place a sustainable probability design. Over time, projects investigating both data sources can lead to program improvements eliminating systematic differences. Given the size of both programs, this will require many years and substantial resources.

7. Conclusions

The important economic time series presented in this paper are a hybrid of two data sources with different characteristics, including different seasonal patterns. The two-step seasonal adjustment method, implemented in 1994, improves smoothness and reduces revisions in seasonally adjusted statistics. In particular, it largely eliminates spurious jumps in January. The CES state program provides an example where seasonally adjusted estimates of 12-month change perform better than unadjusted estimates. The two-step method is a short-term solution for the CES state program. The preferred long-term solution is to eliminate the systematic differences between the data sources.

References

Berger, Franklin D. and Keith R. Phillips (1993), "Reassessing Texas Employment Growth," *The Southwest Economy*, July/August, Federal Reserve Bank of Dallas, pp. 1-3

__________________ (1994), "The Disappearing January Blip and Other State Employment Mysteries," *Federal Reserve Bank of Dallas Working Paper 94-03*

Dagum, Estela Bee (1980), *The X-11-ARIMA Seasonal Adjustment Method*, Catalogue 12-546E, Statistics Canada

Findley, David F., Brian Monsell, Mark Otto, William Bell, and Marian Pugh (1988), "Towards X-12-ARIMA," *Proceedings of the Bureau of the Census Annual Research Conference*, 591-622

McKenzie, Sandra K. (1984), "Concurrent Seasonal Adjustment with Census X-11," *Journal of Business & Economic Statistics* 2, 235-249

Shipp, Kenneth and Thomas J. Sullivan, (1992), "Using X-11-ARIMA to Seasonally Adjust Industry Employment Data in the Current Employment Statistics Program," *Proceedings of the ASA Business and Economic Statistics Section*, 349-354

Stamas, George, Diem Tran Kratzke, and Kirk Mueller (1993), "Improving Models Used to Estimate Bias in Payroll Employment Estimate." *Proceedings of the ASA Survey Methods Research Section*, vol. 1, 498-503.