Causes and Treatments of Non-Economic Fluctuations in Average Weekly Hours and Average Hourly Earnings Series

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1. Introduction

The Current Employment Statistics (CES) program is a survey of nearly 380,000 business establishments nationwide, which provides monthly estimates of nonfarm payroll jobs, average weekly hours (AWH) and average hourly earnings (AHE) of workers. The month-to-month movements in these series are closely followed by policy makers and forecasters as timely indicators of the overall strength and direction of the nation's economy. In recent years a number of CES data users inquired about fluctuation in AWH and AHE series which seemed to be calendar related rather than driven by economic reasons. In 1997, researchers both within and outside the Bureau of Labor Statistics (BLS) established a correlation between over-the-month changes in AWH and AHE series and the number of weekdays in a month.

An initial review of the AWH and AHE series revealed that the fluctuations were concentrated in the service-producing industries, especially in the finance, insurance and real estate division (FIRE), and could be traced to survey reporters with a high proportion of salaried employees and semi-monthly or monthly payrolls. These findings led to an examination of the treatment of these hours and earnings reports within the CES production system. The examination revealed that the conversion process used to normalize these reports, that is converting reports with other than weekly pay periods to the weekly equivalent, was treating some reports inappropriately and was in part causing the fluctuations.

Several ways of identifying and measuring the fluctuations were approached:

- The microdata were tested for statistical differences between reported hours and earnings for months with fewer versus larger number of workdays.
- Reporters were contacted in order to clarify their reporting practices, specifically their methods of calculating the hours and earnings they listed on the reporting form.
- REGARIMA models were developed to capture the effect of the length-of-pay period with variables and to treat AWH and AHE series in order to eliminate the fluctuations.

The methods employed in this research and the results obtained are listed in detail in this paper. Our findings confirmed the initial discoveries and are summarized as follows:

- The source of the calendar related fluctuations in the AWH and AHE series are the monthly and semi-monthly reports and their treatment in the CES production system.
- A modification of the CES production system would be required to convert each report appropriately depending upon the reporting practice of the respondent.
- Respondents have to be educated on the 'correct' method of reporting hours if these are calculated by a formula rather then actually recorded.
- Payroll and hours data have to be collected as separate data items for hourly and salaried employees in order to ensure proper conversion.
- The implementation of these corrective measures requires considerable time and resources and could only be accomplished as a long-term project.
- In the short run, the use of REGARIMA models proved to be the most feasible and effective measure to correct for the fluctuation, however the correction is applied to the seasonally adjusted data series only.

2. The Current Employment Statistics Survey

In the CES survey AWH and AHE are not collected directly, they are derived from the data types that are collected on the survey form. The series are based on the reports' gross payroll and the corresponding paid worker-hours for production workers. The payroll data item refers to the total gross production worker payrolls paid directly by the company to the production workers for the pay period reported. The worker-hours data item refers to the total number of hours worked by production workers and paid for by the company during the pay period reported.

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AWH information relates to the average number of hours per workweek for which pay was received and is computed as:

$$AWH = WH / PW$$

where WH = total worker hours and PW = total of production workers.

AHE information relates to the gross average hourly earnings as actual return to a worker for a stated period of time and is computed as:

$$AHE = PR / WH$$

where PR = payroll.

The pay period for which data are reported includes the 12th of the month. The respondent indicates the pay period as:

- weekly = assumes 5 days worked/paid
- biweekly = assumes 10 days worked/paid
- semimonthly = from 10 to 12 days worked/paid
- monthly = from 20 to 23 days worked/paid

When a respondent reports data for a pay period that is longer than one week, it is necessary to reduce the reported hours and payroll data to 1-week equivalents (normalization). For this purpose a conversion factor or length-of-pay period code is applied to the reported figure which depends on the number of workdays (D) in the pay period (PP). Worker hours and payrolls are normalized and AWH and AHE are calculated as:

$$AWH = (LP_{D,\,PP} * WH_R) / PW$$

$$AHE = (LP_{D,\,PP} * PR) / WH_N$$

where $LP_{D,\,PP}$ =

- .45 if D = 11 days and PP = semimonthly
- .50 if D = 10 days and PP = semimonthly
- .22 if D = 23 days and PP = monthly
- .23 if D = 22 days and PP = monthly
- .24 if D = 21 days and PP = monthly
- .25 if D = 20 days and PP = monthly
- .50 if PP = biweekly
- 1.0 otherwise

and WH_R = reported worker hours
WH_N = normalized worker hours.

3. Test of Microdata

The microdata, that is the reported, normalized data, was tested in an attempt to identify problematic reports. The underlying assumption in the CES estimation process for AWH and AHE is that respondents vary their worker hours and payroll by the number of days per pay period. This assumption is certainly justify for respondents with weekly or biweekly payrolls, with a majority of their employees being paid hourly and with accurate record keeping of the hours worked. In cases where the respondent has a high percentage of salaried employees who are paid a fixed amount for each pay period, the reported payroll number does not vary by the number of days in a pay period and an accurate record of the hours worked might not be available. Here the number of worker hours reported could reflect a fixed payroll and might not vary by the number of days worked either. Therefore, if a respondent with semimonthly or monthly pay periods reports fixed worker hours and fixed payroll, the normalization procedure of the CES production system could introduce fluctuations for pay periods with varying number of workdays. This hypothesis is translated into a test of the difference between two population (pop) means:

$$H_0: \mu_1 - \mu_2 = 0$$
$$H_A: \mu_1 - \mu_2 < 0$$

Test Statistic: $t = (y_1 - y_2) / s_p \sqrt{ (1/n_1 + 1/n_2)}$
where $s_p = \sqrt{ [(n_1-1)s_1^2 + (n_2-1)s_2^2]/(n_1+ n_2-2)}$

Rejection Region: $\alpha = .025$ $df = n_1 + n_2 - 2$
Reject H_0 if $t > t_\alpha$
Where
μ_1 = pop mean for pay periods with 10 workdays (semimonthly) or 20 and 21 workdays (monthly)
μ_2 = pop mean for pay periods with 11 workdays (semimonthly) or 22 and 23 workdays (monthly)
y_1 = sample mean for pay periods with 10 workdays (semimonthly) or 20 and 21 workdays (monthly)
y_2 = sample mean for pay periods with 11 workdays (semimonthly) or 22 and 23 workdays (monthly)
n_1 = number of reported months with 10 workdays (semimonthly) or 20 and 21 workdays (monthly)
n_2 = number of reported months with 11 workdays (semimonthly) or 22 and 23 workdays (monthly)

s_p = estimate of the standard deviation σ for the two populations, formed by pooling information from the samples

$s_{1,2}$ = sample variances

The data tested was the calculated $AWH = WH_n / PW$ and $AHE = PR_n / WH_n$ for each reporter.

Table 1. Distribution of Reports by Pay Period Failing Means Test for AWH

Industry	Total		Weekly		Biweekly		Semimonthly		Monthly	
	Reports	Failing	Reports	Failing	Reports	Failing	Reports	Failing	Reports	Failing
Total Private	223903	8.5%	52.6%	3.9%	32.9%	4.6%	9.2%	46.3%	5.3%	16.6%
Mining	2130	10.3%	42.9%	3.1%	39.4%	5.1%	9.6%	51.2%	8.1%	25.0%
Construction	23320	3.1%	89.2%	2.7%	6.6%	3.8%	1.1%	22.1%	3.1%	7.8%
Manufacturing	48763	5.6%	74.2%	4.5%	20.2%	4.9%	3.0%	32.2%	2.6%	12.1%
TPU	11660	8.7%	36.2%	3.2%	44.1%	3.2%	11.9%	42.1%	7.7%	14.1%
Wholesale	17939	10.4%	47.6%	3.5%	35.1%	4.6%	10.4%	52.4%	6.9%	24.7%
Retail	49231	6.5%	53.3%	3.0%	36.6%	4.7%	6.3%	41.1%	3.8%	15.2%
FIRE	15078	20.1%	16.9%	2.9%	48.0%	6.2%	24.2%	58.5%	10.9%	22.7%
Service	55782	11.6%	32.8%	3.3%	44.3%	4.4%	15.7%	45.3%	7.2%	15.1%

A reporter failing this means test, that is H_0 is rejected, is assumed to report fixed worker hours and payroll. By normalizing the reported data, the CES production system introduces the observed fluctuations into the data for these reporters. Table 1 lists the distribution of reports by pay period and the percentage of reports failing the test for AWH.

The results of the means test for AWH indicate that nearly half of the semimonthly reports display significant differences in normalized worker hours between months with varying workdays per pay period. The table also indicates that the majority of semimonthly reporters are in the service-producing industries with FIRE having the largest share.

The results of the means test for AHE are not as apparent as for the AWH series. However, about 10 percent of semimonthly and 6 percent of the monthly reports display significant differences in normalized payrolls between months with varying workdays per pay periods. The smaller number of reports testing significantly different for AHE can be best explained by recalling the procedure the CES production system uses to calculate AHE:

$$AHE = (LP_{D,\,PP} * PR) / WH_N$$

The product $LP_{D,\,PP} * PR$ calculates the normalized payroll which is divided by the normalized worker hours. The same conversion factor (LP) is used to normalize both data elements. Therefore, for respondents who report fixed worker hours and fixed payroll, the division of the two data elements neutralizes the conversion factors and the resulting AHE series do not display the fluctuations introduced by the factors. Only the AHE series for those respondents who report fixed payroll figures but vary the number of reported worker hours according to the number of workdays per pay period display the fluctuations, in this case introduced by the conversion factor during the normalization of the payroll figures.

4. Respondents Contact

As an independent effort to confirm what we concluded from examining the microdata, we selected a sample of 100 monthly and semimonthly respondents and made telephone calls to ask about their hours and earnings reporting practices. An important basic finding is that 70 percent of the respondents had both salaried and hourly workers.

For their hourly paid workers respondents stated using actual hours figures over 90 percent of the time; for salaried workers actual hours were available only 12 percent of the time, the rest of the time the hours figures were estimated usually according to some fixed formula or using a constant value. When asked if the number of hours they reported would vary with the number of weekdays in a month, about 80 percent of the respondents said yes for the hourly paid workers but only 20 percent varied the hours for the salaried workers. For the payroll, the results are similar except a higher percentage of respondents, about 50 percent, had actual payroll data for salaried workers.

The overall conclusion from the set of data is that the CES conversion practices are appropriate for hourly paid workers, but not salaried worker reports. Since most of the respondents had both types of workers it argues for CES to collect hourly and salaried worker reports as two separate figures and normalize these reports independently. This would

require far reaching changes with regard to the CES production system and electronic data collection system. However, separate reports might be feasible from the respondents' point of view since 77 percent of the respondents said they could provide separate payroll figures for hourly and salaried workers.

The interviews with the respondents and the test of the microdata were essential in identifying the source of the problem, however these research elements did not provide an immediate and feasible solution which was found by REGARIMA modeling.

5. REGARIMA Modeling and Diagnostics

5.1. The Model

Data series in the CES program are seasonally adjusted with X-12-ARIMA software developed by the Bureau of the Census. A technique known in X-12-ARIMA software as REGARIMA modeling is used to identify the estimated size and significance of calendar effects in CES series. Example of these calendar effects are the adjustments for interval effects between survey weeks currently applied to the employment series of the program and the adjustment for moving holidays in AWH series. The REGARIMA models evaluate the variation in levels attributable to varying calendar effects in the same month of different years. The effects are examined by a joint chi-square test, which provides evidence of statistical significance across all model variables, and by t-tests on individual coefficients. Adjustment factors are calculated and applied to the original series in connection with the seasonal factors. Since calendar effects are known in advance, factors can be forecasted based on the observed effects in past months. The observed fluctuation in the AWH and AHE series are also related to calendar effects which makes the application of the REGARIMA modeling technique a feasible alternative in the mitigation of the fluctuations.

The multiplicative decomposition of time series is described by the model $Y = T * S * I * P$, where P denotes a prior adjustment factor, and has the decomposition $P = P_T * P_L * P_I$. In this application, the length of the period is month-specific, and is estimated as the factor P_L . For seasonal adjustment, P_L is combined with the seasonal factor, and the seasonally adjusted values become

$$Y / (S * P_L) = T * I * P_T * P_I .$$

As with other interventions and calendar effects, extended ARIMA models are used to estimate the length-of-pay period effect, written as

$$\text{Log } y_t - \sum \alpha_j M_{jt} - \sum \beta_j X_{jt} = \psi (B, B^{12}) \ a_t$$

Where y_t is the observed series, the M_j's represent the month variables, the X_j's represent the outliers or other interventions, a_t represents the noise term and ψ denotes a seasonal ARIMA model. On the log scale, the effect of the length of the pay period in month j at time t is

$$-\alpha_j M_{jt} , \qquad M_{jt} = \begin{cases} 1, \ t = j \ (\text{mod } 12), \\ \quad 10 \text{ day pay period} \\ -.4, \ t = j \ (\text{mod } 12), \\ \quad 11 \text{ day pay period} \\ 0, \ \text{otherwise} \end{cases}$$

The adjustment for the length-of-pay period is sometimes positive and sometimes negative. Since there are more instances of 11 days pay periods, the factor -0.4 helps achieve balance in these effects. This is analogous to the property that the mean of the seasonally adjusted series should be close to the mean of the unadjusted series. Notice also that only two factors are used which test only the effects of semimonthly reports on the series. Tests showed that by including four additional factors to account for the effects of the differences in monthly pay periods, the model does not improve and the estimated adjustment factors become weaker for some months.

5.2 Tests for Significance of the Length-of-pay period Variables

Chi-square and t-statistics are observed to test the significance of the joint contribution and coefficients for the 12 monthly length-of-pay period variables. Of the 29 published AWH series fitted with models using the explanatory variables, all 5 service-producing divisions display t-statistics greater than 2 for at least 8 months (see table 2.) and Chi-square values smaller than 0.005. The FIRE division had t-statistics greater than 10 for all 12 variables, indicating that the length-of-pay period has a dominating effect on the over-the-month changes of this AWH series. For the goods-producing industries the variables tested insignificant. These industries do not display the spikes and do not require an adjustment for this calendar effect.

Of the 8 published AHE series fitted with models using the explanatory variables, three service-producing divisions had t-statistics greater than 2 for at least 11 of the 12 variables displaying the same sign. The other 5 divisions displayed only a few t-statistics greater than 2 and the signs of the t-statistics were not equal. Based on these results, the

AHE series for the divisions wholesale, FIRE and services are adjusted for the length-of-pay period effect.

Table 2. T-Statistics of Length-of Pay-Period Variable for AWH in Selected Divisions

Month	TPU	Whole-sale	Retail	FIRE	Ser-vices
Jan	3.87	5.15	5.79	12.29	9.20
Feb	2.19	6.30	5.06	14.28	7.53
Mar	0.44	6.50	1.97	14.05	7.56
Apr	4.49	3.87	5.94	10.11	6.70
May	1.86	6.14	1.47	11.68	9.06
Jun	3.80	5.66	4.54	14.25	6.15
Jul	3.11	4.51	3.51	10.68	6.40
Aug	0.52	4.48	2.49	12.68	6.93
Sep	2.54	3.25	1.81	11.63	4.91
Oct	3.26	5.78	4.02	12.10	8.23
Nov	4.16	4.65	0.98	13.13	6.63
Dec	2.81	4.50	2.91	11.74	5.90

5.3 Tests of Smoothness, Sliding Spans and Seasonal Adjustment Statistics

For validation of the REGARIMA models the following tests were conducted, the results of which are listed in table 3:

- A smoothness ratio was calculated for each treated series by dividing the square root of the sum of the squared first differences of the LP-adjusted series and the unadjusted series. A value smaller than 100 indicates that the adjusted series is smoother.
- The percent change in root-mean-squared error is calculated as percent difference of RMSE of the unadjusted series and the LP-adjusted series, displayed for the full series and for the last three years. A negative percentage indicates that the LP-adjusted series is smoother.
- For the sliding span analysis three spans (1988-1995, 1989-1996 and 1990-1997) were tested separately. A t-statistic greater than 2 indicates the number of significant variables or months in the model (max. 12) for each span. The joint p-value smaller than 0.10 indicates that the variables are jointly significant for each span.

The adjustment for the length-of-pay period resulted in additional improvements of the seasonal adjustment procedure of the CES program. Before the LP-adjustment, two AWH data series, for finance, insurance and real estate and for service, were not available to the public because their seasonal adjustment statistics did not pass the BLS publication standards for quality. After the treatment of these two series for the length-of-pay period effect, both series pass the BLS standards.

6. Effects of the Treatment on the Series

The Implementation of the REGARIMA-based smoothing techniques eliminates a significant source of non-economic volatility in the CES hours and earning series, thereby improving the month-to-month measurement of underlying economic trends (see Tables 4 and 5). A recent example for AWH occurs for the months of November and December 1997. As shown in table 4, the over-the-month change for AWH not adjusted for the length-of-pay period in November (a 10-day pay period) is +0.3 hour. This change is reversed in December (a 11 day pay period) with an over-the-month change of -0.2 hour. When the series is adjusted for the length-of-pay period effect, it shows less volatility. The November over- the-month change is +0.1 hour while the over-the-month change in December is zero, indicating there is little actual change in AWH for those months. Similarly for AHE, as shown in table 5, the series not adjusted for the length-of-pay period increases in November by +0.08 cents and is flat for the December over-the-month change. The adjustment corrects the series to increase in November by +0.04 cents and by +0.03 cents in December, figures more reflective of the actual underlying earnings trend.

7. Conclusion and Limitations

The CES hours and earnings series are effected by calendar related fluctuation which are caused by semi-monthly and monthly reports and their treatment in the CES production system. The modeling with the REGARIMA technique results in the successful treatment of these fluctuations and smoothens the affected series. This treatment also succeeds in correcting historical data and incorporating the treatment in forecasted seasonal factors. Its methodology is analogous to the treatment of employment series for the interval effect between survey periods. A drawback of this practice is the restriction of the application to the seasonal adjusted series, therefore the length-of-pay period effect is not removed from the unadjusted series. The removal of of the calendar effect from these series requires a change in the CES data collection procedure to solicit AWH and AHE data separated by hourly paid and salaried employees and a change of the CES production system with regard to the treatment of these reports. Both measures are currently being tested but require the investment of resources and time and are planned for the long run.

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Table 3. Smoothness Tests and Sliding Span Evaluation of the LP-Adjustment

Data Series	Smoothness Tests		Span 1: 1988-1995		Span 2: 1989-1996		Span 3: 1990-1997	
Division	Smooth-ness	RMSE	Months w/	Joint	Months w/	Joint	Months w/	Joint
AHE	Ratio	%-Change	t > 2.0	p-value	t > 2.0	p-value	t > 2.0	p-value
Wholesale	71.0	-40.1/-53.4	11	0.00	11	0.00	12	0.00
FIRE	66.0	-52.0/-47.4	12	0.00	12	0.00	12	0.00
Services	78.0	-27.5/-31.4	11	0.00	12	0.00	11	0.00
AWH								
TPU	74.0	-35.8/-46.9	7	0.00	9	0.00	10	0.00
Wholesale	60.0	-66.6/-89.4	12	0.00	11	0.00	11	0.00
Retail	68.0	-48.0/-56.8	7	0.00	8	0.00	8	0.00
FIRE	47.0	-113 / -210	12	0.00	12	0.00	12	0.00
Service	45.0	-123 /-99.2	12	0.00	12	0.00	12	0.00

Table 4. CES Total Private Average Weekly Hours, Seasonally Adjusted Over-the-Month Changes, Length-of-Pay Period Adjustment vs. No LP-Adjustment

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1993	LP-Treatment	0.1	0	-0.2	0.2	0	-0.1	0.1	0	0.1	0	0	0
	No LP-Treatment	0.1	0	-0.2	0.2	0.2	-0.2	0.1	0.1	-0.1	0	0	0
	Difference	0.0	0.0	-0.0	0.0	-0.2	0.1	0.0	-0.1	0.2	0.0	0.0	0.0
1994	LP-Treatment	0	-0.2	0.3	-0.1	0.1	0	0	-0.1	0	0.1	-0.1	0.1
	No LP-Treatment	0.3	-0.5	0.3	0	0.1	-0.1	0	-0.1	0.1	0.2	-0.2	0
	Difference	-0.3	0.3	0.0	-0.1	0.0	0.1	0.0	0.0	-0.1	-0.1	0.1	0.1
1995	LP-Treatment	0	-0.2	0	0	-0.2	0.1	0	0	0	0	0	-0.1
	No LP-Treatment	0.3	-0.4	0	0.1	-0.4	0.2	0.1	-0.1	0	0.1	-0.1	-0.1
	Difference	-0.3	0.2	0.0	-0.1	0.2	-0.1	-0.1	0.1	0.0	-0.1	0.1	0.0
1996	LP-Treatment	-0.4	0.6	-0.1	-0.1	0.1	0.2	-0.2	0.1	0.1	-0.1	0	0.1
	No LP-Treatment	-0.4	0.5	0	-0.1	0	0.4	-0.4	0.2	0.2	-0.3	0.1	0.2
	Difference	0.0	0.1	-0.1	0.0	0.1	-0.2	0.2	-0.1	-0.1	0.2	-0.1	-0.1
1997	LP-Treatment	-0.1	0.1	0.1	-0.1	0.1	-0.2	0	0.2	-0.1	0	0.1	0
	No LP-Treatment	-0.3	0.4	0	-0.3	0	0.1	-0.2	0.2	-0.1	0	0.3	-0.2
	Difference	0.2	-0.3	0.1	0.2	0.1	-0.3	0.2	0.0	0.0	0.0	-0.2	0.2
1998	LP-Treatment	0.1	-0.1	-0.1	-0.1								
	No LP-Treatment	0.2	0.1	-0.2	-0.3								
	Difference	-0.1	-0.2	0.1	0.2								

Table 5. CES Total Private Average Hourly Earnings, Seasonally Adjusted Over-the-Month Changes, Length-of-Pay Period Adjustment vs. No LP-Adjustment

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1993	LP-Treatment	0.03	0.01	0.05	0.00	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.03
	No LP-Treatment	0.04	0.02	0.03	0.01	0.04	-0.01	0.03	0.03	0.01	0.02	0.03	0.03
	Difference	-0.01	-0.01	0.02	-0.01	-0.02	0.03	-0.01	-0.01	0.02	-0.00	-0.01	0.00
1994	LP-Treatment	0.03	0.03	0.01	0.02	0.03	0.02	0.02	0.02	0.03	0.04	0.02	0.03
	No LP-Treatment	0.03	0.04	0.00	0.03	0.03	0.01	0.02	0.02	0.03	0.06	0.00	0.03
	Difference	-0.00	-0.01	0.01	-0.01	0.00	0.01	0.00	0.00	0.00	-0.02	0.02	0.00
1995	LP-Treatment	0.01	0.04	0.02	0.02	0.02	0.04	0.04	0.03	0.03	0.03	0.02	0.03
	No LP-Treatment	0.02	0.04	0.01	0.04	0.00	0.04	0.06	0.00	0.04	0.05	0.01	0.02
	Difference	-0.01	0.00	0.01	-0.02	0.02	0.00	-0.02	0.03	-0.01	-0.02	0.01	0.01
1996	LP-Treatment	0.05	0.00	0.03	0.06	0.02	0.06	0.03	0.03	0.04	0.03	0.05	0.04
	No LP-Treatment	0.04	0.02	0.02	0.05	0.03	0.07	0.00	0.05	0.05	0.00	0.07	0.05
	Difference	0.01	-0.02	0.01	0.01	-0.01	-0.01	0.03	-0.02	-0.01	0.03	-0.02	-0.01
1997	LP-Treatment	0.04	0.03	0.04	0.03	0.04	0.03	0.03	0.07	0.03	0.06	0.04	0.03
	No LP-Treatment	0.02	0.05	0.04	0.00	0.05	0.04	0.01	0.07	0.04	0.05	0.08	0.00
	Difference	0.02	-0.02	0.00	0.03	-0.01	-0.01	0.02	0.00	-0.01	0.01	-0.04	0.03
1998	LP-Treatment	0.04	0.05	0.04	0.07								
	No LP-Treatment	0.04	0.07	0.04	0.04								
	Difference	0.00	-0.02	0.00	0.03								

Months with borders have 10 day pay periods.