The Rewards and Challenges of Seasonally Adjusting a Short Series: Seasonal Adjustment Research for the U.S. Census Bureau's Quarterly Services Survey[1]

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The Quarterly Services Survey (QSS) was introduced in 2004 as the Federal Government's first new economic indicator in nearly 30 years. The survey provides quarterly revenue estimates for information, technology, administrative, and health sectors of the service economy. As the time series has lengthened for these industries, the Census Bureau has researched the feasibility of seasonally adjusting the data. This paper describes the research conducted to determine appropriate methods for producing seasonally adjusted estimates for QSS. Using X-12-ARIMA software diagnostics, we first identify those series that have a stable seasonal component. Then, we determine the industry levels at which the adjustment should be performed, the type of adjustment to be used, and the appropriate ARIMA model. This paper also summarizes the challenges that short data series pose to seasonal adjustment and to the X-12-ARIMA software.

[1] This report is released to inform interested parties of ongoing research and to encourage discussion. Any views expressed on statistical, methodological, technical, or operational issues are those of the authors and not necessarily those of the U.S. Census Bureau.

Introduction

The Quarterly Services Survey (QSS) was introduced in 2004 as the Federal Government's first new economic indicator in nearly 30 years. The survey provides quarterly revenue estimates for employer businesses engaged in technology-intensive, administrative, and health sectors of the service economy.[2]

As the number of datapoints in QSS has increased, the U.S. Census Bureau has researched the feasibility of seasonally adjusting the data. This paper describes the research conducted to determine methods for producing seasonally adjusted estimates for QSS. Using X-12-ARIMA software diagnostics, we first identify those series that have a sufficiently stable seasonal component. Then, we determine the industry levels at which the adjustment should be performed, the type of adjustment to be used, and the appropriate Autoregressive Integrated Moving Average (ARIMA) model. This paper also summarizes the challenges that short data series pose to seasonal adjustment and to the X-12-ARIMA software.

Series

Our seasonal adjustment research used the revenue estimates from all four 2002 North American Industry Classification System (NAICS) sectors, subsectors, industry groups, industries, and other aggregates for which estimates are developed for QSS include:[3]

- Information (NAICS Sector 51)
  - 5112 – Software publishers
  - 512 – Motion picture and sound recording industries
  - 5151 – Radio and television broadcasting
  - 5171 – Wired telecommunications carriers
  - 5172 – Wireless telecommunications carriers (except satellite)
  - 517x – Other telecommunications
  - 5182 – Data processing, hosting, and related services

- Professional, Scientific, and Technical Services (NAICS Sector 54pt)
  - 5411 – Legal Services
  - 5412 – Accounting, Tax Preparation, Bookkeeping, and Payroll Services
  - 5413z – Architectural, Engineering, and Related Services excluding Landscape Architectural Services
  - 5414 – Specialized Design Services
  - 5415 – Computer Systems Designs and Related Services
  - 5416 – Management, scientific, and technical consulting services
  - 5417 – Scientific Research and Development Services
  - 5418 – Advertising and Related Services
  - 54191 – Marketing Research and Public Opinion Polling
  - 5419e – Other Professional, Scientific, and Technical Services excluding Marketing Research and Public Opinion Polling and Veterinary Services
  - Special Aggregates
    - 541y = 5411 + 5414 + 5417 + 5419 – 54194
    - 541z = 5414 + 5417 + 5419 - 54194
- Administrative and Support and Waste Management and Remediation Services (NAICS Sector 56pt)

[2] Information on QSS data sources and reliability can be found at http://www.census.gov/services/qss/qsstechdoc.html

[3] QSS is currently undergoing an expansion that will extend coverage both to additional NAICS sectors and to detail levels within the Health Care Sector. Estimates from the expansion will first be published in September 2009.

- 561pt – Administrative and Support Services excluding Landscaping Services
- 5613 – Employment Services
- 5614 – Business Support Services
- 5615 – Travel Arrangement and Reservation Services
- 561e – Administrative and Support Services excluding Employment Services, Business Support Services, Travel Arrangement and Reservation Services, and Landscaping Services
- 561z – Administrative and Support Services excluding Employment Services, Travel Arrangement and Reservation Services, and Landscaping
- 562 – Waste Management and Remediation Services

- Selected Health Care Services (NAICS Sector 62)
  - 62(t) pt – Selected Health Care Services (taxable)
  - 62(e) pt – Selected Health Care Services (tax-exempt)
  - 622 – Hospitals
  - 622(t) – Hospitals (taxable)
  - 622(e) – Hospitals (tax-exempt)
  - 623 – Nursing and Residential Care Facilities
  - 623(t) – Nursing and Residential Care Facilities (taxable)
  - 623(e) – Nursing and Residential Care Facilities (tax-exempt)

The Selected Health Care Services sector also has taxable, (t), and tax-exempt, (e), components at each level, both aggregate and detail.

The data series for the NAICS Sectors 51, 54, and 56 were first published using data for the fourth quarter of 2003. The NAICS Sector 62 series were first published using data for the first quarter of 2005.

The NAICS code composition of the 54, 56, and 62 series changed in the second quarter of 2006, so that is when the data series for these aggregate series begin. However, the NAICS code composition for 54pt, 56pt, and 62pt has remained the same.[4] Therefore, we have a complete data series back to 2003q4[5] for three aggregate series. By using these part series, we lose landscape architectural services and veterinary services from the NAICS Sector 54 and landscape services for the NAICS Sector 56. For the NAICS Sector 62, we lose ambulatory services (NAICS Sector 621) and social assistance (NAICS Sector 624). But for each of these, we gain the ability to seasonally adjust a full time series of data at the aggregate level.

Challenges of Short Series

QSS is the newest economic indicator to be published by the Census Bureau. As such, the data series are quite short relative to other indicators for which seasonally adjusted estimates are published. A quarterly series should have at least 16 data points before seasonally adjusting a series.[6] When we made our seasonal adjustment decisions, there were 20 data points available for the 51, 54pt, and 56pt NAICS series and 15 points for the 62 NAICS series.[7] We now have 22 points for the 51, 54pt, and 56pt NAICS series

[4] While the data for the series has been collected since 2003q4, it was not published until 2006q4.
[5] For the purposes of this paper, all year quarter notation will be of the format YYYYqQ. For example 2003q4 is the fourth quarter of 2003.
[6] Introduction to Seasonal Adjustment. Arthur Andrysiak, United Nations Economic Commission for Europe Statistical Division Available at http://www.*unece.org/stats/documents/ece/ces/ge.22/2008/mtg2/zip.11.e.ppt*
[7] Please note that we did not begin research on the NAICS sector 62 until we had 13 data points.

and 17 data points for the 62 series. By comparison, our Monthly Retail Trade Survey has 208 data points used to create seasonally adjusted estimates.

Working with such short series posed a variety of challenges. First and foremost, there has been little research done on the seasonal adjustment of short series. While we were able to draw upon the knowledge of the Census Bureau Time Series Staff, we were perpetually treading on new ground as we determined both what model settings and critical values were appropriate for a short series as well as what was normal behavior for a seasonally adjusted short series. There are also only a small number of diagnostics in X-12-ARIMA suitable for testing the seasonal stability of a short series.

With such short series, we never quite knew what surprises would pop up when we added in a data point. A few of the quirks that we encountered along the way:

- The 562 NAICS series would flip-flop each quarter on whether or not a log transformation should be used.
- The 561e NAICS series would switch from seasonal to nonseasonal depending on the quarter.
- The 5415 and 5417 NAICS series are seasonal in the past three years of the series but the entire series, despite being just five years total, is not seasonal.
- The 5419e NAICS series exhibited outlier identification volatility early in our research. When 2007q2 was added in, six of the 15 data points were identified as outliers and the t-values on these outliers were substantial. Then when 2007q3 data was added, no outliers were identified, and we have not had an outlier identified in this series since then.

Model Settings

We began our review by selecting the most stable and conservative ARIMA model for our short series: the airline model, (0, 1, 1) (0, 1, 1). The type of seasonal effect (multiplicative or additive) was chosen by X-12-ARIMA based upon likelihood tests. An additive adjustment is preferred when the seasonal variations are roughly constant in magnitude, while a multiplicative adjustment is preferred when the seasonal variations are proportional to the level of the series.

Using a critical value of 3.5 we checked for two types of outliers, the level shift (LS) and the additive outlier (AO). We consulted the subject-matter analysts for explanations of any quarters that were identified as outliers (t-value $\geq$ 3.5) and potential outliers (3.0 < t-value < 3.5). Outliers can impact the seasonality diagnostic.

Trading day adjustments were not included in the models because we do not have enough data to accurately detect them. Even in longer series, trading day effects tend to be subtle in quarterly series.

The Easter effect is the only moving holiday that is relevant to a quarterly series given that it can fall in either the first quarter or the second. Until we have more data, we will not include significant Easter effects in the model. We are, however, tracking the Easter effect in the series, using an AIC test to determine if the Easter effect is significant.[8]

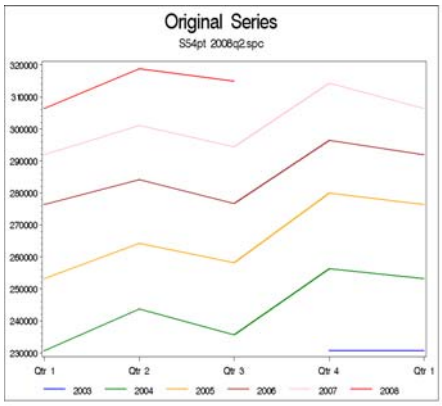
[8] *Issues in Estimating Easter Regressors Using RegARIMA Models With X-12-ARIMA* by David F. Findley, Kellie Wills, and Brian C. Monsell. Available at: http://www.census.gov/ts/papers/jsm2005bcm.pdf

The seasonal filter length specifies how the seasonal factors are estimated. Since we have such short series, we used the 3x3 filter which requires fewer years of data than the more commonly used 3x5 filter

Diagnostics Used to Determine Seasonality

The first step in our analysis was to review the year-over-year graphs for each of the series. The year-over-year graphs were generated using X-12-Graph and are useful for checking for the shape and magnitude of seasonal patterns. The year-over-year graph for the 54pt series is shown in Figure 1.

Figure 1: Year-Over-Year Graph for 54pt



The F-statistic is a one-way analysis-of-variance test that measures the degree of stability of the seasonal component of a time series.[9] The F-statistic summarizes quarterly differences among means of the seasonal-irregular (SI) ratios. The null hypothesis of the F-test is that all four quarterly seasonal means are equal. If the means are not equal, then the series is considered seasonal. The critical value used for the F-test is 7.0. Thus, if a series F-statistic is greater than or equal to 7.0, the series is considered to have stable seasonality.

The M7 statistic is calculated by X-12-ARIMA and indicates whether a series has a seasonal pattern or not.[10] It is a function of the F-statistic described above and an F-test for moving seasonality. Low values of the M7 statistic indicate that X-12-ARIMA has identified a series as one with a clear and stable seasonal pattern. More specifically, values between zero and one indicate strong, relatively stable seasonality. Values around one imply that the series is marginally seasonal and seasonality is inconclusive. As values of M7 get closer to three, the series is considered nonseasonal.

Table 1 shows the distribution of M7 statistics and F-statistics for each of the industries we researched. Because the F-statistic is part of the equation for the M7 statistic, these two diagnostics usually agree in determining whether or not a series is seasonal. Series with M7 < 1 and F-statistic > 7 would be seasonal series. Series with M7 > 1 and F-statistic < 7 were, for the most part, nonseasonal series. Series with M7 < 1 and F-statistic < 7 or with M7 > 1 and F-statistic > 7 demonstrate series where one diagnostic

[9] *The X-11 Variant of the Census Method II Seasonal Adjustment Program.* by Julius Shiskin, Allan H. Young, and John C. Musgrove. Available at: http://www.census.gov/ts/papers/ShiskinYoungMusgrave1967.pdf

[10] *A Set of Quality Control Statistics for X-11 ARIMA*, by Jack Lothian and Marietta Morry (1978) Available at: http://www.census.gov/ts/papers/LothianMorry1978.pdf

indicate seasonality and the other does not. In these scenarios, we relied on graphs or other diagnostics to help with our determination of seasonality.

Table 1: Distribution of M7 and F-Statistics Using Data Through 2008q3				
NAICS Code Series	**51**	**54**	**56**	**62**
Number of series with M7<1 and F-Statistic>7 *(Most likely seasonal)*	7	11	5	6
Number of series with M7<1 and F-Statistic<7 *(Seasonality unclear)*	0	1	0	0
Number of series with M7>1 and F-Statistic>7 *(Seasonality unclear)*	0	1	0	0
Number of series with M7>1 and F-Statistic<7 *(Most likely nonseasonal)*	1	0	3	3

If the year-over-year graph, the M7 statistic, or the F-statistic do not provide strong evidence for or against seasonality, we considered the chi-square test for seasonal regressors. The test is performed by fitting a regression model to the data using fixed seasonal effects. For quarterly data, we are constrained to three seasonal regressors, so the chi-square test for the significance of the seasonal regression model has three degrees of freedom. Based on this test, if the p-value is less than 0.05, then we would accept that the series is seasonal. Conversely, a p-value greater than 0.05 suggests that the series is not seasonal and should not be adjusted. A related F-test is now available in X-13-ARIMA-SEATS software that is currently under development at the U.S. Census Bureau.

Table 2 shows the distribution of p-values for the each of the industries.

Table 2: Distribution of P-Values for Chi-Square Test on Seasonal Dummies Using Data Through 2008q3				
NAICS Code Series	**51**	**54**	**56**	**62**
p=0.00	7	11	5	6
0.00 < p < 0.05	1	2	2	0
p ≥ 0.05	0	0	1	3

The airline model includes two parameters (θ, Θ) that relate to the behavior of a series: θ is the nonseasonal theta and Θ is the seasonal theta. The nonseasonal θ relates how much the current value is related to the prior value. A θ value close to 1 indicates overdifferencing. A negative θ value can be problematic because it contributes to a wider trend peak.[11] Table 3 shows the distribution of θ values for each of the industries.

Table 3: Distribution of θ Values Using Data Through 2008q3				
NAICS Code Series	**51**	**54**	**56**	**62**
θ < 0.00	6	3	1	5
0.00 ≤ θ >0.50	2	3	4	1
0.50 ≤ θ > 0.75	0	0	0	1
θ ≥ 0.75	1	7	3	2

[11] Personal communication with Kathy McDonald-Johnson and Tucker McElroy, U.S. Census Bureau. September 6, 2007.

A Θ value close to 1 indicates stable seasonality. We observe that most of the series have stable seasonality. What is problematic about these results is the number of negative values of Θ. In general, a negative Θ is not a good result. A negative Θ indicates wide spectral peaks. Wide spectral peaks indicate that the seasonality is not particularly stable. The shortness of the series can cause instability that leads to the wide spectral peaks. Table 4 shows the distribution of Θ values for each of the industries.

Table 4: Distribution of Θ Values Using Data Through 2008q3				
NAICS Code Series	**51**	**54**	**56**	**62**
Θ < 0.00	1	2	1	2
0.00≤Θ < 0.50	2	1	0	5
0.50 ≤ Θ < 0.75	2	1	0	1
Θ ≥ 0.75	4	9	7	1

Seasonality of Series

Using the diagnostics discussed above, we determined the seasonality or nonseasonality of each series. A summary of the results follows in Table 5 below.

Table 5: Summary of Seasonality Status for Each Series				
Industry	**Seasonal Series**	**Seasonal Series with Unstable Seasonal Patterns**	**Borderline Seasonal Series**	**Nonseasonal Series**
51	51	5112 512 5151 5182	5171 5172	517x
54	54pt 5411 5412	5418 5419 5419e	5416	5413z 5414 5415 5417
56	56pt 561pt 5613 5615 562	None	None	5614 561e 561z
62	62(e) 622 622(t) 622(e)	None	62	62(t) 623 623(t) 623(e)

A few of the series were particularly challenging to analyze. These series and their unique seasonal adjustment issues include the following:

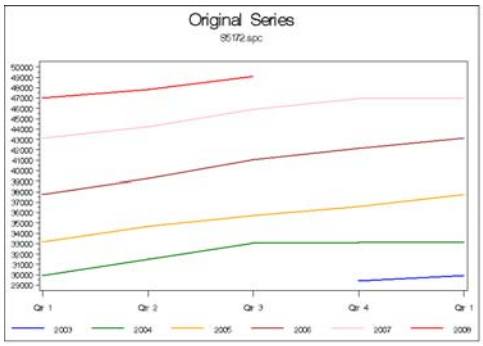
- 512 NAICS Sector – Series' graph highlights our concern with seasonally adjusting this series. The year 2004 and 2007 have graphs of the same shape and magnitude, the two most important elements when identifying stable seasonality through graphs.

The year 2006 is similar to the years 2004 and 2007 but varies for quarters 3 and 4 while the graph for 2005 varies in shape and magnitude from all of the other years.

- 5171 NAICS Sector – The seasonality of this series is somewhat questionable. Since 2006q4, the M7 statistic has fluctuated between 0.67 (in 2008q1) and 1.23 (in 2007q2). The F-statistic has always indicated seasonality but it is still rather low, ranging between 10.14 (2007q4) and 18.29 (2006q4). That the most recent data point addition produced the second lowest M7 to date is promising in terms of the series being seasonal, we must continue to monitor this series. In 2008q1, X-12-ARIMA identified the series as "probably not seasonal" which is demonstrated by the seasonal factors for this series being quite close to 1, ranging from 0.993 to 1.007.

- 5172 NAICS Sector – There is little variation between the seasonally adjusted and not adjusted data for this series, as evidenced by the graphs. The year-over-year graphs are nearly straight lines as can be seen below in Figure 2.

Figure 2: Year-Over-Year Graph for 5172



- 5413z NAICS Sector – This series is not seasonal and has never been seasonal. The M7 is 1.03and F-statistic is 7.30, both indicative of very weak seasonality. This is also one of the series where the past three years are seasonal but the entire series is not.

- 5414 NAICS Sector – In 2007q4, X-12-ARIMA identified this series as "probably not seasonal." This series provides an excellent example of having to use many diagnostics to make a seasonality decision. Over time, this series has had an M7 statistic that has hovered in the grey area (M7 greater than 0.80 but less than 1.00) but then dropped back into the seasonal range (M7 less than 0.80). When 2008q1 was added in, the M7 statistic dropped to 0.67 from 0.83 in 2007q4. But when 2008q2 data was added, the M7 statistic increased to 0.80 and remained there through 2008q3.

  The F-statistic in 2007q4 was also 8.895. An F-statistic of 7.0 or higher indicates stable seasonality. In previous quarters, the F-statistic has ranged from 11.86 to 19.17. When 2008q1 was added in, the F-statistic went up to 12.5 but dropped to 9.9 with the 2008q2 data added in and increased slightly to 10.4 with 2008q3 data.

Additionally, Θ, the seasonal theta, has varied greatly over time. In 2006q4, the Θ had a value of 0.955. In 2007q4, the Θ dropped to 0.019, and in 2008q1, the Θ was 0.100. Recall that a Θ value of 1 indicates stable seasonality. The value has increased slightly to 0.356 with the more recent data.

- 5415 NAICS Sector – Series has always been nonseasonal. However, with the addition of 2008q3 data, the M7 statistic fell to 0.943, its lowest value to date, indicating borderline seasonality. The F-statistic value of 6.983 indicates nonseasonality as does the p-value on the seasonal dummy of 0.04. When the series is run as nonseasonal, there is residual seasonality showing up in the past three years at the 1 percent level. It appears as though this series is becoming seasonal.

- 5416 NAICS Sector – Between 2006q4 and 2007q3, we labeled this series as borderline seasonal. This series had an M7 statistic and F-statistic that indicated nonseasonality. The M7 statistic dropped in 2007q4 to 0.893 from 1.13 in 2007q3. The M7 statistic dropped again in 2008q1 to 0.87 but has increased to 0.951 with 2008q3 data. In recent months, the F-statistic has varied between 8.8 and 11.7. X-12 identified this series as not seasonal in 2008q3.

- 5418 NAICS Sector – Series exhibits stable seasonality but appears to have a two-year seasonal pattern. Given that this industry, Advertising and Related Services, is driven by political campaigns, the two-year pattern is intuitive. However, we continue to research how many data points are needed in order to develop the best estimates for a two-year seasonal pattern.

- 5614 NAICS Sector – Series has always been nonseasonal. Over time though, the M7 statistic has dropped from 1.73 to 1.147 in the most recent quarter. However, the F-Statistic of 4.1 and the p-value on the seasonal dummy is 0.07, both strongly indicative of nonseasonality.

- 561e NAICS Sector – Prior to 2007q4, the diagnostics for this series suggested that the series was seasonal. With the addition of the 2007q4 data point, the series no longer seemed seasonal. With the addition of the 2008q1 data point, the M7 value increased to 3.00, and the F-statistic fell to 0.6, which strongly indicates nonseasonality. When the more recent data were added in, the M7 fell to 2.4 and F-Statistic increased to 1.4, but both these value strongly indicate nonseasonality.

- 62 NAICS Sector – Until 2008q1, this aggregate level series was identified as probably not seasonal by X-12-ARIMA. In 2008q1 and 2008q2, X-12-ARIMA identified the series as seasonal. Given that the 623 NAICS code series accounts for just 18% of the aggregate total, we were surprised at the impact that its nonseasonality has at the aggregate level. The 62(t) NAICS code series is not seasonal but the 62(e) NAICS code series is seasonal.

Direct and Indirect Adjustments

After identifying any series that may pose a problem (i.e., nonseasonal or borderline seasonal series), we began to look for ways to group series at higher levels and then seasonally adjust those grouped series.

Our initial review of X-12-ARIMA diagnostics led us to narrow our seasonal adjustment options down to a variety of methods for each series. In particular, we looked for ways to include the borderline seasonal or nonseasonal series in higher-level series.

We selected both direct and indirect seasonal adjustment methods. A direct seasonal adjustment is obtained by applying the seasonal adjustment procedure directly to the aggregate data series. An indirect seasonal adjustment involves summing the seasonally adjusted component series to obtain the seasonally adjusted aggregate series and is particularly useful when detail level series have different seasonal patterns.[12]

NAICS Sector 51 Series
We do not have data series beginning in 2003q4 for any combination of detail level series that add up to the aggregate level. Therefore, an indirect adjustment was not an option for the NAICS Sector 51 series.

NAICS Sector 54pt Series
The NAICS Sector 54pt series has several options for indirect adjustment. By making use of the special aggregates 541y and 541z, we were able to group together series that were not seasonal with those that were to create an aggregate level that did demonstrate stable seasonality. There were five possible ways to adjust the 54pt NAICS code series.

- Method 1– Directly adjust only the 54pt.
- Method 2 – Indirectly adjust 54pt using direct adjustments of 5411, 5412, 5413z, 5414, 5416, 5418, and 54191, and 5419e. Additionally, 5415 and 5417 are not seasonal—thus not seasonally adjusted—but are used in tabulating the adjusted 54pt.
- Method 3 – Indirectly adjust 54pt using direct adjustments of 5412, 5413z, 5416, 5418, and 541y. The 5415 series is not seasonal—thus not seasonally adjusted—but is used in tabulating the adjusted 54pt. This allows us to group the nonseasonal 5417 into 541y, a series with stable seasonality.
- Method 4 – Indirectly adjust 54pt using direct adjustments of 5411, 5412, 5413z, 5416, 5418, and 541z. The 5415 series is not seasonal—thus not seasonally adjusted—but is used in tabulating the adjusted 54pt. This allows us to group the nonseasonal 5417 into 541z, a series with stable seasonality.
- Method 5 – Not seasonally adjusting this series.

Methods 2, 3, and 4 would require the seasonal adjustment of some series that have not yet established stable seasonal patterns. Once the series have stabilized, these three options look promising. There are also components to this series, including the aggregate, that exhibit stable seasonality.

NAICS Sector 56pt Series
Like the NAICS Sector 54pt series, there were several options for seasonally adjusting the NAICS Sector 56pt series. Unique to this series is that the component series within this industry have very distinct seasonal patterns. Thus, we considered the following four options:

- Method 1 – Directly adjust only 56pt.
- Method 2 – Indirectly adjust 56pt using direct adjustments of 561pt and 562.

[12] *E-Commerce Seasonal Adjustment Study*. Lora Gillott (2003) U.S. Census Bureau.

- Method 3 – Indirectly adjust 56pt using direct adjustments of 5613, 5615, and 562. 561z will not be adjusted, but it will be used to sum to the aggregate.
- Method 4 – Not seasonally adjusting this series.

We considered a direct adjustment only of the 56pt series but the analysts were concerned with a potential outlier that was identified in this aggregate series and there was no identifiable reason for there to be an outlier. The nonseasonal component 561z comprises about 45% of the aggregate, so large changes in 561z could potentially cause outliers in 56pt. Most importantly, the seasonal component series have distinct patterns, thereby favoring an indirect adjustment

NAICS Sector 62 Series
When we have more data points, we will begin to analyze indirect seasonal adjustment methods for this series.

Conclusions
Based on our recommendations, the Census Bureau published the following seasonally adjusted estimates beginning in March 2009 with 2008q4 data:

- Direct seasonally adjusted estimate of 51.
- Direct seasonally adjusted estimates of 54pt, 5411, and 5412.
- Indirect seasonally adjusted estimate of 56pt generated using direct seasonal adjustments of 5613, 5615, and 562 along with the nonseasonal 561z.

Future Research
With each quarter's data publication, we continue to monitor the remaining series for stable seasonality and record our results. We also continue to check for feasibility of indirect seasonal adjustment methods for both the NAICS Sector 54 series and the NAICS Sector 62 series.

We are monitoring expense estimates for the NAICS Sector 62 series for seasonality.

We are also using this quarterly data as an opportunity to research Easter effects and trading day effects in short quarterly series.