Adjusting for Calendar Effects in Payroll Hours and Earnings Series

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Abstract

This paper examines the causes and treatments of calendar-related movements in the payroll hours and earnings time series from the Current Employment Statistics (CES) survey. Prior research has established that there is a correlation between the number of workdays in the month and fluctuations in CES hours and earnings. The strongest correlation was determined to exist for reporting establishments with a semi-monthly or monthly payroll. These predictable movements are related to respondent error in semi-monthly and monthly payroll reports and processing limitations for payrolls. Currently, the CES hours and earnings series are adjusted for variations in the number of workdays in the 1st through the 15th of the month to treat for these effects. This paper discusses the current methods used to adjust for this effect along with the methods used to monitor changes in these correlations over time. This paper also discusses methods to detect and evaluate any residual effects of these movements in the final seasonally adjusted series and future improvements.

The results show that the length of pay period effect exists for the additional data types added to collect hours and payroll for all employees. The models currently used continue to perform well and provide an accurate means of adjusting for the length of pay period effect.

Key Words: calendar effects, time series models, seasonal adjustment, X-13ARIMA-SEATS

1. Introduction

The U.S. Bureau of Labor Statistics (BLS) collects data each month on employment, hours, and earnings from a sample of nonfarm establishments through the Current Employment Statistics (CES) program. The movements in these series from month to month are closely followed as timely indicators of the overall strength and direction of the nation's economy. Predictable movements such as seasonal patterns and calendar related variations in the survey data are measured and removed to reveal how the data series change from month to month. These adjustments make it easier to observe the cyclical, underlying trend, and other economic movements in the series.

This paper discusses one of these calendar related variations referred to as the length of pay period effect. The length of pay period effect is a correlation that exists between the number of workdays in a month and movements in the payroll hours and earnings series for establishments in the survey with semi-monthly or monthly payrolls. Figure 1 provides an example of a series with the length of pay period effect. The final series without adjustment shows the fluctuations in the data series caused by the length of pay period

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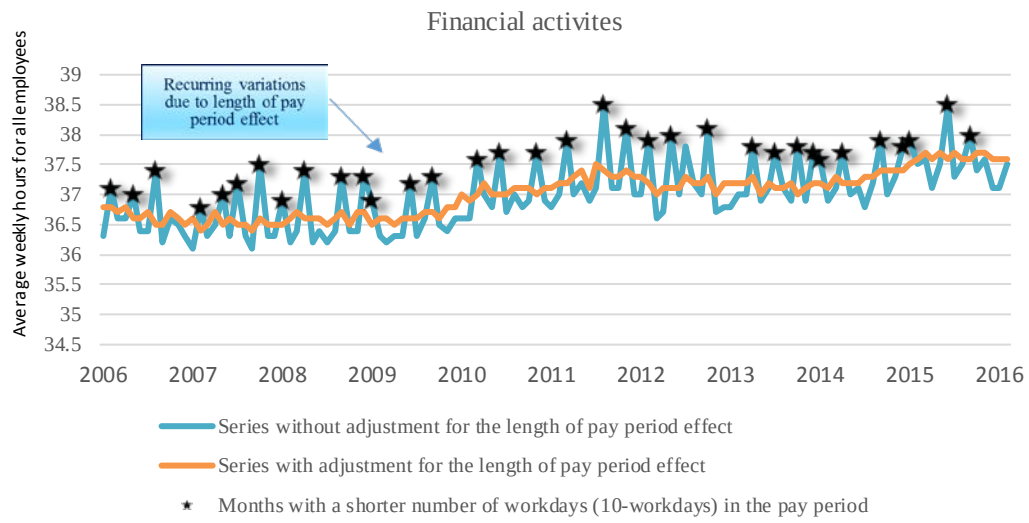
effect. The final series with adjustment shows the smoother series with the length of pay period effect removed. The underlying trend in the series with the adjustment for the length of pay period effect is easier to observe.

Figure 1: Average weekly hours for all employees with and without adjustment for the length of pay period effect, seasonally adjusted Mar 2006 - March 2016



Previous research identifies and provides the current method used for measuring and adjusting the CES estimates for these predictable movements (Kropf, et al., 1999). At the time of the previous research, the CES survey collected payroll hours and earnings data only for production employees. Since then additional data types have been added to collect payroll hours and earnings data for all employees. This paper expands on prior research by Kropf, et al. (1999) to identify the length of pay period effect in the payroll hours and earnings series for all employees and re-examines this effect in the payroll hours and earning series for production employees. This paper also discusses the current method used to adjust for the length of pay period effect and monitor changes over time. Finally, the method used to detect any residual effects in the final series after adjustment is also discussed.

2. Payroll Hours and Earnings in the Current Employment Statistics Survey

The CES survey includes about 146,000 businesses and government agencies, which cover approximately 623,000 individual worksites drawn from a sampling frame of Unemployment Insurance (UI) tax accounts covering roughly 9.3 million establishments. The active CES sample includes approximately one-third of all nonfarm payroll employees in the 50 states and the District of Columbia. From these data, a large number of employment, hours, and earnings series in considerable industry and geographic detail are prepared and published each month.

2.1 Employment

Employment data refer to persons on establishment payrolls who worked or received pay for any part of the pay period that includes the 12th of the month.

2.2 Hours

These are the hours worked or for which pay was received during the pay period that includes the 12th of the month for all employees, production, construction, and nonsupervisory employees.

2.3 Payroll

Payroll refers to dollars paid for all full- and part-time employees, and for production, construction, and nonsupervisory employees who received pay for any part of the pay period that includes the 12th day of the month.

2.4 Average Weekly Hours

Average weekly hours (AWH) are not collected directly, they are derived from the hours and employment collected on the survey form as defined above.

AWH for all employees is the average number of hours per week for which pay was received and is computed as:

$$AWH\ for\ all\ employees = \frac{WH}{AE} \tag{2.4.1}$$

$$where\ WH = total\ employee\ hours\ worked$$
$$AE = total\ of\ all\ employees$$

AWH for production employees is calculated using the same formula (2.4.1) above with the corresponding production employee data.

2.5 Average Hourly Earnings

Average hourly earnings (AHE) are not collected directly, they are derived from the payroll and hours and are collected on the survey form as defined above.

AHE for all employees is the average hourly earnings per week for which pay was received and is computed as:

$$AHE\ for\ all\ employees = \frac{PR}{WH} \tag{2.5.1}$$

$$where\ PR = total\ payroll\ of\ all\ employees$$
$$WH = total\ employee\ hours\ worked$$

AHE for production employees is calculated using the same formula (2.5.1) above with the corresponding production employee data.

2.6 Length of Pay Period

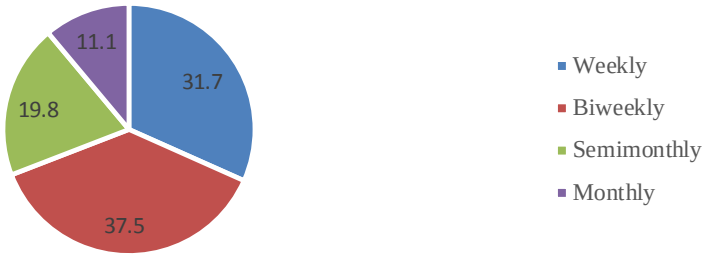
Data for employment, hours, and earnings are collected each month for the pay period that includes the 12th of the month. The length of this pay period is specific to the establishment and depends on how frequently it pays its employees. This means that establishments in the CES survey report information on total hours and earnings that covers various lengths of pay period.

The length of pay period for an establishment is collected in order to adjust hours and earnings information to a common basis for CES estimates. For example, a business that pays employees for a 2-week pay period will need to have its average hours divided by 2 in order to calculate average weekly hours. For this reason, any respondent reporting hours

or earnings information is asked to provide the length of pay period it uses. Possible length of pay periods are weekly, biweekly, semimonthly, or monthly pay periods. Figure 2 shows the percentage of establishments reporting for each length of pay period (Burgess 2014). The establishment indicates the pay period as:

- weekly = assumes 5 days worked/paid
- biweekly = assumes 10 days worked/paid
- semimonthly = from 10 to 11 days worked/paid
- monthly = from 20 to 23 days worked/paid

Figure 2: Percentage of Establishments Reporting for Each Length of Pay Period, March 2014



2.7 Normalization

When an establishment 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).

Hours and payrolls for all employees are normalized and AWH and AHE are calculated as:

$$AWH = \frac{LP_{D,PP} * WH}{AE} \tag{2.7.1}$$

$$AHE = \frac{LP_{D,PP} * PR}{LP_{D,PP} * WH} \tag{2.7.2}$$

$$where\ WH = reported\ hours$$
$$PR = reported\ payroll$$
$$LP_{D,PP} = \begin{cases} .45\ if\ D = 11\ days\ and\ PP = semimonthly \\ .50\ if\ D = 10\ days\ and\ PP = semimonthly \\ .22\ if\ D = 23\ days\ and\ PP = monthly \\ .23\ if\ D = 22\ days\ and\ PP = monthly \\ .24\ if\ D = 21\ days\ and\ PP = monthly \\ .25\ if\ D = 20\ days\ and\ PP = monthly \\ .50\ if\ PP = biweekly \\ 1.0\ otherwise \end{cases}$$

Hours and payrolls for production employees are calculated using the same formulas (2.7.1 and 2.7.2) above with the corresponding production employee data.

3. Testing for the Length of Pay Period Effect in the Micro-Level Data

Each establishment that reported valid hours and earnings data is tested for the length of pay period effect. The reported establishment data is referred to as the microdata. The microdata tested is the normalized AWH and AHE for each establishment as defined above. Hours and earnings collected by the CES survey are limited to private establishments.

3.1 Assumption

The underlying assumption in the CES estimation process for AWH and AHE is that establishments vary their hours and payroll by the number of workdays per pay period. This assumption is justified 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.

3.2 Hypothesis Test

In cases where the establishment 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 workdays in a pay period and an accurate record of the hours worked might not be available. Here the number of hours reported could reflect a fixed payroll and might not vary by the number of workdays either. Therefore, if an establishment with semimonthly or monthly pay periods reports fixed 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 means μ_1 and μ_2, where μ_1 is the average parameter for periods with less number of workdays and μ_2 is the average parameter for periods with more workdays. The hours and earnings are normalized to weekly equivalents for each establishment assuming that they vary their hours and earnings based on the number of workdays in the pay period. If this assumption is true then there is not a statistically significant difference between the normalized hours and earnings in months with a shorter versus a longer number workdays, so H_o is true:

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

But, if an establishment reports fixed hours and payroll that do not vary by the number of workdays then the normalization procedure can introduce predictable fluctuations dependent on the number of workdays resulting in different population means, so H_A is true:

$$H_A: \mu_1 - \mu_2 \neq 0$$

$$Test\ Statistic: t = \frac{(y_1 - y_2)}{s_p\sqrt{1/n_1 + 1/n_2}} \qquad (3.2.1)$$

$$where\ s_p = \frac{\sqrt{(n_1 - 1){s_1}^2 + (n_2 - 1){s_2}^2}}{n_1 + n_2 - 2}$$

$\mu_1 = pop\ mean\ for\ months\ with\ 10\ workdays\ (semimonthly)\ or\ 20\ and\ 21\ workdays\ (monthly)$
$\mu_2 = pop\ mean\ for\ months\ with\ 11\ workdays\ (semimonthly) or\ 22\ and\ 23\ workdays\ (monthly)$
y_1
$= sample\ mean\ for\ months\ with\ 10\ workdays\ (semimonthly)\ or\ 20\ and\ 21\ workdays\ (monthly)$
y_2
$= sample\ mean\ for\ months\ with\ 11\ workdays\ (semimonthly)\ or\ 22\ and\ 23\ workdays\ (monthly)$
n_1
$= number\ of\ reported\ months\ with\ 10\ workdays\ (semimonthly)\ or\ 20\ and\ 21\ workdays\ (monthly)$
n_2
$= number\ ofreported\ months\ with\ 11\ workdays\ (semimonthly) or\ 22\ and\ 23\ workdays\ (monthly)$
$s_p = estimate\ of\ the\ standard\ deviation\ \sigma\ for\ the\ two\ populations\ calculated\ from\ the\ sample\ variances\ s_{1,2}$

The t-test is performed at the α=.05 significance. Therefore, we can reject H_0 with 95% confidence that the means are not equal if $|t| > t_\alpha$ where t_α is the rejection point. The mean of each establishment reporting hours and payroll is tested using this criteria and the percentage of establishments failing this means test is calculated using the same procedure from the previous research to identify the length of pay period effect (Kropf, et al., 1999).

3.3 Weighting

Each business in the CES survey is assigned a weight, which represents the probability of selection, or the inverse of the sampling rate. It is computed as:

$$Sample\ selection\ weight = N_h/n_h \tag{3.3.1}$$

$where\ N_h = the\ number\ of\ noncertainty\ UI\ accounts\ within\ the\ allocation\ cell\ that\ are\ eligible\ for\ sample\ selection$
$n_h = the\ number\ of\ noncertainty\ UI\ accounts\ selected\ within\ each\ allocation\ cell$

This weight (3.3.1) is used in producing the survey's employment, hours, and earnings estimates. The weight can also be applied to the length of pay period data for the establishment. The weighted length-of-pay-period data gives an estimate of the percentage of private establishments operating under each length of pay period shown in Figure 2 (Burgess 2014). The weight is also applied to the data tested for the length of pay period effect in the means test. The data from the weighted means test gives an estimate of the percentage of establishments failing the test.

4. Results

The hours and payroll for establishments in the CES survey are normalized assuming that hours and payroll vary based on the number of workdays in the pay period. The null hypothesis, H_0, is rejected when an establishment fails the means test and is assumed to report fixed worker hours and payroll that do not vary based on the number of workdays in the pay period. So by normalizing the reported data, the CES production system introduces predictable movements into the data for these establishments resulting in different population means for the months with a shorter number of workdays compared to the months with a longer number of workdays.

At the time of the previous research, hours and earnings were published only for production employees (Kropf, et al., 1999). CES now publishes hours and earnings for all employees as well. The hours and earnings for both all employees and production employees were tested for the length of pay period effect and the results presented in the tables below.

4.1 Hours

Table 1 shows the percentage of establishments failing the weighted length of pay means test for average weekly hours of all employees. The results show that the previous findings are confirmed for the average weekly hours of all employees and production employees (Kropf, et al., 1999):

- The source of the length of pay period effect are the semimonthly and monthly establishments. Table 1 shows that a large percentage of the establishments that fail the length of pay means test have a semimonthly or monthly pay period.
- The establishments with the length of pay period effect are concentrated in the service industries with a higher proportion of salaried employees and semimonthly payrolls. Table 1 shows that the service industries have a higher percentage of establishments on a semimonthly or monthly pay period and a higher percentage of establishments failing the length of pay means test.

Table 1: Distribution of Reports by Pay Period Failing the Length of Pay Means Test for Average Weekly Hours of All Employees

	Total		Weekly		Biweekly		Semimonthly		Monthly	
Industry	Reports	% Failing	% of Reports	% Failing	% of Reports	% Failing	% of Reports	% Failing	% of Reports	% Failing
Total Private	202,292	16.8%	33.4%	6.2%	39.3%	4.7%	19.6%	47.1%	7.7%	46.9%
Natural Resources and Mining	1,167	16.0%	41.1%	2.2%	38.5%	12.4%	12.7%	57.3%	7.8%	39.0%
Construction	8,691	14.6%	73.9%	12.2%	19.4%	11.8%	3.6%	41.2%	3.1%	60.0%
Manufacturing	8,409	10.8%	54.2%	6.0%	34.9%	7.1%	7.6%	46.8%	3.3%	45.9%
Trade, Transportation, and Utilities	77,253	16.3%	37.0%	4.7%	39.6%	5.2%	16.8%	53.7%	6.6%	53.9%
Information	10,273	29.0%	8.6%	2.5%	42.7%	4.1%	37.7%	60.4%	11.0%	39.2%
Financial Activities	22,799	25.3%	18.7%	4.8%	38.1%	4.3%	31.0%	53.4%	12.2%	50.9%
Professional and Business Services	24,773	22.0%	20.9%	3.8%	38.5%	4.6%	29.3%	48.2%	11.3%	47.0%
Education and Health Services	17,014	11.8%	11.4%	2.6%	59.2%	3.6%	22.0%	30.7%	7.4%	35.8%
Leisure and Hospitality	26,780	10.5%	29.4%	3.7%	48.9%	3.2%	16.2%	35.3%	5.4%	40.1%
Other Services	5,133	13.0%	41.8%	5.1%	33.4%	1.9%	17.1%	43.8%	7.7%	35.1%

4.2 Payroll

Table 2 shows the percentage of establishments failing the weighted length of pay means test for average hourly earnings of all employees. As in the previous research, the results for the average hourly earnings of all employees are not as conclusive (Kropf, et al., 1999):

- The length of pay period effect is not as apparent in the average hourly earnings of all employees. Table 2 shows that a small percentage of establishments fail the length of pay means test.
- The length of pay period effect cannot be as easily identified because the source of the effect is offset in the formula (2.7.2) used to calculate average hourly earnings. This can best be explained by recalling the procedure used to calculate average

hourly earnings. The normalized payroll is divided by the normalized hours and the same LP factor is used to normalize both data elements. Therefore, the effect does not appear for establishments that report fixed hours and fixed payroll because the fluctuations introduced by the LP factors are offset by division of the two data elements.

Table 2: Distribution of Reports by Pay Period Failing the Length of Pay Means Test for Average Hourly Earnings of All Employees

	Total		Weekly		Biweekly		Semimonthly		Monthly	
Industry	Reports	% Failing	% of Reports	% Failing	% of Reports	% Failing	% of Reports	% Failing	% of Reports	% Failing
Total Private	202,292	7.3%	33.6%	5.2%	39.2%	3.7%	19.6%	13.3%	7.7%	18.7%
Natural Resources and Mining	1,167	12.6%	41.1%	7.9%	38.4%	9.4%	12.7%	30.6%	7.8%	24.3%
Construction	8,691	11.5%	73.9%	11.4%	19.4%	7.0%	3.6%	17.4%	3.1%	36.6%
Manufacturing	8,409	6.8%	54.1%	5.1%	35.0%	7.1%	7.6%	14.1%	3.3%	14.5%
Trade, Transportation, and Utilities	77,253	5.9%	37.0%	3.3%	39.6%	2.8%	16.9%	14.7%	6.6%	15.3%
Information	10,273	9.5%	9.0%	3.8%	42.1%	3.8%	37.9%	17.9%	11.0%	7.1%
Financial Activities	22,799	8.9%	18.6%	2.3%	38.1%	3.3%	31.1%	14.4%	12.2%	22.6%
Professional and Business Services	24,773	9.0%	21.7%	3.9%	38.1%	3.7%	28.9%	14.9%	11.3%	21.5%
Education and Health Services	17,014	5.8%	11.5%	3.2%	59.1%	4.2%	22.0%	9.0%	7.4%	13.8%
Leisure and Hospitality	26,780	4.0%	29.4%	3.0%	48.9%	2.6%	16.2%	6.2%	5.4%	15.8%
Other Services	5,133	5.2%	42.5%	2.5%	33.0%	3.9%	16.8%	10.5%	7.7%	13.2%

5. Solution: How to Adjust for the Length of Pay Period Effect

As established in previous research and reconfirmed here, the length of pay period effect exists as a result of a discrepancy between the normalization method used by the processing system and the way establishments report hours and payroll (Kropf, et al., 1999). The normalization method assumes that establishments vary hours and payroll based on the number of workdays in the pay period and uses LP or length of pay factors to adjust the hours and payroll. While this assumption is correct for employees that are paid hourly, this assumption is not correct for salaried employees. The results confirm that the length of pay period effect exists for industries with a higher percentage of salaried employees. The solutions to resolve the discrepancy are discussed here.

5.1 Micro Level – Collecting Two Payrolls

The previous research established that most establishments have both hourly and salaried employees (Kropf, et al., 1999). However, the normalization method is appropriate for hourly, but not salaried employees. Since most establishments have both types of workers, the hourly and salaried data should be collected as two separate figures and normalized independently to eliminate the length of pay period effect. The CES survey is a voluntary sample and we are now collecting two payrolls; however, only a small percentage (5%) of establishments actually report two payrolls. For these reasons, the micro level solution of collecting and normalizing two independent payrolls does not provide an immediate and feasible solution.

5.2 Macro Level – Modeling

Instead of modifying the normalization method for the data collected at the establishment level, CES uses a model to calculate adjustment factors that are applied to the average weekly hours and average hourly earnings estimates at the industry level to remove the length of pay period effect. Researchers initially discovered the fluctuations caused by the length of pay period effect in the estimates at the industry level. These fluctuations were then traced back to the establishment level data in the previous research (Kropf, et al., 1999). For the reasons discussed above, adjusting the data collected at the establishment level is not a feasible solution. Therefore, a modelling procedure known as regARIMA is used to adjust for the length of pay period effect.

5.2.1 RegARIMA

A technique known as regARIMA modeling is used to identify and adjust for the length of pay period effect along with other calendar related effects in the series. The regARIMA model evaluates the variation in levels attributable to varying calendar effects in the same month of different years. RegARIMA modeling capabilities are available in the X-13ARIMA-SEATS software developed by the U.S. Census Bureau that is also used for seasonal adjustment (X-13ARIMA-SEATS Reference Manual 2015). The regARIMA can be thought of as a generalized regression model that allows the errors to follow the ARIMA model. The addition of the ARIMA component to the model addresses the fundamental problem with applying standard regression methodology to time series data, which is that standard regression assumes that the regression errors are uncorrelated over time. For time series data, the errors will usually be auto correlated. Assuming the errors are uncorrelated can lead to invalid results, hence the need for the ARIMA component. The multiplicative regARIMA model used to estimate the length of pay is:

$$\log y_t - \sum \propto_j M_{jt} - \sum \beta_j X_{jt} = \varphi(B, B^{12}) a_t \qquad (5.2.1.1)$$

$y_t = the\ original\ time\ series$
$M_{jt} = the\ month\ variables$
$X_{jt} = the\ outliers\ or\ other\ interventions$
$a_t = the\ error\ term$
$\varphi = a\ seasonal\ ARIMA\ model$
$B = the\ backshift\ operator\ (Ba_t = a_{t-1})$
$j = the\ length\ of\ pay\ period\ at\ at\ time\ t$
$t = time$

On the log scale, the effect of the length of pay period in month j at time t is:

$$\propto_j M_{jt}, M_t = \begin{cases} 1, t = j\ (mod\ 12), 10\ day\ pay\ period \\ -0.4, t = j\ (mod\ 12), 11\ day\ pay\ period \\ 0, otherwise \end{cases}$$

Only two levels are used, which test the effects of the semimonthly pay periods on the series. Tests conducted during previous research showed that including four levels to account for the effects of both the semimonthly and monthly pay periods did not improve the estimated factors and caused some of them to become weaker for some months (Kropf, et al., 1999). Recent tests also showed that there is no residual effect from the monthly pay periods in the estimates.

The adjustment for the length-of-pay period can be either positive or negative. Since there are more instances of 11 day pay periods, the factor -0.4 helps achieve balance in these effects over 10 years to ensure that the mean of the adjusted series is close to the mean of the unadjusted series.

5.2.2 Time Series Decomposition

Once the length of pay adjustment factors are calculated using the regARIMA model described above, the factors are then applied to the original series and incorporated into the seasonally adjusted series. A time series can be described by a multiplicative or additive decomposition. Here we use a mulitiplicatve decomposition:

$$Y = T * S * I * P \quad (5.2.2.1)$$

$$\begin{aligned} where\ Y &= the\ original\ time\ series \\ T &= the\ trend - cycle \\ S &= the\ seasonal \\ I &= the\ irregular \\ P &= other\ variations\ that\ can\ be\ modelled \\ &\quad and\ adjusted \end{aligned}$$

The length of pay period effect is included in P and describes any other variations such as calendar effects that can be modelled and adjusted prior to seasonal adjustment of the series. P has the decomposition:

$$P = P_T * P_L * P_I \quad (5.2.2.2)$$

$$\begin{aligned} where\ P_T &= other\ variations\ affecting\ the\ trend - cycle \\ P_L &= the\ variations\ from\ the\ length\ of\ pay\ effect \\ P_I &= other\ variations\ affecting\ the\ irregular \end{aligned}$$

The regARIMA model described in (5.2.1.1) above is used to estimate the length of pay period effect, P_L, and combined with the seasonal factor to calculate the seasonally adjusted series (A):

$$A = \frac{Y}{S * P_L} = T * I * P_T * P_I \quad (5.2.2.3)$$

The final seasonally adjusted series has both the seasonal and length of pay variations removed to make it easier to observe the cyclical, underlying trend, and other economic movements. The next section of the paper describes how the diagnostics from the regARIMA model are used to identify the series that need to be adjusted for the the length of pay period effect.

6. Identifying the Length of Pay Period effect in the Industry-Level Estimates

To identify the series that need to be adjusted for the length of pay period effect, the average weekly hours and average hourly earnings series are tested at the industry level. The months with a shorter pay period (10 workdays for semimonthly) are specified as the independent variables in a regression model using the regARIMA technique described above. The significance of the t-values are evaluated using 10 years of data as input to the model. If a majority of the t-values are significant, then the series is adjusted for the length of pay period effect. Table 3 and 4 show the distribution of t-values by industry for average weekly hours and average hourly earnings:

- The length of pay period effect found in the estimates is concentrated in the service-providing industries as found in the test of the establishment level data above, although a few of the goods-producing industries also show the effect.
- The length of pay period effect does exist for both average weekly hours and average hourly earnings at the industry estimate level (Table 3 and 4).

The distribution of t-values are evaluated annually to verify the existence of the length of pay period effect in the industries currently adjusted and to identify any additional industries that require adjustment. If a majority of the t-values are significant, then the series is selected for adjustment. After the industries that require adjustment are identified, the regARIMA model described in the previous section is used to adjust these series for the length of pay period effect. The next section discusses the methods used to evaluate the accuracy of the model.

Table 3: Length of Pay Period T-statistic Distribution for Average Weekly Hours of All Employees

Industry	T-test Values on months with a shorter pay period (10-day)				
	Lower - -2*	-1.99 - -0.01	0	0.01 - 1.99	2 - Higher*
Mining and logging	1	3	.	10	16
Construction	2	11	.	13	4
Wood products	.	6	.	17	7
Non-metallic mineral products	2	10	.	15	3
Primary metals	3	1	.	7	19
Fabricated metal products	1	11	.	10	8
Machinery	1	.	.	8	21
Computer and electronic products	.	2	.	2	26
Electrical equipment and appliances	1	8	.	5	16
Transportation equipment	6	3	.	11	10
Motor vehicles and parts	5	5	.	10	10
Furniture and related products	3	7	.	16	4
Miscellaneous durable goods manufacturing	3	9	.	6	12
Food manufacturing	1	10	.	9	10
Textile mills	3	10	.	13	4
Textile product mills	7	6	.	6	11
Apparel	1	8	.	18	3
Paper and paper products	4	7	.	5	14
Printing and related support activities	2	6	.	13	9
Petroleum and coal products	3	7	.	16	4
Chemicals	.	.	.	7	23
Plastics and rubber products	2	6	.	9	13
Miscellaneous nondurable goods manufacturing	4	4	.	6	16
Wholesale trade	.	.	.	.	30
Retail trade	.	2	.	11	17
Transportation and warehousing	.	1	.	5	24
Utilities	.	6	.	19	5
Information	.	.	.	.	30
Financial activities	.	.	.	.	30
Professional and business services	.	.	.	1	29
Education and health services	.	.	.	1	29
Leisure and hospitality	.	1	.	.	29
Other services	1	.	.	3	26

*Series with majority (at least 15 out of 30) significant t-values are highlighted

Table 4: Length of Pay Period T-statistic Distribution for Average Hourly Earnings of All Employees

Industry	T-test Values for on months with a shorter pay period (10-day)				
	Lower - -2*	-1.99 - -0.01	0	0.01 - 1.99	2 - Higher*
Mining and logging	2	5	.	7	16
Construction	1	7	.	14	8
Wood products	3	5	.	17	5
Non-metallic mineral products	.	5	.	10	15
Primary metals	4	10	.	4	12
Fabricated metal products	1	7	.	10	12
Machinery	1	1	.	6	22
Computer and electronic products	.	8	.	10	12
Electrical equipment and appliances	.	3	.	19	8
Transportation equipment	2	6	.	20	2
Motor vehicles and parts	2	5	.	11	12
Furniture and related products	.	10	.	14	6
Miscellaneous durable goods manufacturing	1	7	.	12	10
Food manufacturing	6	6	.	10	8
Textile mills	.	8	.	17	5
Textile product mills	4	7	.	11	8
Apparel	3	8	.	16	3
Paper and paper products	.	7	.	16	7
Printing and related support activities	.	7	.	15	8
Petroleum and coal products	2	8	.	11	9
Chemicals	1	8	.	6	15
Plastics and rubber products	.	11	.	14	5
Miscellaneous nondurable goods manufacturing	5	9	.	5	11
Wholesale trade	.	.	.	3	27
Retail trade	.	.	.	15	15
Transportation and warehousing	1	.	.	10	19
Utilities	1	3	.	10	16
Information	.	.	.	5	25
Financial activities	.	.	.	.	30
Professional and business services	.	.	.	.	30
Education and health services	3	5	.	14	8
Leisure and hospitality	.	8	.	5	17
Other services	1	.	.	4	25

*Series with majority (at least 15 out of 30) significant t-values are highlighted

7. Evaluating the Model Used for the Length of Pay Period Adjustment

The regARIMA model used to adjust the series identified for the length of pay period effect is evaluated by a joint chi-square test, which provides statistical significance across all model variables, and by t-tests on individual coefficients. The joint chi-square test is used to generate an F-test that is aimed at verifying an overall effect that can be attributed to the length of pay period. While the t-values on the individual coefficients are aimed at verifying the significance of the length of pay period effect for each month. The results in Tables 5 and 6 show that the regARIMA model provides a good fit:

- The chi-square P-values are significant (< 0.005) for all of the series fitted with models using the explanatory variables, indicating an overall goodness of fit for both the average weekly hours and average hourly earnings series.
- The t-values on the individual coeffcients for each month are significant (> 2) for a majority of months in the model indicating that the indivdual explanatory variables are significant in explaining the variation due to the length of pay period effect for the average weekly hours series and the average hourly earnings series.

Table 5: T-values of Length of Pay Period Variables for Average Weekly Hours of All Employees for Selected Industries

Month	Wholesale trade	Retail trade	Transportation and warehousing	Information	Financial activities	Professional and business services	Education and health services	Leisure and hospitality	Other services
January	8.06	8.06	3.61	7.46	15.57	7.98	8.17	6.82	6.68
February	8.55	8.55	0.24	14.56	14.1	9.79	7.12	1.57	4.83
March	9.87	9.87	3.7	13.64	14.8	10.35	9.33	6.79	7.02
April	8.08	8.08	3.44	9.73	13.03	8.26	7.94	5.66	3.42
May	7.47	7.47	2.25	10.33	15.41	9.86	7.72	4.84	5.71
June	9.08	9.08	7.02	12.16	16.01	10.8	9.19	8.03	7.64
July	8.11	8.11	3.65	12.04	14.68	8.28	8.69	6.87	5.68
August	7.97	7.97	6.08	10.83	16.06	11.23	8.07	6.16	5.88
September	9.52	9.52	4.28	11.86	15.96	11.66	9.82	7.64	8.53
October	7.94	7.94	7.75	9.9	15.45	8.81	6.29	6.27	5.01
November	10.01	10.01	1.74	11.94	15.96	11.1	9.91	8	7.13
December	10.07	10.07	4.73	12.23	17.06	11.64	7.6	8.32	6.19
F test (joint chi square P-values)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 6: T-values of Length of Pay Period Variables for Average Hourly Earnings of All Employees for Selected Industries

Month	Wholesale trade	Retail trade	Transportation and warehousing	Information	Financial activities	Professional and businessservices	Other services
January	4.22	2.68	3.12	4.52	6.47	10.32	3.56
February	4.49	1.93	1.71	3.08	4.68	7.18	3.88
March	5.20	1.57	2.86	4.93	7.12	10.17	5.24
April	4.16	3.97	5.73	4.43	8.55	9.19	3.6
May	3.94	1.88	5.65	4.02	4.35	8.50	2.94
June	4.17	3.43	1.60	5.22	6.97	8.59	3.85
July	4.89	2.17	3.94	2.62	5.47	9.26	2.38
August	4.54	3.65	5.01	5.81	5.52	7.43	3.04
September	4.13	2.62	3.64	3.56	7.63	8.17	3.02
October	3.83	2.25	2.14	2.28	5.93	8.29	2.05
November	3.38	4.86	3.32	5.06	5.70	11.05	3.91
December	3.85	3.57	1.47	4.50	5.87	7.20	4.74
F test (joint chi square P-values)	0.00	0.00	0.00	0.00	0.00	0.00	0.00

7.1 Residual Effects from the Length of Pay Period

One limitation to the model is that only the semi-monthly effects are adjusted for in the model. The test of the microdata collected at the establishment level showed that establishments with both a semimonthly and monthly pay period had a higher percentage of establishment failing the length of pay means test. However, tests conducted during previous research showed that including four additional factors to account for the effects of the monthly pay periods did not improve the estimated factors and caused some of them to become weaker for some months (Kropf, et al., 1999). So, the adjustment for the monthly pay periods is not included in the model. To verify that there are no residual effects left from the monthly pay periods, a length of pay means test is conducted on the final estimates after adjusting for the length of pay period effect using the number of workdays per month. A hypothesis test is used similar to the one used to test the microdata for the length of pay period effect in 3.2.1 above. If there is no effect in the estimate due to the monthly pay periods then H_0 is true. If there is an effect due to the monthly pay periods then H_A is true:

$$H_0: \mu_3 - \mu_4 = 0$$
$$H_A: \mu_3 - \mu_4 \neq 0 \qquad (7.1.1)$$
$$where\ \mu_3 = 20\ and\ 21\ days\ (monthly)$$
$$\mu_4 = 22\ and\ 23\ days\ (monthly)$$

Table 7 shows the t-statistic values from the length of pay means test for the estimates after adjustment for the length of pay period effect. The t values are not significant for any of the series. Therefore, we accept that H_0 is true at the α=.05 significance level indicating that there is no residual effect remaining in the estimates due to the monthly pay periods.

Table 7: T-statistic Values from Length of Pay Period Means Test on Estimates after Adjustment

Industry	Test Statistic t Value			
	Average weekly hours for all employees	Average weekly hours for production employees	Average hourly earnings for all employees	Average hourly earnings for production employees
Mining and logging	-1.67	-0.91	-0.21	-0.02
Construction	-0.90	-0.10	0.01	0.07
Manufacturing	-0.90	-0.57	-0.13	0.02
Wholesale trade	-0.64	-0.81	-0.20	-0.10
Retail trade	-0.77	-0.40	-0.21	-0.17
Transportation and warehousing	-0.53	-0.25	0.00	0.04
Utilities	-1.31	-0.65	-0.31	-0.06
Information	0.15	-0.42	-0.11	-0.07
Financial activities	-0.29	-0.54	-0.13	-0.06
Professional and business services	-0.78	-0.41	0.02	0.04
Education and health services	-0.83	-0.13	-0.08	0.06
Leisure and hospitality	-1.12	-0.64	-0.07	0.06
Other services	-0.46	-1.14	0.08	0.02

8. Conclusion

The findings from this paper confirm that the length of pay period effect continues to be a predictable influence in the hours and payroll series for industries with a high percentage of salaried workers paid on a semimonthly or monthly pay period. Here are the key findings of this research:

- The length of pay period effect exists in the hours and payroll for all employees and continues to exist in the hours and payroll for production employees.
- The length of pay period effect continues to be stronger in the hours series than in the payroll series due to the formula used to normalize the payrolls to weekly equivalents, which cancels out some of the effect.
- Although the payroll series does not display a strong length of pay period effect in the microdata collected at the establishment level, the average hourly earnings series estimated from the payroll does display the effect at the industry level. Additional tests to identify the length of pay period effect in the estimates are necessary to determine which industries require adjustment to remove the effect.
- After adjusting for variations due to semi-monthly pay periods, there are no residual effects detected in the final seasonally adjusted estimates. Because the monthly pay period reporters are the smallest percentage (11.1%) of the total (Burgess 2014), their length of pay period effect is not significant at the estimate level.

The length of pay period model continues to provide an accurate and timely method of adjusting for these calendar effects. One of the limitations to adjusting for the length of pay period effect after estimation is that the variations from the effect remain in the non-seasonally adjusted series. The length of pay adjustment is a component of the seasonal adjustment procedure used to estimate the final adjusted series. Advances have been made in the CES survey and data collection systems to collect two payrolls, which allows for the use of two length of pay factors during normalization of the data at the establishment level. However, not all establishments maintain separate payrolls for different pay period lengths, so research into using two payrolls as a means for eliminating the variations from the length of pay period is ongoing.

References

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