

Residual Seasonality in GDP and GDI

Findings and Next Steps

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THE BUREAU OF ECONOMIC ANALYSIS (BEA) has long adjusted its widely followed estimates of quarterly gross domestic product (GDP) and gross domestic income (GDI) to account for seasonality.¹ Seasonal adjustment involves a set of statistical methods designed to remove fluctuations that normally occur at about the same time and the same magnitude each year. Seasonal adjustment allows for economic series that are often easier to interpret and analyze because they are not affected by routine seasonal patterns due to factors such as seasonal weather patterns and holidays. Quarterly data on consumer spending, for example, are easier to compare and analyze if the effects of the holiday shopping season are removed.

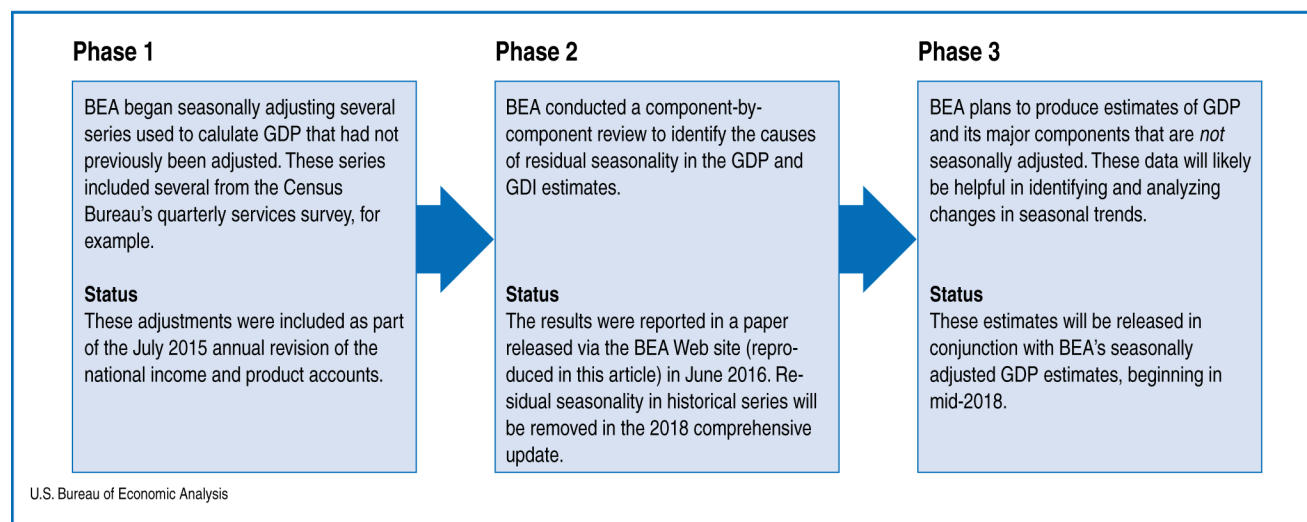
In early 2015, several reports noted that over the last decade or longer, first-quarter GDP has tended to grow, on average, at a slower pace, compared with other quarters. Analysts debated the extent to which this phenomenon reflects special factors, such as unusually harsh winter weather, and/or “residual season-

1. GDI is calculated as the sum of the costs incurred and the incomes earned in the production of GDP. In theory, GDI should equal GDP, but in practice they differ because their components are estimated using largely independent and less-than-perfect source data.

Summary

This paper presents the results of a component-by-component review of seasonally adjusted estimates of gross domestic product (GDP) and gross domestic income (GDI), two widely followed economic measures published by the Bureau of Economic Analysis (BEA). The goal of the review was to test specific components for “residual seasonality” and, if present, to identify the main causes. The review found that the two most important causes of residual seasonality were (1) inconsistencies arising from the manner in which monthly source data are utilized in the compilation of quarterly GDP estimates and (2) issues arising from revision policies and practices that prevented the most recent seasonal adjustments from being applied to historical time series. This paper also discusses BEA’s on-going three-phase strategy to improve its seasonal adjustment methods. The strategy, which was announced in the [June 2015 SURVEY OF CURRENT BUSINESS](#), includes this review as well as a plan to release GDP and GDI estimates that are not seasonally adjusted. Such estimates will provide a valuable reference point when assessing the seasonally adjusted estimates. The three-phase strategy is scheduled to conclude in July 2018.

Chart 1. BEA’s Three-Phase Plan To Enhance Its Seasonal Adjustment Approach



ality,” that is, lingering seasonality even though the data have already been adjusted to remove seasonal effects.² BEA subsequently announced a three-phase plan for addressing residual seasonality.³

In the first phase, as part of the July 2015 annual revision of the national income and product accounts (NIPAs), BEA began seasonally adjusting several series used to calculate GDP that exhibited seasonality but had not previously been adjusted. These series included several from the Census Bureau’s quarterly services survey, for example.⁴

In the second phase, BEA conducted a component-by-component review, the results of which are reported in this paper, to identify the causes of residual seasonality in the GDP and GDI estimates.

In the third phase, BEA plans to produce estimates of GDP and its major components that are not seasonally adjusted. These not seasonally adjusted estimates will be released in conjunction with BEA’s seasonally adjusted GDP estimates, beginning in mid-2018. These data will likely prove particularly helpful in identifying and analyzing changes in seasonal trends.

What is residual seasonality?

Seasonal adjustment refers to statistical processes aimed at removing seasonal effects from a time series—that is, the fluctuations that normally occur at about the same time and the same magnitude each year. Seasonal effects are estimated using procedures that decompose time series into seasonal, trend-cycle, and irregular components. The seasonal adjustment procedure essentially removes the seasonal effects, leaving the trend-cycle and irregular components. Residual seasonality refers to the presence of lingering seasonal effects even after seasonal adjustment processes have been applied to the data.

The detection of residual seasonality can be difficult. A time series that has been correctly seasonally adjusted may still display unusually high or low growth for specific quarters over particular time spans. Even after seasonal adjustment, the irregular components of a time series are often noisy and variable. And like any

series subject to random variation, the variations in seasonally adjusted series are not likely to balance or fully offset across quarters. Just as it is possible when flipping a coin to obtain four tails in five flips, it is similarly possible that a particular quarter may exhibit below average growth in four of the most recent five years, even if the series has been correctly seasonally adjusted. One should not expect the growth rates of seasonally adjusted quarters to be uniform; the question is whether the variation exceeds what would be expected by chance over time.

The determination of whether a series exhibits residual seasonality thus must rely on the application of statistical tests that can analyze the variation. These tests can be quite sensitive to the period selected for analysis. In the case of GDP, the evidence for residual seasonality is somewhat ambiguous, with tests finding evidence for residual seasonality over some time spans but not others.

In the remainder of this paper, we provide the following:

- An overview of the seasonal adjustment methodologies used by BEA in preparing the NIPAs, including GDP and GDI.
- The findings of our recent component-by-component review of residual seasonality in the NIPAs. We identify the major reasons for residual seasonality and detail some steps that BEA and other federal statistical agencies may take to help resolve some of the issues.
- An update of BEA’s plans for addressing residual seasonality and a rough timetable for scheduled improvements.

Overview of NIPA Seasonal Adjustment Methodology

GDP and GDI are each calculated as aggregates of many component series. For such aggregates, there are two potential approaches for seasonal adjustment. In the direct approach, component series that have not been seasonally adjusted are aggregated. After this aggregation, the seasonal adjustment processes are applied.

In contrast, the indirect approach seasonally adjusts the component series or uses source data that have already been seasonally adjusted. These seasonally adjusted components are then directly aggregated to generate seasonally adjusted aggregate series, including GDP.⁵

BEA’s long-standing practice has been to produce its

2. See, for example, Jason Furman, “Second Estimate of GDP for the First Quarter of 2015,” Council of Economic Advisers Blog, May 29, 2015; Charles E. Gilbert, Norman J. Morin, Andrew D. Paciorek, and Claudia R. Sahm, “Residual Seasonality in GDP,” *FEDS Notes* (May 14, 2015); Glenn D. Rudebusch, Daniel Wilson, and Tim Mahedy, “The Puzzle of Weak First-Quarter GDP Growth,” FRBSF Economic Letter, May 18, 2015; and Jan Groen and Patrick Russo, “The Myth of First-Quarter Residual Seasonality,” Liberty Street Economics, June 8, 2015.

3. See the box, “Seasonality in the National Income and Product Accounts (NIPAs),” in Stephanie H. McCulla and Shelly Smith, “Preview of the 2015 Annual Revision of the National Income and Product Accounts,” *SURVEY OF CURRENT BUSINESS* 95 (June 2015): 4.

4. See Stephanie H. McCulla and Shelly Smith, “The 2015 Annual Revision of the National Income and Product Accounts,” *SURVEY OF CURRENT BUSINESS* 95 (August 2015).

5. For further discussion of these two approaches, see chapter 8 of Adriaan M. Bloem, Robert J. Dippelsman, and Nils O. Maehle, *Quarterly National Accounts Manual—Concepts, Data Sources, and Compilation* (Washington, DC: International Monetary Fund, 2001).

featured estimates of GDP and GDI using the indirect approach.

Most of the source data that are used to estimate GDP are available in seasonally adjusted form from source agencies. When seasonally adjusted source data are not available, BEA generally seasonally adjusts the source data before using them in its various estimation processes, such as interpolation, extrapolation and commodity flow, retail control, and perpetual inventory methods. These processes are described in [chapter 4 of *Concepts and Methods of the U.S. National Income and Product Accounts*](#).

There are several advantages to this indirect approach.

First, because the estimates are usually based on seasonally adjusted source data, the effects of such source data on the NIPA estimates are more transparent and intuitive to data users. For example, BEA sometimes lacks source data in making its earliest estimate of quarterly GDP (the “advance” estimate, which is published about a month after the end of a quarter). To account for this missing data, BEA makes various assumptions. When the seasonally adjusted source data subsequently become available from the source agency, data users can quickly infer the impact on GDP without concerns about the effect of seasonal adjustment. In addition, the indirect approach makes it easier to establish trends necessary to estimate components for which monthly or quarterly source data are lacking.

Second, the consistent use of seasonally adjusted source data makes it easier for BEA’s staff to review and spot anomalies in comparing the NIPA estimates with the source data.

Third, BEA publishes many useful GDP measures beyond nominal GDP; “contributions to percent change” and “chained” index values are among the most widely used. Because these measures are derived from seasonally adjusted components, they remain generally consistent with one another. If the estimates were directly seasonally adjusted only at the end of the estimation and aggregation process (direct method), such consistency would be lacking. Indeed, under the direct approach, the seasonally adjusted component series generally would not add up to the seasonally adjusted aggregates, even when measured in current dollars.

There are also some disadvantages to the indirect approach to seasonal adjustment.

Notably, because GDP is not directly adjusted as a single data series at the end of the estimation process, it is possible that the indirect approach can allow some

residual seasonality to seep into the aggregates. And because the seasonal adjustments take place at the beginning of the estimation process at the source data level, the effect of seasonal adjustment on the main aggregates can be relatively opaque for researchers.

As part of its three-phase strategy noted above, BEA intends to produce and publish estimates of GDP and GDI that are not seasonally adjusted to foster even greater transparency and allow for heightened analysis of the effects of seasonal adjustment.⁶

Component Review of Residual Seasonality

A team of BEA analysts conducted a component-by-component investigation of residual seasonality within quarterly GDP and GDI estimates.⁷ This review represents phase 2 of BEA’s three-phase strategy for grappling with residual seasonality.

Objectives

The goal of the component-by-component review was to identify and investigate instances of residual seasonality, to determine the causes, and to propose solutions. The team sought to uncover broad cases of residual seasonality that might be addressed in a systematic fashion rather than with ad hoc fixes.

Methodology

Because BEA derives its seasonally adjusted estimates of GDP and GDI using an indirect, or “bottom-up,” approach, the team focused on the most finely detailed series contributing to those aggregates. The investigation ultimately examined approximately 2,000 nominal data series. For the GDP estimates, price and quantity measures were examined for each of these series as well as nominal estimates. For GDI, separate price and quantity estimates are not available for the detailed component series. Instead, real GDI is derived by deflating nominal GDI using the GDP price index.

The Census Bureau’s widely used X–12 ARIMA seasonal adjustment program was applied to the seasonally adjusted NIPA series to test for residual seasonality.⁸ Because of the large number of series involved, simplified criteria were used to standardize and

6. BEA formerly published GDP data without seasonal adjustment as a service to users. However, it discontinued publication of such data due to budget cutbacks in 2008.

7. The team members were Steve Andrews, Kyle Brown, Ben Cowan, Ryan Howley, Andrea Julca, Kate Pinard, and Andy Vargo.

8. The X–12 ARIMA program was used instead of the more recent Census Bureau X–13 program because the NIPA database was already linked to the X–12 ARIMA program. For the residual seasonality diagnostics analyzed in this paper, the two programs are essentially identical, and the distinction would not have influenced the findings.

automate the process.⁹ Seasonal adjustment tests were applied on several data ranges, focusing especially on 10-year, 15-year, and 30-year ranges (2006–2015, 2001–2015, and 1986–2015, respectively). Several other timespans were also examined (for example, a 5-year range was calculated to investigate the effects of the recent availability of data from the quarterly services survey). In general, results of residual seasonality tests were often quite sensitive to the period selected for analysis, especially for series, such as real GDP, that yield test statistics quite close to the critical threshold values.

Results

Table 1 presents the results of tests for residual seasonality for the major aggregates of real GDP and its price index. The results indicate that (1) real GDP exhibits residual seasonality when tested over either a 10-year or a 30-year time span, (2) the GDP price index exhibits its residual seasonality over the 30-year time span, and (3) several real GDP components—such as nonresidential structures, exports of goods, federal government spending (especially defense spending), and state and local government spending—exhibit residual seasonality over various time spans.

9. In particular, based on criteria recommended by the Census Bureau, values of the M7 statistic that were less than 1.0 and values of the F-test statistic for stable seasonality from table D8 that were greater than 7.0 were interpreted as evidence of residual seasonality. Census Bureau, *Seasonal Adjustment Diagnostics: Census Bureau Guideline*, version 1.1, 5 (March 2010).

Table 2 presents tests for residual seasonality in current-dollar GDI and its components.¹⁰ GDI does not exhibit residual seasonality over any of the time periods. The only major components exhibiting significant residual seasonality are “net interest and miscellaneous payments” and “current surplus of government enterprises,” which exhibit residual seasonality over some

10. Real GDI is calculated by deflating current-dollar GDI by the GDP price index.

Table 2. Tests for Residual Seasonality of Nominal Gross Domestic Income (GDI)

	Nominal GDI					
	10 year		15 year		30 year	
	M7	F	M7	F	M7	F
Gross domestic income	1.6	1.6	2.3	0.6	2.4	1.0
Compensation of employees	2.9	0.3	3.0	0.2	2.9	0.6
Taxes on production and imports	2.0	1.2	2.4	0.9	2.7	0.6
Less: Subsidies	2.2	2.2	1.8	2.7	1.7	2.8
Net operating surplus	1.5	2.0	2.0	1.4	1.7	1.9
Private enterprises	1.6	1.9	2.0	1.2	1.9	1.6
Net interest and miscellaneous payments	(*) 0.7	(*) 10.2	1.0	(*) 8.3	1.3	6.5
Business current transfer payments	3.0	0.2	3.0	0.1	2.2	1.5
Proprietors income with IVA and CCAAdj	1.5	2.6	2.8	0.8	2.4	1.0
Rental income of persons with CCAAdj	2.5	1.8	2.1	1.8	2.7	1.0
Corporate profits with IVA and CCAAdj	1.6	2.8	1.7	2.5	1.3	3.9
Current surplus of government enterprises	(*) 0.8	(*) 7.5	1.3	4.0	(*) 0.9	6.9
Consumption of fixed capital	1.6	2.7	1.8	2.2	3.0	0.7
Private	1.8	3.1	1.8	2.6	3.0	0.8
Government	1.2	3.5	3.0	0.1	3.0	0.3

* Null hypothesis of no residual seasonality rejected if $M7 < 1.0$, $F > 7.0$.

CCAAdj Capital consumption adjustment

F Statistical test for stable seasonality

IVA Inventory valuation adjustment

M7 Statistical diagnostic for identifiable seasonality

Table 1. Tests for Residual Seasonality of Real Gross Domestic Product (GDP) and Price Indexes

	Real GDP						Price indexes					
	10 year		15 year		30 year		10 year		15 year		30 year	
	M7	F	M7	F	M7	F	M7	F	M7	F	M7	F
Gross domestic product	(*) 0.8	(*) 13.1	1.1	5.3	(*) 0.8	(*) 9.2	1.3	3.2	1.1	4.5	(*) 0.9	(*) 7.6
Personal consumption expenditures	3.0	0.3	2.6	0.9	1.8	1.9	1.1	4.5	1.1	4.9	1.4	3.2
Goods	3.0	0.4	3.0	0.4	2.1	1.5	1.1	5.3	1.1	5.2	1.3	3.8
Durable goods	2.1	1.3	2.0	1.6	1.6	2.6	1.4	2.8	1.2	3.4	2.0	1.1
Nondurable goods	3.0	0.3	1.5	2.4	2.4	0.9	1.1	5.5	1.0	5.7	1.2	4.3
Services	1.3	3.0	1.4	2.8	3.0	0.3	1.6	1.8	1.5	2.1	2.1	1.2
Gross private domestic investment	1.1	5.5	1.9	1.5	1.8	1.8	1.3	6.6	1.1	(*) 8.8	1.1	(*) 7.3
Fixed investment	1.4	5.3	1.1	5.8	(*) 0.9	5.9	1.2	6.6	1.0	(*) 9.6	1.0	(*) 8.1
Nonresidential	1.0	5.4	(*) 0.8	(*) 8.0	(*) 0.9	6.1	1.8	2.6	1.8	2.7	1.3	4.3
Structures	1.0	6.9	1.0	(*) 7.4	(*) 0.9	6.7	1.2	5.2	1.0	(*) 7.8	1.3	5.6
Equipment	1.9	1.7	1.2	3.2	1.3	3.3	1.8	2.1	2.1	1.5	1.3	3.6
Intellectual property products	1.6	2.0	2.6	0.7	2.4	0.9	2.7	0.4	2.4	0.8	1.9	1.5
Residential	2.7	1.3	2.9	0.9	1.9	2.3	1.1	(*) 8.5	(*) 0.8	(*) 10.4	1.3	3.9
Change in private inventories	1.6	2.4	3.0	0.2	1.6	2.1						
Net exports of goods and services	1.2	4.1	1.7	1.7	1.5	2.7						
Exports	(*) 0.7	(*) 14.1	1.3	3.6	1.1	4.1	1.1	6.6	1.0	(*) 7.2	1.0	(*) 7.8
Goods	(*) 0.7	(*) 12.1	1.2	4.2	1.3	3.1	1.1	(*) 7.3	1.1	(*) 7.1	1.1	(*) 8.3
Services	1.2	5.5	1.5	2.4	1.4	2.8	1.4	2.8	1.1	4.3	1.5	2.6
Imports	1.8	2.2	2.5	1.1	2.2	1.2	1.5	2.5	1.8	1.7	3.0	0.1
Goods	1.9	1.9	2.1	1.4	1.8	1.8	1.5	2.5	1.9	1.5	3.0	0.0
Services	1.3	3.0	2.9	0.7	2.5	0.9	1.4	4.1	1.2	5.2	1.1	5.4
Government consumption expenditures and gross investment	(*) 0.4	(*) 31.6	(*) 0.6	(*) 15.3	(*) 0.5	(*) 15.8	1.2	3.1	(*) 0.8	(*) 7.8	(*) 0.7	(*) 11.2
Federal	(*) 0.6	(*) 12.3	(*) 0.9	6.8	(*) 0.6	(*) 14.5	1.5	3.6	(*) 0.8	(*) 16.6	(*) 0.6	(*) 24.7
National defense	(*) 0.6	(*) 14.6	(*) 0.7	(*) 10.6	(*) 0.5	(*) 24.0	1.1	(*) 7.3	(*) 0.6	(*) 19.5	(*) 0.5	(*) 31.5
Nondefense	1.5	2.1	1.2	3.6	1.3	3.7	2.8	0.8	1.0	(*) 9.4	(*) 0.8	(*) 9.3
State and local	(*) 0.6	(*) 14.7	1.0	(*) 7.5	1.5	2.6	1.2	3.3	1.6	1.8	2.7	0.5

* Null hypothesis of no residual seasonality rejected if $M7 < 1.0$, $F > 7.0$.

F Statistical test for stable seasonality

M7 Statistical diagnostic for identifiable seasonality

periods. Within the major components, some more detailed GDI components not shown in the table also exhibited residual seasonality.

These results, along with the team's analysis of the more detailed deflation-level components, will guide BEA's efforts in addressing residual seasonality moving forward.

Detailed series exhibiting residual seasonality were flagged for further examination. For each flagged series, team members worked with the BEA analysts to determine the specific cause of the residual seasonality. This effort allowed the team to identify broad categories of causes of residual seasonality.

Causes of residual seasonality

The team identified two main categories of factors that caused residual seasonality. The most pervasive problem involved the manner in which monthly frequency source data are treated in the derivation of quarterly NIPA estimates. In the most common case, the monthly data are tested for seasonality (either by BEA or by the source data agency) with the conclusion that the monthly series does not exhibit seasonality. However, when the data are aggregated to a quarterly frequency for use in preparing the NIPA estimates, the resultant series exhibits seasonality that was not detected at a monthly frequency. A somewhat less common variant of this problem is that a series may be seasonally adjusted at a monthly frequency, but when the seasonally adjusted monthly series is aggregated to a quarterly frequency, the resultant series still exhibits significant seasonality. The solution to this problem will involve testing all monthly source data series for seasonality at both monthly and quarterly frequencies. BEA will also communicate and cooperate with source data agencies to attempt to harmonize seasonal adjustment processes by applying consistent seasonal adjustment criteria across agencies. The development of optimal criteria for seasonal adjustment of data that are used at both monthly and quarterly frequencies is also a subject for research.

Another source of residual seasonality arises when seasonal adjustment is not applied consistently over time due to limitations on the number of years that are open to revision. This problem can reflect either BEA's own revision policies or the policies of the source data agency. For example, in the 2015 NIPA annual revision, BEA seasonally adjusted several series that had recently begun exhibiting seasonality, but carried those revisions back for only 3 years. Residual seasonality can still be detected in a test of those series over a 10-year span because the earlier years have not yet been seasonally adjusted. Another example is the revision

policy for the Census Bureau's survey of value of construction put-in-place. The revision policy for this survey is to revise monthly estimates for only the previous 2 years, even though the seasonal adjustment procedure is performed over a longer time span. In both cases, the published series did not reflect consistent seasonal adjustment. Rather, the series was essentially spliced together based on the revision policy for the statistical product.

The most straightforward method for resolving this problem is to modify the revision policies of BEA and, to the extent possible, of the source data agencies to allow for consistent and complete seasonal adjustment. That change will require longer time periods to be opened for revision to incorporate revised seasonal adjustments and to reflect changes to the seasonal status of component series. For example, each year the current employment statistics from the Bureau of Labor Statistics typically allow for revisions over the most recent 5-year period to capture revisions to the seasonal adjustment factors. Five years is probably the minimum period over which data should be revised so that the published seasonally adjusted estimates maintain consistency with estimates derived from the most recent seasonal adjustment procedures.

The review also found that other, less common factors can contribute to residual seasonality in some cases.

BEA has, by convention, intentionally avoided seasonally adjusting certain series related to government policy in order to make the effects of policy changes more transparent to users. For example, for federal government employees, a general pay raise is often scheduled to take place in January. The NIPA estimates show these pay increases as step increases in nominal government wages and salaries in the first quarter. Thus, these federal pay increases are reflected without seasonal adjustment in nominal GDP and in the GDP price index and are potentially a source of residual seasonality for the affected series. A potential solution would be for BEA to start seasonally adjusting these series, recognizing that such a change in estimation methods may make it more difficult for interested users to detect easily the effects of policy changes in the relevant data series. This problem may be ameliorated by BEA's plan to begin publishing not seasonally adjusted estimates concurrently with seasonally adjusted estimates.

Residual seasonality can occur when seasonally adjusted source data are used as inputs into an estimation process that involves additional estimation steps—such as aggregation, interpolation, or deflation. This can result in residual seasonality, despite a lack of

seasonality in the source data. BEA can address this problem by regularly testing estimates for residual seasonality even when seasonally adjusted source data are used. In some cases, modifications to the estimation process may need to be considered, for example, applying seasonal adjustment later in the estimation process. In addition, if the input data include both seasonally adjusted and unadjusted source data, it may be necessary to modify the criteria for determining whether the input series is seasonal.

BEA's Updated Plan for Addressing Residual Seasonality

BEA will continue to move forward with its three-phase comprehensive strategy to improve its seasonal adjustment techniques. The first phase of that strategy was completed in the July 2015 annual revision.

In this report, we have embarked on the second phase of this strategy by describing the results of the component-by-component review of the GDP and GDI estimates and the main sources of residual seasonality. The second phase will include additional steps:

- BEA will use the results of the component-by-component review to identify and implement improvements to seasonal adjustment in the upcoming 2016 annual revision of the NIPAs. For example, BEA may begin seasonally adjusting certain series that exhibit seasonality at a quarterly frequency but not at a monthly frequency. The 2016 annual revision will also include the regular updating of seasonal
- factors for the period open to revision—the most recent 3 years, 2013 through 2015 as well as the first quarter of 2016.
- BEA will communicate the findings of this component-by-component review to the Census Bureau and to other source data agencies. BEA will work with these agencies to implement strategies for removing residual seasonality in source data. In particular, BEA will take advantage of new research results from the Census Bureau and new diagnostics available in the updated X-13 program.
- BEA will review and modify its own revision policies, and it will work with other agencies to develop revision policies that will allow longer time periods for revision to reflect updated seasonal adjustments in published estimates.
- BEA will introduce revisions to the historical time series to remove any remaining residual seasonality as part of the 2018 comprehensive revision of the NIPAs. The third phase in BEA's strategy is to develop methods and procedures for compiling estimates for GDP and its major components that are not seasonally adjusted. These estimates will be released concurrently with BEA's seasonally adjusted GDP estimates and could be particularly useful to identify changes in seasonal trends over time. These estimates will allow users to isolate data revisions more distinctly from revisions to seasonal factors. The expected completion date for this project and publishing the not-seasonally-adjusted estimates is also July 2018.