

Appendix A

Definitions of Fundamental LEHD

Concepts

A.1 Fundamental concepts

A.1.1 Dates

The QWI are a quarterly data system with calendar year timing. We use the notation $yyyy:q$ to refer to a year and quarter combination. For example, 1999:4 refers to the fourth quarter of 1999, which includes the months October, November, and December.

A.1.2 Employer

An employer in the QWI system consists of a single Unemployment Insurance (UI) account in a given state's UI wage reporting system. For statistical purposes the QWI system creates an employer identifier called a State Employer Identification Number (SEIN) from the UI-account number and information about the state (FIPS code). Thus, within the QWI system, the SEIN is a unique identifier within and across states but the entity to which it refers is a UI account.

A.1.3 Establishment

For a given employer in the QWI system, an SEIN, each physical location within the state is assigned a unit number, called the SEINUNIT. This SEINUNIT is based on the reporting unit in the ES-202 files supplied by the states. All QWI statistics are produced by aggregating statistics calculated at the establishment level. Single-unit SEINs are UI accounts associated with a single reporting unit in the state. Thus, single-unit SEINs have only one associated SEINUNIT in every quarter. Multi-unit SEINs have two or more SEINUNITs associated for some quarters. Since the UI wage records are not coded down to the SEINUNIT, SEINUNITs are multiply imputed as described in Section 4.2 on the unit-to-worker imputation. A feature of this imputation system is that it does not permit SEINUNIT to SEINUNIT movements within the same SEIN. Thus, for multi-unit SEINs, the definitions below produce the same flow estimates at the SEIN level whether the definition is applied to the SEIN or the SEINUNIT.

A.1.4 Employee

Individual employees are identified by their Social Security Numbers (SSN) on the UI wage records that provide the input to the QWI. To protect privacy and confidentiality of the SSN and the individual's name, a different branch of the Census Bureau, PRED, removes the name and replaces the SSN with an internal Census identifier called a Protected Identification Key (PIK).

A.1.5 Job

The QWI system definition of a job is the association of an individual (PIK) with an establishment (SEINUNIT) in a given year and quarter. The QWI system stores the entire history of every job that an individual holds. Estimates are based on the definitions presented below, which formalize how the QWI system estimates the start of a job (accession), employment status (beginning- and end-of-quarter employment), continuous employment (full-quarter employment), the end of a job

(separation), and average earnings for different groups.

A.1.6 Unemployment Insurance wage records (the QWI system universe)

The Quarterly Workforce Indicators are built upon concepts that begin with the report of an individual's UI-covered earnings by an employing entity (SEIN). An individual's UI wage record enters the QWI system if at least one employer reports earnings of at least one dollar for that individual (PIK) during the quarter. Thus, the job must produce at least one dollar of UI-covered earnings during a given quarter to count in the QWI system. The presence of this valid UI wage record in the QWI system triggers the beginning of calculations that estimate whether that individual was employed at the beginning of the quarter, at the end of the quarter, and continuously throughout the quarter. These designations are discussed below. Once these point-in-time employment measures have been estimated for the individual, further analysis of the individual's wage records results in estimates of full-quarter employment, accessions, separations (point-in-time and full-quarter), job creations and destructions, and a variety of full-quarter average earnings measures.

A.1.7 Employment at a point in time

Employment is estimated at two points in time during the quarter, corresponding to the first and last calendar days. An individual is defined as employed at the beginning of the quarter when that individual has valid UI wage records for the current quarter and the preceding quarter. Both records must apply to the same employer (SEIN). An individual is defined as employed at the end of the quarter when that individual has valid UI wage records for the current quarter and the subsequent quarter. Again, both records must show the same employer. The QWI system uses beginning and end of quarter employment as the basis for constructing worker and job flows. In addition, these measures are used to check the external consistency of the data, since a variety of employment estimates are available as point-in-time measures. Many federal statistics are based upon estimates

of employment as of the 12th day of particular months. The Census Bureau uses March 12 as the reference date for employment measures contained in its Business Register and on the Economic Censuses and Surveys. The BLS “Covered Employment and Wages (CEW)” series, which is based on the QCEW, formerly ES-202, data, use the 12th of each month as the reference date for employment. The QWI system cannot use exactly the same reference date as these other systems because UI wage reports do not specify additional detail regarding the timing of these payments. LEHD research has shown that the point-in-time definitions used to estimate beginning- and end-of-quarter employment track the CEW month one employment estimates well at the level of an employer (SEIN). For single-unit SEINs, there is no difference between an employer-based definition and an establishment-based definition of point-in-time employment. For multi-unit SEINs, the unit-to-worker imputation model assumes that unit-to-unit transitions within the same SEIN cannot occur. So, point in time employment defined at either the SEIN or SEINUNIT level produces the same result.

A.1.8 Employment for a full quarter

The concept of full quarter employment estimates individuals who are likely to have been continuously employed throughout the quarter at a given employer. An individual is defined as full-quarter-employed if that individual has valid UI-wage records in the current quarter, the preceding quarter, and the subsequent quarter at the same employer (SEIN). That is, in terms of the point-in-time definitions, if the individual is employed at the same employer at both the beginning and end of the quarter, then the individual is considered full-quarter employed in the QWI system.

Consider the following example. Suppose that an individual has valid UI wage records at employer A in 1999:2, 1999:3, and 1999:4. This individual does not have a valid UI wage record at employer A in 1999:1 or 2000:1. Then, according to the definitions above, the individual is employed at the end of 1999:2, the beginning and end of 1999:3, and the beginning of 1999:4 at employer A. The QWI system treats this individual as a full-quarter employee in 1999:3 but not in

1999:2 or 1999:4. Full-quarter status is not defined for either the first or last quarter of available data.

A.1.9 Point-in-time estimates of accession and separation

An accession occurs in the QWI system when it encounters the first valid UI wage record for a job (an individual (PIK)-employer (SEIN) pair). Accessions are not defined for the first quarter of available data from a given state. The QWI definition of an accession can be interpreted as an estimate of the number of new employees added to the payroll of the employer (SEIN) during the quarter. The individuals who acceded to a particular employer were not employed by that employer during the previous quarter but received at least one dollar of UI-covered earnings during the quarter of accession.

A separation occurs in the current quarter of the QWI system when it encounters no valid UI wage record for an individual-employer pair in the subsequent quarter. This definition of separation can be interpreted as an estimate of the number of employees who left the employer during the current quarter. These individuals received UI-covered earnings during the current quarter but did not receive any UI-covered earnings in the next quarter from this employer. Separations are not defined for the last quarter of available data.

A.1.10 Accession and separation from full-quarter employment

Full-quarter employment is not a point-in-time concept. Full-quarter accession refers to the quarter in which an individual first attains full-quarter employment status at a given employer. Full-quarter separation occurs in the last full-quarter that an individual worked for a given employer.

As noted above, full-quarter employment refers to an estimate of the number of employees who were employed at a given employer during the entire quarter. An accession to full-quarter employment, then, involves two additional conditions that are not relevant for ordinary accessions.

First, the individual (PIK) must still be employed at the end of the quarter at the same employer (SEIN) for which the ordinary accession is defined. At this point (the end of the quarter where the accession occurred and the beginning of the next quarter) the individual has acceded to continuing-quarter status. An accession to continuing-quarter status means that the individual acceded in the current quarter and is end-of-quarter employed. Next the QWI system must check for the possibility that the individual becomes a full-quarter employee in the subsequent quarter. An accession to full-quarter status occurs if the individual acceded in the previous quarter, and is employed at both the beginning and end of the current quarter. Consider the following example. An individual's first valid UI wage record with employer *A* occurs in 1999:2. The individual, thus acceded in 1999:2. The same individual has a valid wage record with employer *A* in 1999:3. The QWI system treats this individual as end-of-quarter employed in 1999:2 and beginning of quarter employed in 1999:3. The individual, thus, acceded to continuing-quarter status in 1999:2. If the individual also has a valid UI wage record at employer *A* in 1999:4, then the individual is full-quarter employed in 1999:3. Since 1999:3 is the first quarter of full-quarter employment, the QWI system considers this individual an accession to full-quarter employment in 1999:3.

Full-quarter separation works much the same way. One must be careful about the timing, however. If an individual separates in the current quarter, then the QWI system looks at the preceding quarter to determine if the individual was employed at the beginning of the current quarter. An individual who separates in a quarter in which that person was employed at the beginning of the quarter is a separation from continuing-quarter status in the current quarter. Finally, the QWI system checks to see if the individual was a full-quarter employee in the preceding quarter. An individual who was a full quarter employee in the previous quarter is treated as a full-quarter separation in the quarter in which that person actually separates. Note, therefore, that the definition of full-quarter separation preserves the timing of the actual separation (current quarter) but restricts the estimate to those individuals who were full-quarter status in the preceding quarter. For example, suppose that an individual separates from employer *A* in 1999:3. This means that the

individual had a valid UI wage record at employer *A* in 1999:3 but did not have a valid UI wage record at employer *A* in 1999:4. The separation is dated 1999:3. Suppose that the individual had a valid UI wage record at employer *A* in 1999:2. Then, a separation from continuing quarter status occurred in 1999:3. Finally, suppose that this individual had a valid UI wage record at employer *A* in 1999:1. Then, this individual was a full-quarter employee at employer *A* in 1999:2. The QWI system records a full-quarter separation in 1999:3.

A.1.11 Point-in-time estimates of new hires and recalls

The QWI system refines the concept of accession into two subcategories: new hires and recalls. In order to do this, the QWI system looks at a full year of wage record history prior to the quarter in which an accession occurs. If there are no valid wage records for this job (PIK-SEIN) during the four quarters preceding an accession, then the accession is called a new hire; otherwise, the accession is called a recall. Thus, new hires and recalls sum to accessions. For example, suppose that an individual accedes to employer *A* in 1999:3. Recall that this means that there is a valid UI wage record for the individual 1 at employer *A* in 1999:3 but not in 1999:2. If there are also no valid UI wage records for individual 1 at employer *A* for 1999:1, 1998:4 and 1998:3, then the QWI system designates this accession as a new hire of individual 1 by employer *A* in 1999:3. Consider a second example in which individual 2 accedes to employer *B* in 2000:2. Once again, the accession implies that there is not a valid wage record for individual 2 at employer *B* in 2000:1. If there is a valid wage record for individual 2 at employer *B* in 1999:4, 1999:3, or 1999:2, then the QWI system designates the accession of individual 2 to employer *B* as a recall in 2000:2. New hire and recall data, because they depend upon having four quarters of historical data, only become available one year after the data required to estimate accessions become available.

A.1.12 New hires and recalls to and from full-quarter employment

Accessions to full-quarter status can also be decomposed into new hires and recalls. The QWI system accomplishes this decomposition by classifying all accessions to full-quarter status who were classified as new hires in the previous quarter as new hires to full-quarter status in the current quarter. Otherwise, the accession to full-quarter status is classified as a recall to full-quarter status. For example, if individual 1 accedes to full-quarter status at employer *A* in 1999:4 then, according to the definitions above, individual 1 acceded to employer *A* in 1999:3 and reached full-quarter status in 1999:4. Suppose that the accession to employer *A* in 1999:3 was classified as a new hire, then the accession to full quarter status in 1999:4 is classified as a full-quarter new hire. For another example, consider individual 2 who accedes to full-quarter status at employer *B* in 2000:3. Suppose that the accession of individual 2 to employer *B* in 2000:2, which is implied by the full-quarter accession in 2000:3, was classified by the QWI system as a recall in 2000:2; then, the accession of individual 2 to full-quarter status at employer *B* in 2000:3 is classified as a recall to full-quarter status.

A.1.13 Job creations and destructions

Job creations and destructions are defined at the employer (SEIN) level and not at the job (PIK-SEIN) level. For single-unit employers, there is never more than one SEINUNIT per quarter, so the definition at the employer level and the definition at the establishment level are equivalent. For multi-unit employers, the QWI system performs the calculations at the establishment level (SEINUNIT); however, the statistical model for imputing establishment described in Section 4.2 does not permit establishment-to-establishment flows. Hence, although the statistics are estimated at the establishment level, the sum of job creations and destructions at a given employer in a given quarter across all establishments active that quarter is exactly equal to the measure of job creations that would have been estimated by using employer-level inputs (SEIN) directly.

To construct an estimate of job creations and destructions, the QWI system totals beginning and ending employment for each quarter for every employer in the UI wage record universe, that is, for an employer who has at least one valid UI wage record during the quarter. The QWI system actually uses the Davis et al. (1996) formulas for job creation and destruction (see definitions in Appendix A.2 on page 85). Here, we use a simplified definition. If end-of-quarter employment is greater than beginning-of-quarter employment, then the employer has created jobs. The QWI system sets job creations in this case equal to end-of-quarter employment less beginning-of-quarter employment. The estimate of job destructions in this case is zero. On the other hand, if beginning-of-quarter employment exceeds end-of-quarter employment, then this employer has destroyed jobs. The QWI system computes job destructions in this case as beginning-of-period employment less end-of-period employment. The QWI system sets job creations to zero in this case. Notice that either job creations are positive or job destructions are positive, but not both. Job creations and job destructions can simultaneously be zero if beginning-of-quarter employment equals end-of-quarter employment. There is an important subtlety regarding job creations and destructions when they are computed for different sex and age groups within the same employer. There can be creation and destruction of jobs for certain demographic groups within the employer without job creation or job destruction occurring overall. That is, jobs can be created for some demographic groups and destroyed for others even at enterprises that have no change in employment as a whole.

Here is a simple example. Suppose employer *A* has 250 employees at the beginning of 2000:3 and 280 employees at the end of 2000:3. Then, employer *A* has 30 job creations and zero job destructions in 2000:3. Now suppose that of the 250 employees 100 are men and 150 are women at the beginning of 2000:3. At the end of the quarter suppose that there are 135 men and 145 women. Then, job creations for men are 35 and job destructions for men are 0 in 2000:3. For women in 2000:3 job creations are 0 and job destructions are 5. Notice that the sum of job creations for the employer by sex ($35 + 0$) is not equal to job creations for the employer as a whole (30) and that the sum of job destructions by sex ($0 + 5$) is not equal to job destructions for the employer as a whole.

A.1.14 Net job flows

Net job flows are also only defined at the level of an employer (SEIN). Once again, the QWI system computes these statistics at the establishment level but does not allow establishment-to-establishment flows. Hence, the estimates for a given employer (SEIN) are the sum of the estimates for that employer's establishments (SEINUNIT) that are active in the given quarter. Net job flows are the difference between job creations and job destructions. Net job flows are, thus, always equal to end-of-quarter employment less beginning of quarter employment.

Returning to the example in the description of job creations and destructions. Employer A has 250 employees at the beginning of 2000:3 and 280 employees at the end of 2000:3. Net job flows are 30 (job creations less job destructions or beginning-of-quarter employment less end-of-quarter employment). Suppose, once again that employment of men goes from 100 to 135 from the beginning to the end of 2000:3 and employment of women goes from 150 to 145. Notice, now, that net job flows for men (35) plus net job flows for women (-5) equals net job flows for the employer as a whole (30). Net job flows are additive across demographic groups even though gross job flows (creations and destructions) are not.

Some useful relations among the worker and job flows include:

- Net job flows = job creations - job destructions
- Net job flows = end-of-quarter employment - beginning-of-period employment
- Net job flows = accessions - separations

These relations hold for every demographic group and for the employer as a whole. Additional identities are shown in [Appendix A.2](#).

A.1.15 Full-quarter job creations, job destructions and net job flows

The QWI system applies the same job flow concepts to full-quarter employment to generate estimates of full-quarter job creations, full-quarter job destructions, and full-quarter net job flows. Full-quarter employment in the current quarter is compared to full-quarter employment in the preceding quarter. If full-quarter employment has increased between the preceding quarter and the current quarter, then full-quarter job creations are equal to full-quarter employment in the current quarter less full-quarter employment in the preceding quarter. In this case full-quarter job destructions are zero. If full-quarter employment has decreased between the previous and current quarters, then full-quarter job destructions are equal to full-quarter employment in the preceding quarter minus full-quarter employment in the current quarter. In this case, full-quarter job destructions are zero. Full-quarter net job flows equal full-quarter job creations minus full-quarter job destructions. The same identities that hold for the regular job flow concepts hold for the full-quarter concepts.

A.1.16 Average earnings of end-of-period employees

The average earnings of end-of-period employees is estimated by first totaling the UI wage records for all individuals who are end-of-period employees at a given employer in a given quarter. Then, the total is divided by the number of end-of-period employees for that employer and quarter.

A.1.17 Average earnings of full-quarter employees

Measuring earnings using UI wage records in the QWI system presents some interesting challenges. The earnings of end-of-quarter employees who are not present at the beginning of the quarter are the earnings of accessions during the quarter. The QWI system does not provide any information about how much of the quarter such individuals worked. The range of possibilities goes from 1 day to every day of the quarter. Hence, estimates of the average earnings of such individuals may not be comparable from quarter to quarter unless one assumes that the average

accession works the same number of quarters regardless of other conditions in the economy. Similarly, the earnings of beginning-of-quarter workers who are not present at the end of the quarter represent the earnings of separations. These present the same comparison problems as the average earnings of accessions; namely, it is difficult to model the number of weeks worked during the quarter. If we consider only those individuals employed at the employer in a given quarter who were neither accessions nor separations during that quarter, we are left, exactly, with the full-quarter employees, as discussed above.

The QWI system measures the average earnings of full-quarter employees by summing the earnings on the UI wage records of all individuals at a given employer who have full-quarter status in a given quarter then dividing by the number of full-quarter employees. For example, suppose that in 2000:2 employer *A* has 10 full-quarter employees and that their total earnings are \$300,000. Then, the average earnings of the full-quarter employees at *A* in 2000:2 is \$30,000. Suppose, further that 6 of these employees are men and that their total earnings are \$150,000. So, the average earnings of full-quarter male employees is \$25,000 in 2000:2 and the average earnings of female full-quarter employees is \$37,500 ($= \$150,000/4$).

A.1.18 Average earnings of full-quarter accessions

As discussed above, a full-quarter accession is an individual who acceded in the preceding quarter and achieved full-quarter status in the current quarter. The QWI system measures the average earnings of full-quarter accessions in a given quarter by summing the UI wage record earnings of all full-quarter accessions during the quarter and dividing by the number of full-quarter accessions in that quarter.

A.1.19 Average earnings of full-quarter new hires

Full-quarter new hires are accessions to full-quarter status who were also new hires in the preceding quarter. The average earnings of full-quarter new hires are measured as the sum of UI wage records for a given employer for all full-quarter new hires in a given quarter divided by the number of full-quarter new hires in that quarter.

A.1.20 Average earnings of full-quarter separations

Full-quarter separations are individuals who separate during the current quarter who were full-quarter employees in the previous quarter. The QWI system measures the average earnings of full-quarter separations by summing the earnings for all individuals who are full-quarter status in the current quarter and who separate in the subsequent quarter. This total is then divided by full-quarter separations in the subsequent quarter. The average earnings of full-quarter separations is, thus, the average earnings of full-quarter employees in the current quarter who separated in the next quarter. Note the dating of this variable.

A.1.21 Average periods of non-employment for accessions, new hires, and recalls

As noted above an accession occurs when a job starts; that is, on the first occurrence of an SEIN-PIK pair following the first quarter of available data. When the QWI system detects an accession, it measures the number of quarters (up to a maximum of four) that the individual spent non-employed in the state prior to the accession. The QWI system estimates the number of quarters spent non-employed by looking for all other jobs held by the individual at any employer in the state in the preceding quarters up to a maximum of four. If the QWI system doesn't find any other valid UI-wage records in a quarter preceding the accession it augments the count of non-employed quarters for the individual who acceded, up to a maximum of four. Total quarters of non-employment for all

accessions is divided by accessions to estimate average periods of non-employment for accessions.

Here is a detailed example. Suppose individual 1 and individual 2 accede to employer *A* in 2000:1. In 1999:4, individual *A* does not work for any other employers in the state. In 1999:1 through 1999:3 individual 1 worked for employer *B*. Individual 1 had one quarter of non-employment preceding the accession to employer *A* in 2000:1. Individual 2 has no valid UI wage records for 1999:1 through 1999:4. Individual 2 has four quarters of non-employment preceding the accession to employer *A* in 2000:1. The accessions to employer *A* in 2000:1 had an average of 2.5 quarters of non-employment in the state prior to accession.

Average periods of non-employment for new hires and recalls are estimated using exactly analogous formulas except that the measures are estimated separately for accessions who are also new hires as compared with accession who are recalls.

A.1.22 Average number of periods of non-employment for separations

Analogous to the average number of periods of non-employment for accessions prior to the accession, the QWI system measures the average number of periods of non-employment in the state for individuals who separated in the current quarter, up to a maximum of four. When the QWI system detects a separation, it looks forward for up to four quarters to find valid UI wage records for the individual who separated among other employers in the state. Each quarter that it fails to detect any such jobs is counted as a period of non-employment, up to a maximum of four. The average number of periods of non-employment is estimated by dividing the total number of periods of non-employment for separations in the current quarter by the number of separations in the quarter.

A.1.23 Average changes in total earnings for accessions and separations

The QWI system measures the change in total earnings for individuals who accede or separate in a given quarter. For an individual accession in a given quarter, the QWI system computes total

earnings from all valid wage records for all of the individual's employers in the preceding quarter. The system then computes the total earnings for the same individual for all valid wage records and all employers in the current quarter. The acceding individual's change in earnings is the difference between the current quarter earnings from all employers and the preceding quarter earnings from all employers. The average change in earnings for all accessions is the total change in earnings for all accessions divided by the number of accessions.

The QWI system computes the average change in earnings for separations in an analogous manner. The system computes total earnings from all employers for the separating individual in the current quarter and subtracts total earnings from all employers in the subsequent quarter. The average change in earnings for all separations is the total change in earnings for all separations divided by the number of separations.

Here is an example for the average change in earnings of accessions. Suppose individual 1 accedes to employer *A* in 2000:3. Earnings for individual 1 at employer *A* in 2000:3 are \$8,000. Individual 1 also worked for employer *B* in 2000:2 and 2000:3. Individual 1's earnings at employer *B* were \$7,000 and \$3,000 in 2000:2 and 2000:3, respectively. Individual 1's change in total earnings between 2000:3 and 2000:2 was \$4,000 ($= \$8,000 + \$3,000 - \$7,000$). Individual 2 also acceded to employer *A* in 2000:3. Individual 2 earned \$9,000 from employer *A* in 2000:3. Individual 2 had no other employers during 2000:2 or 2000:3. Individual 2's change in total earnings is \$9,000. The average change in earnings for all of employer *A*'s accessions is \$6,500 ($= (\$4,000 + \$9,000) / 2$), the average change in total earnings for individuals 1 and 2.

A.2 Definitions of job flow, worker flow, and earnings Statistics

A.2.1 Overview and basic data processing conventions

For internal processing the variable t refers to the sequential quarter. The variable t runs from $qmin$ to $qmax$, regardless of the state being processed. The quarters are numbered sequentially from 1 (1985:1) to the latest available quarter. These values are $qmin = 1$ (1985:1) and $qmax = 80$ (2004:4), as of November 30, 2005. For publication, presentation, and internal data files, all dates are presented as (year:quarter) pairs, *e.g.* (1990:1) for first quarter 1990. The variable $qfirst$ refers to the first available sequential quarter of data for a state (*e.g.*, $qfirst = 21$ for Illinois). The variable $qlast$ refers to the last available sequential quarter of data for a state (*e.g.*, $qlast = 80$ for Illinois). Unless otherwise specified a variable is defined for $qfirst \leq t \leq qlast$. Statistics are produced for both sexes combined, as well as separately, for all age groups, ages 14-18, 19-21, 22-24, 25-34, 35-44, 45-54, 55-64, 65+, and all combinations of these age groups and sexes. An individual's age is measured as of the last day of the quarter.

A.2.2 Individual concepts

Flow employment (m): for $qfirst \leq t \leq qlast$, individual i employed (matched to a job) at some time during period t at establishment j

$$m_{ijt} = \begin{cases} 1, & \text{if } i \text{ has positive earnings at establishment } j \text{ during quarter } t \\ 0, & \text{otherwise.} \end{cases} \quad (\text{A.1})$$

Beginning of quarter employment (*b*): for $qfirst < t$, individual i employed at the beginning of t (and the end of $t - 1$),

$$b_{ijt} = \begin{cases} 1, & \text{if } m_{ijt-1} = m_{ijt} = 1 \\ 0, & \text{otherwise.} \end{cases} \quad (\text{A.2})$$

End of quarter employment (*e*): for $t < qlast$, individual i employed at j at the end of t (and the beginning of $t + 1$),

$$e_{ijt} = \begin{cases} 1, & \text{if } m_{ijt} = m_{ijt+1} = 1 \\ 0, & \text{otherwise.} \end{cases} \quad (\text{A.3})$$

Accessions (a_1): for $qfirst < t$, individual i acceded to j during t

$$a_{1ijt} = \begin{cases} 1, & \text{if } m_{ijt-1} = 0 \ \& \ m_{ijt} = 1 \\ 0, & \text{otherwise.} \end{cases} \quad (\text{A.4})$$

Separations (s_1): for $t < qlast$, individual i separated from j during t

$$s_{1ijt} = \begin{cases} 1, & \text{if } m_{ijt} = 1 \ \& \ m_{ijt+1} = 0 \\ 0, & \text{otherwise.} \end{cases} \quad (\text{A.5})$$

Full quarter employment (*f*): for $qfirst < t < qlast$, individual i was employed at j at the beginning and end of quarter t (full-quarter job)

$$f_{ijt} = \begin{cases} 1, & \text{if } m_{ijt-1} = 1 \ \& \ m_{ijt} = 1 \ \& \ m_{ijt+1} = 1 \\ 0, & \text{otherwise.} \end{cases} \quad (\text{A.6})$$

New hires (h_1): for $qfirst + 3 < t$, individual i was newly hired at j during period t

$$h_{1ijt} = \begin{cases} 1, & \text{if } m_{ijt-4} = 0 \ \& \ m_{ijt-3} = 0 \ \& \ m_{ijt-2} = 0 \ \& \ m_{ijt-1} = 0 \ \& \ m_{ijt} = 1 \\ 0, & \text{otherwise.} \end{cases} \quad (\text{A.7})$$

Recalls (r_1): for $qfirst + 3 < t$, individual i was recalled from layoff at j during period t

$$r_{1ijt} = \begin{cases} 1, & \text{if } m_{ijt-1} = 0 \ \& \ m_{ijt} = 1 \ \& \ h_{ijt} = 0 \\ 0, & \text{otherwise.} \end{cases} \quad (\text{A.8})$$

Accessions to consecutive quarter status (a_2): for $qfirst < t < qlast$, individual i transited from accession to consecutive-quarter status at j at the end of t and the beginning of $t+1$ (accession in t and still employed at the end of the quarter)

$$a_{2ijt} = \begin{cases} 1, & \text{if } a_{1ijt} = 1 \ \& \ m_{ijt+1} = 1 \\ 0, & \text{otherwise.} \end{cases} \quad (\text{A.9})$$

Accessions to full quarter status (a_3): for $qfirst + 1 < t < qlast$, individual i transited from consecutive-quarter to full-quarter status at j during period t (accession in $t - 1$ and employed for the full quarter in t)

$$a_{3ijt} = \begin{cases} 1, & \text{if } a_{2ijt-1} = 1 \ \& \ m_{ijt+1} = 1 \\ 0, & \text{otherwise.} \end{cases} \quad (\text{A.10})$$

New hires to consecutive quarter status (h_2): for $qfirst + 3 < t < qlast$, individual i transited from newly hired to consecutive-quarter hired status at j at the end of t and the beginning of $t + 1$

(hired in t and still employed at the end of the quarter)

$$h_{2ijt} = \begin{cases} 1, & \text{if } h_{1ijt} = 1 \ \& \ m_{ijt+1} = 1 \\ 0, & \text{otherwise.} \end{cases} \quad (\text{A.11})$$

New hires to full quarter status (a_3): for $qfirst + 4 < t < qlast$, individual i transited from consecutive-quarter hired to full-quarter hired status at j during period t (hired in $t - 1$ and full-quarter employed in t)

$$h_{3ijt} = \begin{cases} 1, & \text{if } h_{2ijt-1} = 1 \ \& \ m_{ijt+1} = 1 \\ 0, & \text{otherwise.} \end{cases} \quad (\text{A.12})$$

Recalls to consecutive quarter status (r_2): for $qfirst + 3 < t < qlast$, individual i transited from recalled to consecutive-quarter recalled status at j at the end of t and beginning of $t + 1$ (recalled in t and still employed at the end of the quarter)

$$r_{2ijt} = \begin{cases} 1, & \text{if } r_{1ijt} = 1 \ \& \ m_{ijt+1} = 1 \\ 0, & \text{otherwise.} \end{cases} \quad (\text{A.13})$$

Recalls to full quarter status (r_3): for $qfirst + 4 < t < qlast$, individual i transited from consecutive-quarter recalled to full-quarter recalled status at j during period t (recalled in $t - 1$ and full-quarter employed in t)

$$r_{3ijt} = \begin{cases} 1, & \text{if } r_{2ijt-1} = 1 \ \& \ m_{ijt+1} = 1 \\ 0, & \text{otherwise.} \end{cases} \quad (\text{A.14})$$

Separations from consecutive quarter status (s_2): for $qfirst < t < qlast$, individual i separated from j during t with consecutive-quarter status at the start of t

$$s_{2ijt} = \begin{cases} 1, & \text{if } s_{1ijt} = 1 \ \& \ m_{ijt-1} = 1 \\ 0, & \text{otherwise.} \end{cases} \quad (\text{A.15})$$

Separations from full-quarter status (s_3): for $qfirst + 1 < t < qlast$, individual i separated from j during t with full-quarter status during $t - 1$

$$s_{3ijt} = \begin{cases} 1, & \text{if } s_{2ijt} = 1 \ \& \ m_{ijt-2} = 1 \\ 0, & \text{otherwise.} \end{cases} \quad (\text{A.16})$$

Total earnings during the quarter (w_1): for $qfirst \leq t \leq qlast$, earnings of individual i at establishment j during period t

$$w_{1ijt} = \sum \text{all UI-covered earnings by } i \text{ at } j \text{ during } t \quad (\text{A.17})$$

Earnings of end-of-period employees (w_2): for $qfirst \leq t < qlast$, earnings of individual i at establishment j during period t

$$w_{2ijt} = \begin{cases} w_{1ijt}, & \text{if } e_{ijt} = 1 \\ \text{undefined,} & \text{otherwise} \end{cases} \quad (\text{A.18})$$

Earnings of full-quarter individual (w_3): for $qfirst < t < qlast$, earnings of individual i at establishment j during period t

$$w_{3ijt} = \begin{cases} w_{1ijt}, & \text{if } f_{ijt} = 1 \\ \text{undefined,} & \text{otherwise} \end{cases} \quad (\text{A.19})$$

Total earnings at all employers ($w_{1\bullet}$): for $qfirst \leq t \leq qlast$, total earnings of individual i during period t

$$w_{1i\bullet t} = \sum_{j \text{ employs } i \text{ during } t} w_{1ijt} \quad (\text{A.20})$$

Total earnings at all employers for of end-of-period employees ($w_{2\bullet}$): for $qfirst \leq t < qlast$, total earnings of individual i during period t

$$w_{2i\bullet t} = \begin{cases} w_{1i\bullet t}, & \text{if } e_{ijt} = 1 \\ \text{undefined,} & \text{otherwise} \end{cases} \quad (\text{A.21})$$

Total earnings at all employers of full-quarter employees ($w_{3\bullet}$): for $qfirst < t < qlast$, total earnings of individual i during period t

$$w_{3i\bullet t} = \begin{cases} w_{1i\bullet t}, & \text{if } f_{ijt} = 1 \\ \text{undefined,} & \text{otherwise} \end{cases} \quad (\text{A.22})$$

Change in total earnings at all employers ($\Delta w_{1\bullet}$): for $qfirst < t \leq qlast$, change in total earnings of individual i between periods $t - 1$ and t

$$\Delta w_{1i\bullet t} = w_{1i\bullet t} - w_{1i\bullet t-1} \quad (\text{A.23})$$

Earnings of accessions (wa_1): for $qfirst < t \leq qlast$, earnings of individual i at employer j during period t

$$wa_{1ijt} = \begin{cases} w_{1ijt}, & \text{if } a_{1ijt} = 1 \\ \text{undefined,} & \text{otherwise} \end{cases} \quad (\text{A.24})$$

Earnings of consecutive-quarter accessions (wa_2): for $qfirst < t < qlast$, earnings of individual i at employer j during period t

$$wa_{2ijt} = \begin{cases} w_{1ijt}, & \text{if } a_{2ijt} = 1 \\ \text{undefined,} & \text{otherwise} \end{cases} \quad (\text{A.25})$$

Earnings of full-quarter accessions (wa_3): for $qfirst + 1 < t < qlast$, earnings of individual i at employer j during period t

$$wa_{3ijt} = \begin{cases} w_{1ijt}, & \text{if } a_{3ijt} = 1 \\ \text{undefined,} & \text{otherwise} \end{cases} \quad (\text{A.26})$$

Earnings of full-quarter new hires (wh_3): for $qfirst + 4 < t < qlast$, earnings of individual i at employer j during period t

$$wh_{3ijt} = \begin{cases} w_{1ijt}, & \text{if } h_{3ijt} = 1 \\ \text{undefined,} & \text{otherwise} \end{cases} \quad (\text{A.27})$$

Total earnings change for accessions (Δwa_1): for $qfirst + 1 < t \leq qlast$, earnings change of individual i at employer j during period t

$$\Delta wa_{1ijt} = \begin{cases} \Delta w_{1i\bullet t}, & \text{if } a_{1ijt} = 1 \\ \text{undefined,} & \text{otherwise} \end{cases} \quad (\text{A.28})$$

Total earnings change for full-quarter accessions (Δwa_3): for $qfirst + 2 < t < qlast$, earnings change of individual i at employer j during period t

$$\Delta wa_{3ijt} = \begin{cases} \Delta w_{1i\bullet t}, & \text{if } a_{3ijt} = 1 \\ \text{undefined,} & \text{otherwise} \end{cases} \quad (\text{A.29})$$

Earnings of separations from establishment (ws_1): for $t < qlast$, earnings of individual i separated from j during t

$$ws_{1ijt} = \begin{cases} w_{1ijt}, & \text{if } s_{1ijt} = 1 \\ \text{undefined,} & \text{otherwise} \end{cases} \quad (\text{A.30})$$

Earnings of full-quarter separations (ws_3): for $qfirst + 1 < t < qlast$, individual i separated from j during $t + 1$ with full-quarter status during t

$$ws_{3ijt} = \begin{cases} w_{1ijt}, & \text{if } s_{3ijt+1} = 1 \\ \text{undefined,} & \text{otherwise} \end{cases} \quad (\text{A.31})$$

Total earnings change for separations (Δws_1): for $t < qlast$, earnings change in period $t + 1$ of individual i separated from j during t

$$\Delta ws_{1ijt} = \begin{cases} \Delta w_{1i\bullet t+1}, \text{if } s_{1ijt} = 1 \\ \text{undefined, otherwise} \end{cases} \quad (\text{A.32})$$

Total earnings change for full-quarter separations (Δws_3): for $t < qlast$, earnings change in period $t + 1$ of individual i full-quarter separated from j during t , last full-quarter employment was $t - 1$

$$\Delta ws_{3ijt} = \begin{cases} \Delta w_{1i\bullet t+1}, \text{if } s_{3ijt} = 1 \\ \text{undefined, otherwise} \end{cases} \quad (\text{A.33})$$

Periods of non-employment prior to an accession (na): for $qfirst + 3 < t$, periods of non-employment during the previous four quarters by i prior to an accession at establishment j during t

$$na_{ijt} = \begin{cases} \sum_{1 \leq s \leq 4} n_{it-s}, \text{if } a_{1ijt} = 1 \\ \text{undefined, otherwise} \end{cases} \quad (\text{A.34})$$

where $n_{it} = 1$, if $m_{ijt} = 0 \forall j$.

Periods of non-employment prior to a new hire (nh): for $qfirst + 3 < t$, periods of non-employment during the previous four quarters by i prior to a new hire at establishment j during t

$$nh_{ijt} = \begin{cases} \sum_{1 \leq s \leq 4} n_{it-s}, \text{if } h_{1ijt} = 1 \\ \text{undefined, otherwise} \end{cases} \quad (\text{A.35})$$

Periods of non-employment prior to a recall (nr): for $qfirst + 3 < t$, periods of non-employment during the previous four quarters by i prior to a recall at establishment j during t

$$nr_{ijt} = \begin{cases} \sum_{1 \leq s \leq 4} n_{it-s}, \text{if } r_{1ijt} = 1 \\ \text{undefined, otherwise} \end{cases} \quad (\text{A.36})$$

Periods of non-employment following a separation (ns): for $t < qlast - 3$, periods of non-employment during the next four quarters by individual i separated from establishment j during t

$$ns_{ijt} = \begin{cases} \sum_{1 \leq s \leq 4} n_{it+s}, \text{if } s_{1ijt} = 1 \\ \text{undefined, otherwise} \end{cases} \quad (\text{A.37})$$

A.2.3 Establishment concepts

For statistic x_{cijt} denote the sum over i during period t as $x_{c.jt}$. For example, beginning of period employment for firm j is written as:

$$b_{.jt} = \sum_i b_{ijt} \quad (\text{A.38})$$

All individual statistics generate establishment totals according to the formula above. The key establishment statistic is the average employment growth rate for establishment j , the components of which are defined here.

Beginning-of-period employment (number of jobs)

$$B_{jt} = b_{.jt} \quad (\text{A.39})$$

End-of-period employment (number of jobs)

$$E_{jt} = e_{.jt} \quad (\text{A.40})$$

Employment any time during the period (number of jobs)

$$M_{jt} = m_{.jt} \quad (\text{A.41})$$

Full-quarter employment

$$F_{jt} = f_{.jt} \quad (\text{A.42})$$

Net job flows (change in employment) for establishment j during period t

$$JF_{jt} = E_{jt} - B_{jt} \quad (\text{A.43})$$

Average employment for establishment j between periods $t - 1$ and t

$$\bar{E}_{jt} = \frac{(B_{jt} + E_{jt})}{2} \quad (\text{A.44})$$

Average employment growth rate for establishment j between periods $t - 1$ and t

$$G_{jt} = \frac{JF_{jt}}{\bar{E}_{jt}} \quad (\text{A.45})$$

Job creation for establishment j between periods $t - 1$ and t

$$JC_{jt} = \bar{E}_{jt} \max(0, G_{jt}) \quad (\text{A.46})$$

Average job creation rate for establishment j between periods $t - 1$ and t

$$JCR_{jt} = \frac{JC_{jt}}{\bar{E}_{jt}} \quad (\text{A.47})$$

Job destruction for establishment j between periods $t - 1$ and t

$$JD_{jt} = \bar{E}_{jt} \text{abs}(\min(0, G_{jt})) \quad (\text{A.48})$$

Average job destruction rate for establishment j between periods $t - 1$ and t

$$JDR_{jt} = \frac{JD_{jt}}{\bar{E}_{jt}} \quad (\text{A.49})$$

Net change in full-quarter employment for establishment j during period t

$$FJF_{jt} = F_{jt} - F_{jt-1} \quad (\text{A.50})$$

Average full-quarter employment for establishment j during period t

$$\bar{F}_{jt} = \frac{F_{jt-1} + F_{jt}}{2} \quad (\text{A.51})$$

Average full-quarter employment growth rate for establishment j between $t - 1$ and t

$$FG_{jt} = \frac{FJF_{jt}}{\bar{F}_{jt}} \quad (\text{A.52})$$

Full-quarter job creations for establishment j between $t - 1$ and t

$$FJC_{jt} = \bar{F}_{jt} \max(0, FG_{jt}) \quad (\text{A.53})$$

Average full-quarter job creation rate for establishment j between $t - 1$ and t

$$FJCR_{jt} = FJC_{jt} / \bar{E}_{jt} \quad (\text{A.54})$$

Full-quarter job destruction for establishment j between $t - 1$ and t

$$FJD_{jt} = \bar{E}_{jt} \text{abs}(\min(0, FG_{jt})) \quad (\text{A.55})$$

Average full-quarter job destruction rate for establishment j between $t - 1$ and t

$$FJDR_{jt} = FJD_{jt} / \bar{E}_{jt} \quad (\text{A.56})$$

Accessions for establishment j during t

$$A_{jt} = a_{1,jt} \quad (\text{A.57})$$

Average accession rate for establishment j during t

$$AR_{jt} = A_{jt} / \bar{E}_{jt} \quad (\text{A.58})$$

Separations for establishment j during t

$$S_{jt} = s_{1,jt} \quad (\text{A.59})$$

Average separation rate for establishment j during t

$$SR_{jt} = S_{jt} / \bar{E}_{jt} \quad (\text{A.60})$$

New hires for establishment j during t

$$H_{jt} = h_{1.jt} \quad (\text{A.61})$$

Full-quarter new hires for establishment j during t

$$H_{3jt} = h_{3.jt} \quad (\text{A.62})$$

Recalls for establishment j during t

$$R_{jt} = r_{1.jt} \quad (\text{A.63})$$

Flow into full-quarter employment for establishment j during t

$$FA_{jt} = a_{3.jt} \quad (\text{A.64})$$

New hires into full-quarter employment for establishment j during t

$$FH_{jt} = h_{3.jt} \quad (\text{A.65})$$

Average rate of flow into full-quarter employment for establishment j during t

$$FAR_{jt} = FA_{jt} / \bar{F}_{jt} \quad (\text{A.66})$$

Flow out of full-quarter employment for establishment j during t

$$FS_{jt} = s_{3.jt} \quad (\text{A.67})$$

Average rate of flow out of full-quarter employment for establishment j during t

$$FSR_{jt} = FS_{jt} / \bar{F}_{jt} \quad (\text{A.68})$$

Flow into consecutive quarter employment for establishment j during t

$$CA_{jt} = a_{2 \cdot jt} \quad (\text{A.69})$$

Flow out of consecutive quarter employment for establishment j during t

$$CS_{jt} = s_{2 \cdot jt} \quad (\text{A.70})$$

Total payroll of all employees

$$W_{1jt} = w_{1 \cdot jt} \quad (\text{A.71})$$

Total payroll of end-of-period employees

$$W_{2jt} = w_{2 \cdot jt} \quad (\text{A.72})$$

Total payroll of full-quarter employees

$$W_{3jt} = w_{3 \cdot jt} \quad (\text{A.73})$$

Total payroll of accessions

$$WA_{jt} = wa_{1 \cdot jt} \quad (\text{A.74})$$

Change in total earnings for accessions

$$\Delta WA_{jt} = \sum_{i \in \{J(i,t)=j\}} \Delta wa_{1ijt} \quad (\text{A.75})$$

Total payroll of transits to consecutive-quarter status

$$WCA_{jt} = wa_{2.jt} \quad (\text{A.76})$$

Total payroll of transits to full-quarter status

$$WFA_{jt} = wa_{3.jt} \quad (\text{A.77})$$

Total payroll of new hires to full-quarter status

$$WFH_{jt} = wh_{3.jt} \quad (\text{A.78})$$

Change in total earnings for transits to full-quarter status

$$\Delta WFA_{jt} = \sum_{i \in \{J(i,t)=j\}} \Delta wa_{3ijt} \quad (\text{A.79})$$

Total periods of non-employment for accessions

$$NA_{jt} = na.jt \quad (\text{A.80})$$

Total periods of non-employment for new hires (last four quarters)

$$NH_{jt} = nh.jt \quad (\text{A.81})$$

Total periods of non-employment for recalls (last four quarters)

$$NR_{jt} = nr_{.jt} \quad (\text{A.82})$$

Total earnings of separations

$$WS_{jt} = ws_{1.jt} \quad (\text{A.83})$$

Total change in total earnings for separations

$$\Delta WS_{jt} = \sum_{i \in \{J(i,t)=j\}} \Delta ws_{1ijt} \quad (\text{A.84})$$

Total earnings of separations from full-quarter status (most recent full quarter)

$$WFS_{jt} = ws_{3.jt} \quad (\text{A.85})$$

Total change in total earnings for full-quarter separations

$$\Delta WFS_{jt} = \sum_{i \in \{J(i,t)=j\}} \Delta ws_{3ijt} \quad (\text{A.86})$$

Total periods of non-employment for separations

$$NS_{jt} = ns_{.jt} \quad (\text{A.87})$$

Average earnings of end-of-period employees

$$ZW_{2jt} = W_{2jt} / E_{jt} \quad (\text{A.88})$$

Average earnings of full-quarter employees

$$ZW_{3jt} = W_{3jt} / F_{jt} \quad (\text{A.89})$$

Average earnings of accessions

$$ZWA_{jt} = WA_{jt} / A_{jt} \quad (\text{A.90})$$

Average change in total earnings for accessions

$$Z\Delta WA_{jt} = \Delta WA_{jt} / A_{jt} \quad (\text{A.91})$$

Average earnings of transits to full-quarter status

$$ZWFA_{jt} = WFA_{jt} / FA_{jt} \quad (\text{A.92})$$

Average earnings of new hires to full-quarter status

$$ZWFH_{jt} = WFH_{jt} / FH_{jt} \quad (\text{A.93})$$

Average change in total earnings for transits to full-quarter status

$$Z\Delta WFA_{jt} = \Delta WFA_{jt} / FA_{jt} \quad (\text{A.94})$$

Average periods of non-employment for accessions

$$ZNA_{jt} = NA_{jt} / A_{jt} \quad (\text{A.95})$$

Average periods of non-employment for new hires (last four quarters)

$$ZNH_{jt} = NH_{jt} / H_{jt} \quad (\text{A.96})$$

Average periods of non-employment for recalls (last four quarters)

$$ZNR_{jt} = NR_{jt} / R_{jt} \quad (\text{A.97})$$

Average earnings of separations

$$ZWS_{jt} = WS_{jt} / S_{jt} \quad (\text{A.98})$$

Average change in total earnings for separations

$$Z\Delta WS_{jt} = \Delta WS_{jt} / S_{jt} \quad (\text{A.99})$$

Average earnings of separations from full-quarter status (most recent full quarter)

$$ZWFS_{jt-1} = WFS_{jt-1} / FS_{jt} \quad (\text{A.100})$$

Average change in total earnings for full-quarter separations

$$Z\Delta WFS_{jt} = \Delta WFS_{jt} / FS_{jt} \quad (\text{A.101})$$

Average periods of non-employment for separations

$$ZNS_{jt} = NS_{jt} / S_{jt} \quad (\text{A.102})$$

End-of-period employment (number of workers) [Aggregate concept not related to a business]

$$N_t = n_t \quad (\text{A.103})$$

A.2.4 Identities

The identities stated below hold at the establishment level for every age group and sex subcategory.

These identities are preserved in the QWI processing.

Definition 1 Employment at beginning of period t equals end of period $t - 1$

$$B_{jt} = E_{jt-1}$$

Definition 2 Evolution of end of period employment

$$E_{jt} = B_{jt} + A_{jt} - S_{jt}$$

Definition 3 Evolution of average employment

$$\bar{E}_{jt} = B_{jt} + (A_{jt} - S_{jt})/2$$

Definition 4 Job flow identity

$$JF_{jt} = JC_{jt} - JD_{jt}$$

Definition 5 Creation-destruction identity

$$E_{jt} = B_{jt} + JC_{jt} - JD_{jt}$$

Definition 6 Creation-destruction/accession-separation identity

$$A_{jt} - S_{jt} = JC_{jt} - JD_{jt}$$

Definition 7 Evolution of full-quarter employment

$$F_{jt} = F_{jt-1} + FA_{jt} - FS_{jt}$$

Definition 8 Full-quarter creation-destruction identity

$$F_{jt} = F_{jt-1} + FJC_{jt} - FJD_{jt}$$

Definition 9 Full-quarter job flow identity

$$FJF_{jt} = FJC_{jt} - FJD_{jt}$$

Definition 10 Full-quarter creation-destruction/accession-separation identity

$$FA_{jt} - FS_{jt} = FJC_{jt} - FJD_{jt}$$

Definition 11 Employment growth rate identity

$$G_{jt} = JCR_{jt} - JDR_{jt}$$

Definition 12 Creation-destruction/accession-separation rate identity

$$JCR_{jt} - JDR_{jt} = AR_{jt} - SR_{jt}$$

Definition 13 Full quarter employment growth rate identity

$$FG_{jt} = FJCR_{jt} - FJDR_{jt}$$

Definition 14 Full quarter creation-destruction/accession-separation rate identity

$$FJCR_{jt} - FJDR_{jt} = FAR_{jt} - FSR_{jt}$$

Definition 15 Total payroll identity

$$W_{1jt} = W_{2jt} + WS_{jt}$$

Definition 16 Payroll identity for consecutive-quarter employees

$$W_{2jt} = W_{1jt} - WCA_{jt} - WS_{jt}$$

Definition 17 Full-quarter payroll identity

$$W_{3jt} = W_{2jt} - WCA_{jt}$$

Definition 18 New hires/recalls identity

$$A_{jt} = H_{jt} + R_{jt}$$

Definition 19 Periods of non-employment identity

$$NA_{jt} = NH_{jt} + NR_{jt}$$

Definition 20 Worker-jobs in period t are the sum of accessions and beginning of period employment.

$$M_{jt} = A_{jt} + B_{jt}$$

Definition 21 Worker-jobs in period t are the sum of accessions to consecutive quarter status, separations, and full quarter workers.

$$M_{jt} = CA_{jt} + S_{jt} + F_{jt}$$

Definition 22 Consecutive quarter accessions in period $t - 1$ are the sum of consecutive quarter separations in period t and full quarter accessions in period t

$$CA_{jt-1} - CS_{jt} = FA_{jt} - FS_{jt}$$

A.2.5 Aggregation of job flows

The aggregation of job flows is performed using growth rates to facilitate confidentiality protection.

The rate of growth JF for establishment j during period t is estimated by:

$$G_{jt} = \frac{JF_{jt}}{\bar{E}_{jt}} \tag{A.104}$$

For an arbitrary aggregate $k = (\text{ownership} \times \text{state} \times \text{substate-geography} \times \text{industry} \times \text{age group} \times \text{sex})$ cell, we have:

$$G_{kt} = \frac{\sum_{j \in \{K(j)=k\}} \bar{E}_{jt} \times G_{jt}}{\bar{E}_{kt}} \tag{A.105}$$

where the function $K(j)$ indicates the classification associated with firm j . We calculate the aggregate net job flow as

$$JF_{kt} = \sum_{j \in \{K(j)=k\}} JF_{jt}. \tag{A.106}$$

Substitution yields

$$JF_{kt} = \sum_j (\bar{E}_{jt} \times G_{jt}) = G_{kt} \times \bar{E}_{kt}, \quad (\text{A.107})$$

so the aggregate job flow, as computed, is equivalent to the aggregate growth rate times aggregate employment. Gross job creation/destruction aggregates are formed from the job creation and destruction rates by analogous formulas substituting JC or JD , as appropriate, for JF (Davis et al.; 1996, p. 189 for details).

A.2.6 Measurement of employment churning

The QWI measure employment churning (also called turnover) using the ratio formula:

$$FT_{kt} = \frac{(FA_{kt} + FS_{kt})/2}{F_{kt}} \quad (\text{A.108})$$

for an arbitrary aggregate $k = (\text{ownership} \times \text{state} \times \text{substate-geography} \times \text{industry} \times \text{age group} \times \text{sex})$ cell. In the actual production of the QWI, the three components of this ratio are computed as separate estimates and are released.

A.2.7 Disclosure control noise infusion factors

To implement the multiplicative noise model in Section 6, a random fuzz factor δ_j is drawn for each establishment j according to the following process:

$$p(\delta_j) = \begin{cases} (b - \delta)/(b - a)^2, & \delta \in [a, b] \\ (b + \delta - 2)/(b - a)^2, & \delta \in [2 - b, 2 - a] \\ 0, & \text{otherwise} \end{cases}$$

$$F(\delta_j) = \begin{cases} 0, & \delta < 2 - b \\ [(\delta + b - 2)^2] / [2(b - a)^2], & \delta \in [2 - b, 2 - a] \\ 0.5, & \delta \in (2 - a, a) \\ 0.5 + [(b - a)^2 - (b - \delta)^2] / [2(b - a)^2], & \delta \in [a, b] \\ 1, & \delta > b \end{cases}$$

where $a = 1 + c/100$ and $b = 1 + d/100$ are constants chosen such that the true value is distorted by a minimum of c percent and a maximum of d percent.²⁴ Note that $1 < a < b < 2$. This produces a random noise factor centered around 1 with distortion of at least c and at most d percent. A fuzz factor is drawn for each employer and for each of the establishments associated with that employer. Although fuzz factors vary across establishments of the same employer, the fuzz factors attached all establishments of the *same* employer are drawn from the same (upper or lower) tail of the fuzz factor distribution. Thus, if the fuzz factor associated with a particular employer (SEIN) is less than unity, then all that employer's establishments (SEINUNITS) will also have fuzz factors less than unity. It is also important to point out that a fuzz factor is attached to each SEIN and SEINUNIT only once and retained for all time periods after the initial assignment.

A.2.8 Applying the fuzz factors to estimates

Although all estimates are distorted based on the multiplicative noise model, the exact implementation depends on the type of estimate that is computed. For completeness we show all the relevant formulas in this appendix and refer the reader to Abowd et al. (2005) for details. In all cases, the micro data noise infusion occurs at the level of an establishment estimate. However, for QWI involving ratios and changes, the basic fuzzed and unfuzzed values are combined at the publication level of aggregation to produce the released estimates. In what follows, distorted values are distinguished from their undistorted counterparts by an asterisk, *i.e.*, the true (unfuzzed) value of

beginning-of-quarter employment is B , its noise-infused (fuzzed) counterpart is B^* .

Fuzzing of estimates of employment The fuzz factor δ_j is used to fuzz all estimates of employment totals by scaling of the true establishment level statistic according to the formula:

$$X_{jt}^* = \delta_j X_{jt}, \quad (\text{A.109})$$

where X_{jt} is an establishment level employment estimate: $B, E, M, F, A, S, H, R, FA, FS,$ and FH .

Fuzzing of averages of magnitude estimates where the denominator is an employment estimate Ratios of magnitude estimates to employment estimates are protected by using fuzzed numerators and unfuzzed denominators according the formula:

$$ZY_{jt}^* = \frac{Y_{jt}^*}{B(Y)_{jt}} = \delta_j \frac{Y_{jt}}{B(Y)_{jt}},$$

where ZY_{jt} is a ratio of a magnitude estimate, Y_{jt} , (dollars or quarters) and $B(Y_{jt})$ is an estimate of employment. The ratio has the interpretation of an average in most cases. The variables protected according to this method are: $ZW_2, ZW_3, ZWFH, ZWA, ZWS, ZNA, ZNH, ZNR,$ and ZNS . The relevant values of Y_{jt} and $B(Y_{jt})$ are shown in the establishment-level statistics above. In the actual QWI processing the numerator and denominator of these confidentiality-protected ratios are tabulated separately for each publication category (*ownership* × *state* × *substate-geography* × *industry* × *age group* × *sex*). Then, the publication ratio is computed when the public-use release files are created.

Fuzzing of differences of counts and magnitudes Fuzzed net job flow (JF) is computed at the aggregate level for $k = (\textit{ownership} \times \textit{state} \times \textit{substate-geography} \times \textit{industry} \times \textit{age group} \times \textit{sex})$ cell as the product of the aggregated, unfuzzed rate of growth of net jobs and the aggregated

fuzzed employment:

$$JF_{kt}^* = G_{kt} \times \bar{E}_{kt}^* = JF_{kt} \times \frac{\bar{E}_{kt}^*}{\bar{E}_{kt}}$$

This method of fuzzing net job flow will consistently estimate net job flow because it takes the product of two consistent estimators. The formulas for fuzzing gross job creation (JC) and job destruction (JD) are similar:

$$JC_{kt}^* = JCR_{kt} \times \bar{E}_{kt}^* = JC_{kt} \times \frac{\bar{E}_{kt}^*}{\bar{E}_{kt}}$$

and

$$JD_{kt}^* = JDR_{kt} \times \bar{E}_{kt}^* = JD_{kt} \times \frac{\bar{E}_{kt}^*}{\bar{E}_{kt}}$$

The same method was used to protect estimates of wage changes for different employment estimates. The unfuzzed estimated total changes were divided by the unfuzzed denominators then multiplied by the ratio of the fuzzed denominator to the unfuzzed denominator, as in the formula:

$$Z\Delta WY_{kt}^* = \frac{\Delta WY_{kt}}{Y_{kt}} \times \frac{Y_{kt}^*}{Y_{kt}}$$

where, again, Y denotes a particular employment, ΔWY denotes the estimated change in wages for that employment estimate and $Z\Delta WY^*$ is the confidentiality protected estimate of the ratio. This method is used for $Z\Delta WA$, $Z\Delta WS$, $Z\Delta WFA$, and $Z\Delta WFS$. The ratio FT involves three QWI that are also in the release file. In order to protect the ratio of the fuzzed to unfuzzed estimate of full-quarter employment, the release value of FT is protected by the formula:

$$FT_{kt}^* = \frac{(FA_{kt}^* + FS_{kt}^*) / 2}{F_{kt}} \frac{F_{kt}^*}{F_{kt}}$$

In the actual QWI processing the numerator and denominator of these confidentiality-protected changes and ratios are tabulated separately for each publication category (*ownership* × *state* × *substate-geography* × *industry* × *age group* × *sex*). Then, the publication change or ratio is computed when the public-use release files are created.