Background

Definition

The overall BLS definition of green jobs includes two approaches -- output and process -- that will be used for two separate BLS products. This release uses the "output" definition.

Under the BLS "output" approach, green jobs are *Jobs in businesses that produce goods and provide services that benefit the environment or conserve natural resources*. These goods and services are sold to customers, and include research and development, installation, and maintenance services. Green goods and services fall into one or more of five groups:

1. *Energy from renewable sources.*
2. *Energy efficiency.*
3. *Pollution reduction and removal, greenhouse gas reduction, and recycling and reuse*.
4. *Natural resources conservation.*
5. *Environmental compliance, education and training, and public awareness.*

To implement the output approach, BLS collects data on jobs associated with producing green goods and services through a sample survey of establishments identified as potentially producing such products and services based on their 2012 North American Industry Classification System (NAICS) classification. The purpose of the Green Goods and Services (GGS) survey is to identify whether the establishment is producing any green goods and services and, if so, to measure the number of associated jobs in the establishment.

The GGS survey estimates the number of green jobs for a NAICS industry based on the green activity found at individual establishments classified within the industry. The methodology does not simply designate an industry as "green" and count all jobs in that industry as GGS jobs, since establishments in the industry may also produce goods and services that are not considered green.

The BLS "output" definition of GGS employment does not include workers from all industries; instead, it focuses on employment within 325 of the approximately 1,083 detailed industries that exist under the NAICS classification. These 325 industries, the GGS scope, were selected by BLS after consultations with industry groups, government agencies, stakeholders, and the public helped identify industries that potentially provide green goods or services. These 325 industries were identified to provide goods and services that directly benefit the environment or conserve natural resources. Only the employment directly associated with the production of green goods and services within these selected industries are considered GGS jobs under the BLS definition.

Businesses and government establishments are assigned industry codes based on their primary activity. BLS recognizes that there may be some GGS employment in other businesses and government agencies in their secondary activities and that these are not counted within the GGS survey scope.

GGS Scope

The U.S. total annual average employment for 2011 was about 129,539,000 as measured by the Quarterly Census of Employment and Wages (QCEW) program. However, the GGS industries in their entirety contained about 25,969,000 workers, or about 20.0 percent of the nation's total employment.

Activities in the GGS scope included hydroelectric and nuclear energy production, as well as energy production from solar, wind, biomass, and other renewable resources. Industries within the GGS scope also produce green goods such as pollution control equipment, hybrid cars, recycled metals and paper, and organic farm products, among others. Green services provided by these selected industries include the operation of waste water treatment facilities, the operation of mass transit systems, the retail of used goods, the sale and trade of pollution control credits, and the enforcement of environmental regulations. These industrial activities occur both within the private sector as well as state, local and federal governments.

Well-recognized industry standards were used to distinguish between green products and others within the same establishment when appropriate. For example, manufacturing of LEED-rated materials and construction using LEED-rated materials are included. Appliances with an EnergyStar rating and products achieving the WaterSense rating are included.

About 122,000 business and government establishments were included in the survey. Each was asked to report the percent of revenue derived from green goods and services included in the definition. That percentage was multiplied by the employment level to derive the number of GGS jobs for that establishment. Non-profits, government units and business start ups without positive revenue were asked to supply a percent of employment. Thus, the employment figure includes workers of all occupations as long as they worked in the establishment with GGS employment or revenue. For example, a solar panel installation business might report that all of its revenue is included in the definition. In this case, all workers are counted, including installers, managers, secretaries, etc. Similarly, mass transit businesses reporting GGS revenue would include workers such as bus and subway drivers, maintenance and repair workers, managers and administrative personnel.

Sampling Methods

Sample Frame

The GGS uses the QCEW as its sampling frame. Private and government (federal, state, and local) establishments are included on the frame, excluding any establishment with an average employment of zero over the past 12 months. The data for the QCEW come from State Unemployment Insurance (UI) files that are collected by individual State agencies. The QCEW includes several descriptive variables, such as name, address, monthly employment counts, industry classification, and geographic information for nearly all establishments in the United States.

Since it takes about one year for these data to be processed, the GGS frame used for the 2012 second quarter (2012Q2) initial sample selection is comprised of 2011 second quarter (2011Q2) QCEW data. The 2011Q2 QCEW has over 9 million business establishments accounting for about 130 million employees. The GGS sample frame is restricted to the 325 in-scope industries and has approximately 2.1 million establishments accounting for about 26.0 million employees. To account for business openings in the third and fourth quarters of 2011, a small birth sample is selected from the 2011Q4 QCEW data. About 80 percent of the 2011 sample units were also selected in the 2010 sample, establishing a high amount of overlap of establishments between survey years.

About 18,500 in-scope establishments comprising approximately one million employees were pre-identified as being involved with some kind of green activity. These units were identified internally by BLS by use of the internet and an environmental database maintained by Environmental Business International (an environmental publishing, research and consulting company). The 18,500 establishments will be referred to as the environmental establishments frame and have special treatment during the GGS allocation and selection phases.

Sample Allocation

The GGS sample size is about 122,000 establishments:

- An initial sample of approximately 119,000 establishments is selected from the second quarter
- A birth sample of approximately 3,000 establishments is selected from the fourth quarter

The total sample counts, rounded to the nearest hundred, are given in Table 1. The frame was randomly separated into three panels of approximately equal size in 2010, and each type of frame unit had its own independent allocation. The sample units selected from two of these panels in 2010 are retained in 2011. A new sample was allocated and selected from the third, non-overlapping panel in 2012. Additional overlap occurs due to the high probability of selection of some units in the third panel.

Table 1: 2011 GGS Sample Counts

Type of Frame Unit	Sample Allocated
Private Establishments	98,400
Local Government Establishments	7,300
State Government Establishments	3,900
Federal Government Units	2,900
Environmental Establishments	9,800
Total	122,300

Private Allocation

The GGS private establishment allocation is stratified two-dimensionally by 1) state / 2-digit NAICS industries and 2) 4- or 6-digit NAICS industries. These 4- or 6-digit industries will be called Allocation NAICS, or ANAICS. Most ANAICS industries are at the 4-digit NAICS detail, however some industries that seemed to be highly environmental, such as 22111 Electric power generation, (ex. 221118 – Other Electric Power Generation) were allocated to 6-digit detail.

The GGS private sample is first allocated by giving a minimum number of sample units to each state by 2-digit NAICS stratum. Second, a fixed number of sample units is allocated within each state using a power allocation, given in the formula below, and the larger of the two allocations is selected. This ensures that each state /2-digit NAICS has adequate sample representation for estimation.

$$n_h = n_s \frac{\sqrt{X_h}}{\sum_{h \in s} \sqrt{X_h}}$$

where

n_h = Amount of sample allocated to stratum h (State by 2-digit NAICS)
n_s = State sample size, initially equal to 1,000
X_h = Number of employees in stratum *h*

After the state level of allocation, the remaining sample is allocated nationally to ANAICS industry strata, using a power allocation. The national sample size is increased and reconciled with the state sample in an iterative procedure until the total private allocation is close to the target sample size.

Government Allocations

The sample units for local, state, and federal establishments use the same allocation methodology as the private sample allocation.

Environmental Establishments Allocation

The environmental establishments frame includes establishments in the private and government sectors. The frame is stratified by 6-digit NAICS industry and establishment size. Generally, establishments from the frame were given a higher probability of inclusion in the sample.

GGS Sample Selection

The private and government samples are selected using a modified probability proportional to size (PPS) method where the size for an establishment is defined as:

$$size_i = \begin{cases} 10 & if\ X_i \leq 10 \\ X_i & if\ X_i > 10 \end{cases}$$ where X_i is 12-month maximum frame employment for establishment i

This type of sampling is sometimes referred to as PPZ sampling. The smallest establishments are treated differently because of the assumption that they have the potential for very large relative employment shifts between the time period of the QCEW data on the frame and when the establishment is collected. By raising the size of the smallest establishments, the selection probabilities are raised, reducing and stabilizing the sampling weights. A pure PPS sampling approach would create the potential for the smallest units to have very large sampling weights, which could create instability among small establishments with a high level of relative employment change.

Another modification to the PPS design arises from the two-dimensional survey design. Selection probabilities are reconciled between national/detailed industry and state/2-digit industry in such a way that an establishment's maximum selection probability from the two-dimensional allocation is assigned as its final probability of selection.

The environmental establishments sample is selected using simple random sampling within each 6-digit NAICS by size class stratum. Since the sample is allocated at a higher rate as the size class increases, there is an implicit probability proportional to size selection scheme.

GGS Birth Sample

A fourth quarter birth sample of about 3,100 establishments is selected to represent the newly-formed establishments that become in business or in-scope between the second and fourth quarters of 2011. Any establishment in the 2011Q4 sample frame that does not match to the 2011Q2 sample frame is considered a birth. The birth sample is allocated at the same rate as the initial sample for each of the five different allocations.

Sampling Weights

Each sampled establishment has a known probability of selection. The inverse of the probability of selection is called the sampling weight.

Estimation

A Horvitz-Thompson (HT) estimator is used to estimate GGS employment. Establishment employment is updated from the Quarterly Census of Employment and Wages (QCEW) files relevant to the reference period of this release. The proportion of an establishment's total revenue associated with producing green goods or providing green goods is used to estimate the number of GGS employees contributed by the establishment. Each establishment has a sampling weight that is multiplied by its number of GGS employees in the HT estimator. Weights are used since a sample of establishments, rather than the whole business population, is included in the survey.

The estimation levels of the GGS survey are

- National, total and private ownership
- 173 ANAICS industries, private
- Statewide, total and private
- State by 2-digit NAICS sector, private

In the estimation formulas, estimation cell *h* refers to any particular estimation level covered in the above list.

For establishment *i* in estimation cell *h*, let:

fw_i = Final weight[1] of *i*
e_i = 12-month average QCEW employment of *i*
p_i = Reported proportion of revenue[2] from GGS goods and services from *i*
$\widehat{GE}_h$ = Estimated GGS employment in *h*

GGS employment for estimation cell *h* is calculated using the formula:

$$\widehat{GE}_h = \sum_{i \in h} (fw_i * e_i * p_i)$$

[1]*For details about the final weight, see Nonresponse and Benchmarking subsections.*
[2]*For non-revenue establishments,* p_i *is the reported proportion of employees involved with the production of green goods and services.*

For calculation of GGS proportion of employment, $\widehat{GE}_h$ is divided by the 12-month average of total QCEW employment for that estimation cell and converted into a percentage. Instead of being limited to the 325 NAICS industries classified in the GGS scope, all QCEW employment within that cell is included in the denominator. Thus, each GGS percentage estimate is relative to total employment in that cell. Out-of-scope industries are assumed to have zero GGS employment.

For estimation cell *h*, let

$QCEW_h$ = 12-month average QCEW employment in *h*
$\widehat{GP}_h$ = Estimated GGS percentage of total employment in estimation cell *h*.

GGS percentage for estimation cell *h* is calculated using the formula:

$$\widehat{GP}_h = 100 * \left(\frac{\widehat{GE}_h}{QCEW_h}\right)$$

Backcasting

The original survey estimates for 2010 were based on the 2007 NAICS classification. In that reference period, data were collected for industries defined in the GGS scope according to their NAICS classification at that time. The 2011 survey estimates are based on the 2012 NAICS classification, which impacted the scope of the GGS survey. Some private-ownership manufacturing industries that were not included in the 2010 GGS scope combined with in-scope industries. Thus, for 2011 estimates, some establishments that were previously out-of-scope are included in the survey.

Revised 2010 estimates are based on the 2012 NAICS classification. To ensure comparability of estimates, a backcasting procedure is applied to the 2010 industries that were incorporated into the scope of the GGS survey in 2011. The 2011 estimate of green percentage for the establishments in these industries is applied to their annual average QCEW employment in 2010 to calculate an estimate of GGS employment for that year, since only survey data for 2011 are available for these industries. Thus, over-the-year change in affected manufacturing industries results from either:

1. Change in QCEW employment
2. Change in rate of GGS employment, from establishments in industries that were in-scope in both the 2007 and 2012 NAICS classifications

Imputation

Establishments that are repeatedly sampled but only report usable data for one year, or beggars, are imputed. Since sample weight and average employment are available for every establishment, only the percent of revenue or employment associated with green goods and services, or green percent, is imputed for beggars.

Three methods are used to impute missing values of green percent in beggar establishments: hot deck imputation; overlays; and mean imputation. Differential nonresponse between survey years, particularly among influential establishments, may distort the true over the year change. The imputation methods described substantially eliminate the potentially strong influence of differential nonresponse on estimates of over-the-year change.
Most beggars are imputed using a hot deck procedure. Among businesses that have reported green percentage data for consecutive sample years, an eligible establishment, or donor, is randomly selected from a pool of establishments based on similarity of industry, geography, size and reported green percent.

The pool of eligible establishments is defined by an imputation hierarchy. All establishments that meet the definitions of the first level of the hierarchy are eligible to be randomly chosen as the donor. If no establishments meet the definitions at the first level, eligible establishments that meet the definitions at the second level are identified, and so on.

Hierarchy for Hot Deck Imputation

The pool of eligible donors is restricted to sample units that responded to consecutive years of the survey and are classified in the same NAICS and ownership codes as the beggar. Given that condition, the hierarchy defining eligible donor pools is given in Table 2, where *b* represents a beggar establishment and *d* represents a donor establishment. To be imputed for year *t*, a beggar must have reported a usable proportion of revenue or employment from green goods and services, or green percent, in year *t-1*. To be imputed for year *t-1*, a beggar must have reported a usable green percent in year t. Any eligible donors for either year must have reported usable green percentages for both *t* and *t-1*.

The hierarchy defined in Table 2 refers to hot-deck imputation for year *t*. The hierarchy for year *t-1* is analogous, such that the subscripts *t* and *t-1* are switched to define imputation levels for year *t-1*.

Let

$e_{b,t}$ = 12-month average QCEW employment of beggar *b* in year *t*
$e_{b,t-1}$ = 12-month average QCEW employment of beggar *b* in year *t-1*
$e_{d,t}$ = 12-month average QCEW employment of potential donor *d* in year *t*
$e_{d,t-1}$ = 12-month average QCEW employment of potential donor *d* in year *t-1*

$p_{b,t}$ = Reported green percent from *b* in sample year *t*
$p_{b,t-1}$ = Reported green percent from *b* in sample year *t-1*
$p_{d,t}$ = Reported green percent from *d* in sample year *t*
$p_{d,t-1}$ = Reported green percent from *d* in sample year *t-1*

Table 2. Hot deck imputation hierarchy.

Level	Employment in year *t-1*[3]	Employment in year *t*[3]	Green percent[4]
1	$e_{d,t-1} \in [0.50*e_{b,t-1}, 1.5*e_{b,t-1}]$	$e_{d,t} \in [0.50*e_{b,t}, 1.5*e_{b,t}]$	$p_{d,t-1} \in [p_{b,t-1} - 10, p_{b,t-1} + 10]$
2	$e_{d,t-1} \in [0.50*e_{b,t-1}, 1.5*e_{b,t-1}]$	$e_{d,t} \in [0.50*e_{b,t}, 1.5*e_{b,t}]$	$p_{d,t-1} \in [p_{b,t-1} - 10, p_{b,t-1} + 10]$
3	$e_{d,t-1} \in [0.25*e_{b,t-1}, 2.0*e_{b,t-1}]$	$e_{d,t} \in [0.25*e_{b,t}, 2.0*e_{b,t}]$	$p_{d,t-1} \in [p_{b,t-1} - 20, p_{b,t-1} + 20]$
4	$e_{d,t-1} \in [0.25*e_{b,t-1}, 2.0*e_{b,t-1}]$	$e_{d,t} \in [0.25*e_{b,t}, 2.0*e_{b,t}]$	$p_{d,t-1} \in [p_{b,t-1} - 20, p_{b,t-1} + 20]$

[3]*Special conditions apply if potential donor d fails one or both employment tests.*

[4]*Green percent intervals in Table 2 only apply if p_b is between 0 and 100 percent. See special conditions below for handling of these cases.*

Special Conditions

For levels 1 and 2, potential donor *d* passes the employment test in year *t*, if $|e_{d,t} - e_{b,t}| \leq 10$.
For levels 3 and 4, potential donor *d* passes the employment test in year *t*, if $|e_{d,t} - e_{b,t}| \leq 25$.

For levels 1 and 2, potential donor *d* passes the employment test in year *t-1*, if $|e_{d,t-1} - e_{b,t-1}| \leq 10$.
For levels 3 and 4, potential donor *d* passes the employment test in year *t-1*, if $|e_{d,t-1} - e_{b,t-1}| \leq 25$.

For levels 1 and 2, if $p_b = 0$ or $p_b = 100$, then potential donor *d* is only eligible if $p_b = p_d$.
For levels 3 and 4, if $p_b = 0$, then potential donor *d* is only eligible if $p_d \leq 1$.
For levels 3 and 4, if $p_b = 100$, then potential donor *d* is only eligible if $p_d \geq 95$.

If multiple donors meet the imputation criteria at a given level, the eligible donor with the smallest Uniform random number is selected. Random numbers are reassigned after the donor pool is defined, such that no establishment consistently has a small random number that would induce a high likelihood of repeated selection for other beggar establishments.

Once a donor has been selected, its over the year change in green percent is calculated and applied to the beggar's reported green percent from year *t-1*. The green percent used in imputation for beggar *b* in year *t* is given by:

$$p^{\theta}_{b,t} = Min\{100, Max[0, p_{b,t-1} + (p_{d,t} - p_{d,t-1})]\}$$

The minimum and maximum functions are used to prevent any beggar from having a green percent less than zero or greater than 100.

Other Imputation Procedures

Overlays are used when a suitable donor cannot be identified using the hierarchy in Table 2. For beggars imputed this way in year *t*, the beggar's reported green percent from year *t-1* is used:

$$p^{\theta}_{b,t} = p_{b,t-1}$$

Relative to hot deck imputation, a small proportion of beggars are overlaid. Since the occurrences are relatively infrequent, and since most establishments do not report large changes in green percent from one year to the next, the amount of change dampened by this procedure is expected to be very small.

Additionally, in each sample year, between forty and fifty units are imputed with the average green percent of respondents in the same 6-digit NAICS code. These units have never provided usable green percentages to the GGS survey and are classified in weighting cells that either have zero or very few respondents. While these mean imputes have minimal impact on published estimates, they are imputed to stabilize weighting adjustments. Weighting cells and adjustments are described in the ensuing sections.

Nonresponse

For a variety of reasons, some establishments sampled by the GGS program either fail to respond or fail to provide complete, usable information on the returned survey form. Both are considered nonrespondents in the formulas below.

When calculating $\widehat{GE}_h$ using the Horvitz-Thompson estimator, initial sample weights are modified by a nonresponse adjustment factor to produce unbiased estimates of the true level of GGS employment. Nonresponse adjustment factors account for those sampled establishments that did not provide usable response information for inclusion in the estimation procedures.

The GGS survey produces estimates at various national and state estimation levels. To accommodate the multi-dimensional nature of the estimation levels, iterative, four-dimensional nonresponse adjustment factors are calculated for each respondent. Establishment size class is incorporated due to the tendency of differential response rates among establishments of varying employment sizes. Size class is determined by maximum 12-month QCEW employment. In some industries, size class or ownership is collapsed if there are too few respondents within a given adjustment cell.

There are four levels of nonresponse adjustment, labeled as *h*, *j*, *k*, and *l*:

- *h*: ANAICS/Size Class
- *j*: State/2-digit NAICS
- *k*: ANAICS/Ownership (private or government)
- *l*: State/Ownership (private, federal, state, or local)

The nonresponse adjustment procedure is iterated so that successive weighting adjustments converge to 1.00. For establishment *i,* let

e_i = 12-month average QCEW employment of unit *i*

w_i = Sampling weight of unit *i* in nonresponse adjustment cells *h, j, l*, and *m*

$w_{ih,k}$ = Nonresponse-adjusted weight of unit *i* in cell *h*, after the k^{th} first stage adjustment

$w_{ij,k}$ = Nonresponse-adjusted weight of unit *i* in cell *j*, after the k^{th} second stage adjustment

$w_{il,k}$ = Nonresponse-adjusted weight of unit *i* in cell *l*, after the k^{th} third stage adjustment

$w_{im,k}$ = Nonresponse-adjusted weight of unit *i* in cell *m*, after the k^{th} fourth stage adjustment

$NRAF_{ih,k}$ = Nonresponse adjustment factor of unit *i* in adjustment cell *h* after the first stage of iteration *k*

$NRAF_{ij,k}$ = Nonresponse adjustment factor of unit *i* in adjustment cell *j* after the second stage of iteration *k*

$NRAF_{il,k}$ = Nonresponse adjustment factor of unit *i* in adjustment cell *l* after the third stage of iteration *k*

$NRAF_{im,k}$ = Nonresponse adjustment factor of unit *i* in adjustment cell *m* after the fourth stage of iteration *k*

$FNRAF_i$ = Final nonresponse adjustment factor of unit *i*

S_h = Sample establishments in *h*, excluding out of business and out of scope units

R_h = Usable respondents in *h*

S_j = Sample establishments in *j*, excluding out of business and out of scope units

R_j = Usable respondents in *j*

S_l = Sample establishments in *l*, excluding out of business and out of scope units

R_l = Usable respondents in l

S_m = Sample establishments in m, excluding out of business and out of scope units

R_m = Usable respondents in m

For the first iteration ($k = 1$), calculate:

$$NRAF_{ih,1} = \frac{\sum_{i \in S_h} w_i * e_i}{\sum_{i \in R_h} w_i * e_i}$$

$$w_{ih,1} = NRAF_{ih,1} * w_i$$

$$NRAF_{ij,1} = \frac{\sum_{i \in S_j} w_i * e_i}{\sum_{i \in R_j} w_{ih,1} * e_i}$$

$$w_{ij,1} = NRAF_{ij,1} * w_{ih,1}$$

$$NRAF_{il,1} = \frac{\sum_{i \in S_l} w_i * e_i}{\sum_{i \in R_l} w_{ij,1} * e_i}$$

$$w_{il,1} = NRAF_{il,1} * w_{ij,1}$$

$$NRAF_{im,1} = \frac{\sum_{i \in S_m} w_i * e_i}{\sum_{i \in R_m} w_{il,1} * e_i}$$

$$w_{im,1} = NRAF_{im,1} * w_{il,1}$$

For successive iterations ($k > 1$), calculate:

$$NRAF_{ih,k} = \frac{\sum_{i \in S_h} w_i * e_i}{\sum_{i \in R_h} w_{im,k-1} * e_i}$$

$$w_{ih,k} = NRAF_{ih,k} * w_{im,k-1}$$

$$NRAF_{ij,k} = \frac{\sum_{i \in S_j} w_i * e_i}{\sum_{i \in R_j} w_{ih,k} * e_i}$$

$$w_{ij,k} = NRAF_{ij,k} * w_{ih,k}$$

$$NRAF_{il,k} = \frac{\sum_{i \in S_l} w_i * e_i}{\sum_{i \in R_l} w_{ij,k} * e_i}$$

$$w_{il,k} = NRAF_{il,k} * w_{ij,k}$$

$$NRAF_{im,k} = \frac{\sum_{i \in S_m} w_i * e_i}{\sum_{i \in R_m} w_{il,k} * e_i}$$

$$w_{im,k} = NRAF_{im,k} * w_{il,k}$$

After all iterations are complete, calculate the final nonresponse adjustment factor:

$$FNRAF_i = \frac{w_{im,k}}{w_i}$$

While the formulas are detailed, the concept is simple:

1. The numerator always contains weighted sample employment for that cell, using all sample units (except those out of business or out of scope) and the original sampling weight, and
2. The denominator always contains weighted response employment for that cell, using only valid respondents and the adjusted weight from the previous step.

Benchmarking

Due to differences between the date of initial sample selection and the reference period of the estimates, the GGS program updates the employment of each establishment to its 12-month average over the estimation reference period. Specifically, the initial sample is selected from the 2nd quarter QCEW files, while the reference period represents the calendar year ending in the 4th quarter. Establishments are linked to the 4th quarter, and their employment is updated with the new 12-month average.

As a result of this procedure, the additivity that the nonresponse procedure guarantees is lost because of new levels of QCEW employment. The GGS program calculates a benchmark factor to ensure that the estimates are additive. This procedure is similar to the nonresponse procedure.

There are three levels of benchmark adjustments, labeled as *h*, *j*, and *l,* that correspond to the most detailed estimation levels published by the GGS program:

- *h*: ANAICS/Ownership (private or government)
- *j*: State/2-digit NAICS/Ownership (private or government)
- *k*: 2-digit NAICS/Ownership (private, federal, state, or local)

The benchmarking procedure is iterated so that successive weighting adjustments converge to 1.00. For establishment i, let

e_i = Average 2010 QCEW employment for establishment *i*

w_i = Sampling weight of unit *i* in estimation cells *h* and *j*

$FNRAF_i$ = Final nonresponse adjustment factor of unit *i*

$aw_i = w_i * FNRAF_i$ = Nonresponse adjusted weight of unit *i*

$w_{ih,k}$ = Benchmark weight of unit *i* in cell *h*, after the k^{th} first stage adjustment

$w_{ij,k}$ = Benchmark weight of unit *i* in cell *j*, after the k^{th} second stage adjustment

$w_{il,k}$ = Benchmark weight of unit *i* in cell *l*, after the k^{th} third stage adjustment

$BMF_{ih,k}$ = Benchmark factor of unit *i* in adjustment cell *h* after the first stage of iteration *k*

$BMF_{ij,k}$ = Benchmark factor of unit *i* in adjustment cell *j* after the second stage of iteration *k*

$BMF_{il,k}$ = Benchmark factor of unit i in adjustment cell l after the third stage of iteration k

$FBMF_i$ = Final benchmark factor of unit i

Q_h = Benchmark employment level in h, derived from QCEW

R_h = Usable respondents in h

Q_j = Benchmark employment level in j, derived from QCEW

R_j = Usable respondents in j

Q_l = Benchmark employment level in l, derived from QCEW

R_l = Usable respondents in l

For the first iteration (k = 1), calculate:

$$BMF_{ih,1} = \frac{Q_h}{\sum_{i \in R_h} aw_i * AEMP_i}$$

$$w_{ih,1} = BMF_{ih,1} * aw_i$$

$$BMF_{ij,1} = \frac{Q_j}{\sum_{i \in R_j} w_{ih,1} * AEMP_i}$$

$$w_{ij,1} = BMF_{ij,1} * w_{ih,1}$$

$$BMF_{il,1} = \frac{Q_l}{\sum_{i \in R_j} w_{ij,1} * AEMP_i}$$

$$w_{il,1} = BMF_{il,1} * w_{ij,1}$$

For successive iterations (k > 1), calculate:

$$BMF_{ih,k} = \frac{Q_h}{\sum_{i \in R_h} w_{il,k-1} * AEMP_i}$$

$$w_{ih,k} = BMF_{ih,k} * w_{il,k-1}$$

$$BMF_{ij,k} = \frac{Q_j}{\sum_{i \in R_j} w_{ih,k} * AEMP_i}$$

$$w_{ij,k} = BMF_{ij,k} * w_{ih,k}$$

$$BMF_{il,k} = \frac{Q_l}{\sum_{i \in R_l} w_{ij,k} * AEMP_i}$$

$$w_{il,k} = BMF_{ij,k} * w_{ij,k}$$

After all iterations are complete, calculate the final benchmark factor and final estimation weight:

$$FBMF_i = \frac{w_{iL,k}}{aw_i}$$

$$fw_i = w_i * FNRAF_i * FBMF_i$$

The concept is similar to nonresponse adjustment:

1. The numerator always contains benchmark employment level (from QCEW) for that cell, and
2. The denominator always contained weighted response employment for that cell, using only valid respondents and the adjusted weight from the previous step.

Reliability

Estimates developed from a sample will differ from the results of a census. An estimate based on a sample survey is subject to two types of error—sampling and nonsampling error. An estimate based on a census is only subject to nonsampling error.

Nonsampling Error

This type of error is attributable to several causes, such as: errors in the sampling frame; an inability to obtain information for all establishments in the sample; differences in respondents' interpretation of a survey question; an inability or unwillingness of the respondents to provide correct information; errors made in recording, coding, or processing the data; and errors made in imputing values for missing data. Explicit measures of the effects of nonsampling error are not available.

Sampling Error

When a sample, rather than an entire population, is surveyed, estimates differ from the true population values that they represent. This difference, or sampling error, occurs by chance, and its variability is measured by the variance of the estimate or the standard error of the estimate (square root of the variance). The relative standard error is the ratio of the standard error to the estimate itself.

Estimates of the sampling error for the GGS employment estimates allow data users to determine if those statistics are reliable enough for their needs. Only a probability-based sample can be used to calculate estimates of sampling error. The formulas used to estimate GGS variances are adaptations of formulas appropriate for the survey design used.

The particular sample used in this survey is one of a large number of possible samples of the same size that could have been selected using the same sample design. Sample estimates from a given design are said to be unbiased when an average of the estimates from all possible samples yields the true population value. In this case, the sample estimate and its standard error can be used to construct confidence intervals, or ranges of values that include the true population value with known probabilities. To illustrate, if the process of selecting a sample from the population were repeated many times, if each sample were surveyed under essentially the same unbiased conditions, and if an estimate and a suitable estimate of its standard error were made from each sample, then:

1. Approximately 68 percent of the intervals from one standard error below to one standard error above the estimate would include the true population value. This interval is called a 68-percent confidence interval.

2. Approximately 90 percent of the intervals from 1.645 standard errors below to 1.645 standard errors above the estimate would include the true population value. This interval is called a 90-percent confidence interval.

3. Approximately 95 percent of the intervals from 1.96 standard errors below to 1.96 standard errors above the estimate would include the true population value. This interval is called the 95-percent confidence interval.

4. Almost all (99.7 percent) of the intervals from 3 standard errors below to 3 standard errors above the estimate would include the true population value.

Sample Variance

The GGS survey used a modified Balanced Repeated Replication (BRR) method to estimate sample variance. Prior to nonresponse adjustment and benchmarking, this replication technique splits the sample within an estimation cell into halves. The establishments within these half-samples have their sampling weights multiplied by 0.5 or 1.5, depending on the values of an orthogonal Hadamard matrix. All GGS estimates are then calculated with the modified sampling weights substituted for the original sampling weights described in the previous sections. Each replicate produces different half-samples and different estimates. The procedure is repeated γ times, and the resulting BRR estimates are used to estimate sample variances. To estimate sample variances of over the year change, establishments that were sampled in consecutive surveys are assigned to the same half-sample each year.

Estimated sample variance and standard error of the GGS employment estimate $\widehat{GE}_h$

$$\hat{V}(\widehat{GE}_h) = \frac{1}{\gamma * (1-\alpha)^2} \sum_{i=1}^{\gamma} (\widehat{GE}_{h,\gamma}^{BRR} - \widehat{GE}_h)^2 \quad (1)$$

$$\hat{S}(\widehat{GE}_h) = \sqrt{\hat{V}(\widehat{GE}_h)} \quad (2)$$

Estimated sample variance and standard error of the GGS percentage estimate $\widehat{GP}_h$

$$\hat{V}(\widehat{GP}_h) = \left(\frac{100}{QCEW_h}\right)^2 \hat{V}(\widehat{GE}_h) \quad (3)$$

$$\hat{S}(\widehat{GP}_h) = \sqrt{\hat{V}(\widehat{GP}_h)} \quad (4)$$

where

$\widehat{GE}_{h,\gamma}^{BRR} = \gamma^{th}$ BRR estimate of GGS employment GE_h

$\widehat{GE}_h$ = Sample-based estimate of GGS employment GE_h

$\gamma = 128$ = Number of BRR replicates

$\alpha = 0.5$

The standard error of over the year change in GGS employment or GGS percent, from year *t-1* to *t*, are calculated by substituting

$\widehat{\Delta GE} = (\widehat{GE}_{h,t} - \widehat{GE}_{h,t-1})$ for $\widehat{GE}_h$ in formulas (1) and (2), and

$\widehat{\Delta GP} = (\widehat{GP}_{h,t} - \widehat{GP}_{h,t-1})$ for $\widehat{GP}_h$ in formulas (3) and (4).

Estimates of sample variance are useful to measure the precision of the GGS employment estimates, but they do have limitations. Generally, variances reflect the error component of the estimates that arise from surveying only a subset of the population, rather than the whole population. They do not reflect nonsampling error, such as response errors and nonresponse bias.

BLS-standard 90% confidence intervals for GGS employment may be constructed as:

$$\widehat{GE}_h \pm 1.645 * \hat{S}(\widehat{GE}_h)$$

If there was no nonsampling error in the survey, approximately 90% of intervals constructed in this fashion, from all possible samples that could be selected, would contain the true population level of GGS employment for that estimation cell.