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Source: *Journal of Business & Economic Statistics*, Vol. 3, No. 3 (Jul., 1985), pp. 254-283
Published by: Taylor & Francis, Ltd. on behalf of American Statistical Association
Stable URL: https://www.jstor.org/stable/1391596

Journal of Business & Economic Statistics, July 1985, Vol. 3, No. 3

Estimating Gross Labor-Force Flows

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We present and apply an adjustment procedure for the Bureau of the Census and Bureau of Labor Statistics gross labor-force flows data that addresses two major defects in the data. First, an adjustment procedure is developed to take account of individuals with missing labor-force classifications who are not missing at random. Second, we provide a procedure for adjustment for individuals with spurious labor-force transitions arising because of classification errors in either the current or the previous Current Population Survey. Our procedures are applied to compute adjusted monthly gross change data for the period January 1977–December 1982. The average adjustment for nonrandom missing classifications ranges from −12% to 15% of the unadjusted gross change data. The average adjustment for spurious labor-force transitions reduces estimated movements by 8%–49%. The classification adjustment also increases estimated consecutive periods of unemployment by 18%. We apply several internal and external consistency checks to our procedure. In general, the adjustments appear reasonable. We also suggest some modifications of Current Population Survey procedures that could reduce the use of ex post adjustment procedures in the future.

KEY WORDS: Current Population Survey; Unemployment rate; Gross change data; Nonrandom missing data; Classification errors

1. INTRODUCTION

Two Presidential Commissions and many business and research professionals have recognized the importance of measuring the flow of persons among employed, unemployed, and not in the labor force. Every month since 1949 the Bureau of Census, under contract from the Bureau of Labor Statistics, has tabulated a variety of gross labor-force flow measures based on the information obtained from matching the responses of the common rotation groups in the current-month and the previous-month Current Population Surveys (CPS; see Table 1). These data are called the *gross flow* data. Publication of summary gross flow data was suspended in 1953. Although these tabulations have never been viewed as ideal, in 1962 the President's Committee to Appraise Employment and Unemployment Statistics recommended "that a program of research be initiated looking toward reducing the defects of the gross-change data, and that publication of the data be resumed as soon as possible" (p. 81). Once again, in 1979 the National Commission on Employment and Unemployment Statistics recommended "that the Census Bureau undertake research to reduce the defects of the gross flow data, with the goal of monthly publication" (p. 217). The Bureau of Labor Statistics (1982a) resumed publication of the unadjusted gross flows in March 1982.

There are two major problems with the unadjusted gross flow data derived from the CPS. First, because the flows are constructed by matching individuals who were surveyed in two consecutive months of the CPS, there is a substantial number that cannot be matched. About 7.5% of the previous month's individuals cannot be located in the current month's survey, and about 7.5% of the current month's individuals cannot be located in the previous month's. Consequently, for any particular month's gross flow table, about 15% of the eligible observations have the labor-force status missing for one month or the other. (These percentages do not include persons in the two rotation groups who are not common to consecutive monthly surveys.) The missing labor-force status of the individuals who cannot be matched introduces a bias in the gross flow measures if these individuals do not constitute a random sample of the relevant population. That this bias may be substantial is suggested by the observation that the marginal distributions of labor-force status constructed from each month's gross flow data (which should be consistent with the labor-force status proportions calculated from the full CPS) often differ substantially from the full CPS proportions. Rotation group bias, normal sampling variability, and the "composite estimator" used for official statistics may also contribute to this discrepancy.

Second, the measurement of changes in labor-force status may be biased because of random respondent, interviewer, or coding errors, even when these classification errors do not generate substantial bias in the measurement of the levels. The bias in the measurement of labor-force flows due to response errors arises because both the error and its subsequent correction in the form of correct classification at the next survey date are counted as labor-force transitions when there have not been any true transitions. Unpublished Census Bureau data suggest that errors for incorrectly classified unemployed individuals have averaged more than 10%. The classification errors for employment and not in the labor force appear to involve less than 1% of the relevant individuals.

In spite of the recurring recommendation that research be undertaken to improve the quality of the gross flow data, there have been relatively few methodological studies of adjustment procedures that might make the historical gross flow data suitable for publication. The principal exception to this pattern in the U.S. is the research program undertaken by the Urban Institute during the early 1970s, which is summarized in Holt et al. (1975). The subsequent uses of the Urban Institute's adjusted gross flow data are reported in Smith and Vanski (1979 and references therein). All of the research uses of the gross flow data that we have been able to trace since the early 1970s make use of the Urban Institute's adjusted data (e.g., Marston 1976 and Clark and Summers 1979, 1982). The only systematic description of the adjustment procedure is contained in Holt et al.'s report (1975, appendices). From this report, it appears that the adjustment procedure addresses the inconsistent margins problem but does not make use of any of the information in the partially observed cells. The misclassification problem does not appear to be handled.

Statistics Canada (1979) also has an ongoing research program designed to improve the quality of gross flow data calculated from the monthly Canadian Labour Force Survey. The Canadian procedure addresses both the missing classification and the response error problems; however, it makes use of the original survey data (rather than tabulated counts), so it would be difficult to apply to existing historical data (see Fienberg and Stasny 1982 for a description). The Statistics Canada procedures are similar to some of the adjustments discussed herein. However, they build the unadjusted gross flow table by using a complicated function of the original sampling weights, a controversial procedure (Fienberg and Stasny 1982). In addition, once the aggregated gross flow table is constructed, the Statistics Canada adjustments proceed without reference to the original data. They force marginal consistency at each point with published data at each point in time, and they adjust for misclassification bias before adjusting the margins. These are substantial departures from the methods described in this article.

A recent resurgence of interest in the adjustment of gross labor-force flow statistics has produced some procedures that are similar in spirit to the methods discussed in this article. Fuller and Chua (1984) discussed response error models for CPS gross flow data and use reinterview data to implement their adjustments. Poterba and Summers (1984) developed several models for response error correction based on different uses and interpretations of the reconciled and unreconciled reinterview survey data. Stasny and Fienberg (1984) developed both discrete and continuous time models of missing labor-force classification, which they applied to CPS gross change data, including the missing-classification cells.

In this article, we present an adjustment procedure that (a) addresses the missing-classification problem without assuming that the missing labor-force status information is missing at random and (b) adjusts the resulting flow estimates for classification error. Our method has several reasonable features. First, it makes use of the information contained in the partially classified observations. Second, it uses summary data in a manner that permits direct application to existing historical gross flow data. Finally, it is invertible provided certain information is disclosed; hence researchers may apply their own adjustment methods if our method seems inappropriate for a given application.

Section 2 provides a description of the gross flow data as they are collected by the Census Bureau and a discussion of the missing-data and classification-error problems. Section 3 explains our adjustment procedure. Section 4 presents the results of applying our adjustment procedure to monthly gross flow data for the civilian noninstitutional population age 16 and over for the period January 1977–December 1982. Section 5 presents diagnostic analysis of our procedures. Section 6 discusses alternatives to adjustment procedures that involve collecting additional information in the CPS. Section 7 presents our conclusions.

2. DESCRIPTION OF THE GROSS FLOW DATA AND SUPPLEMENTARY DATA SOURCES

The CPS consists of eight rotation groups of approximately equal size—6,000–7,000 households (see Bureau of the Census 1978). Each group is surveyed for four consecutive months, removed from the survey for eight consecutive months, and then surveyed for an additional four months. The gross flow data are constructed by matching survey responses from individuals in consecutive months. In the process of the match, two distinct files are created: identicals—individuals who have responses in both surveys—and nonidenticals—individuals who have responses in only the current or previous survey.

A maximum of 75% of all respondents are common to the two consecutive survey months. Individuals who are successfully matched are used to generate tables of employment status in the current month by employment status in the previous month. These tables are weighted by the current-month CPS weight. A variety of such tables are generated; we will use CPS gross change table 1 (see Bureau of Census 1977). In practice, about 7.5% of all weighted respondents in the current month who are eligible for matching (month in sample = 2, 3, 4, 6, 7, and 8) cannot be matched. An additional 7.5% of all weighted respondents in the previous month who are eligible for matching (month in sample = 1, 2, 3, 5, 6, and 7) cannot be matched. All individuals who cannot be matched are used to generate tables that show the employment status for the month in which the individual actually appears in the sample. These tables are weighted by the CPS weight for the month in which the individual actually appears in the sample. Once again, a variety of such tables are generated; we will use CPS gross change table 1B (Bureau of the Census 1977).

Table 1 shows the raw gross flow data for the civilian noninstitutional population age 16 and over in December 1982. The 3 × 3 block labeled Employed (E), Unemployed (U), and Not in LF (N) on both rows and columns is copied directly from CPS gross change table 1. This table is uninflated. Consequently, if there were no missing data, the weighted total from these nine cells would be approximately 75% of the current-month population. The row labeled Missing (M) shows the weighted count of individuals whose labor-force status is known in the current month but unknown in the previous month. These entries are taken from the current-month entries of the nonidenticals in CPS gross change table 1B. The column labeled M shows the weighted count of individuals whose labor-force status is known in the previous month but missing in the current month. These entries are taken from the previous-month entries of the nonidenticals in CPS gross change table 1B. Entries for both current- and previous-month nonidenticals appear in CPS gross change table 1B for December 1982. The column of Table 1 labeled CPS Total contains the November 1982 labor-force status estimates for the complete CPS. The row of Table 1 labeled CPS Total contains the December 1982 labor-force status estimates for the complete survey.

Table 1 illustrates the missing-data problem caused by the individuals who cannot be matched across months. For the All Persons section, the Total row is the column margin from the gross flow data, including individuals whose previous-month labor-force status is missing. The E, U, and N entries for the Total row are approximately 75% of the appropriate CPS row entry. Similarly, the Total column is the row margin from the gross flow data, including individuals whose current-month labor-force status is missing. The entries in the Total column are also approximately 75% of the appro-

Table 1. Example of Unadjusted Gross Labor-Force (LF) Flow Data, Current Population Survey (CPS) Data, and Unpublished Inflow/Outflow Data for December 1982 Civilian Noninstitutional Population Age 16 and Over (thousands of persons)

	Monthly CPS Gross Change Tables, Current-Month Status					Monthly Data	
Status Last Month	E	U	N	M	Total	CPS Outflow	CPS Total
All Persons							
Employed	66,578	1,958	1,735	4,857	75,128		99,379
Unemployed	1,398	5,178	1,447	766	8,789		11,476
Not in LF	1,392	1,285	41,024	2,675	46,376		62,203
Missing	4,754	866	2,784	0	8,404		
Total	74,122	9,287	46,990	8,298	138,697	219	173,058
CPS Inflow					360		
CPS Total	98,849	11,628	62,722		173,199		
Male							
Employed	37,452	963	675	2,726	41,816		55,707
Unemployed	808	3,267	563	441	5,079		6,660
Not in LF	494	525	12,744	858	14,621		19,519
Missing	2,637	540	871	0	4,048		
Total	41,391	5,295	14,853	4,025	65,564	32	81,886
CPS Inflow					198		
CPS Total	55,280	7,009	19,764		82,052		
Female							
Employed	29,127	495	1,060	2,132	32,814		43,672
Unemployed	590	1,911	884	325	3,710		4,816
Not in LF	897	760	28,280	1,817	31,754		42,684
Missing	2,118	326	1,912	0	4,356		
Total	32,732	3,492	32,136	4,274	72,634	192	91,172
CPS Inflow					167		
CPS Total	43,570	4,619	42,958		91,147		

NOTE: CPS data are from appropriate tables in Volume 1 (seasonally unadjusted). Monthly CPS gross change missing data are from table 1B (nonidenticals inflated) of the unpublished gross change estimates. Inflow and outflow data were estimated by the authors from unpublished population component estimates, military turnover data, and institutional population turnover data.

Source: Bureau of the Census 1977.

priate CPS column entry. The entry 173,058 is the CPS estimate of the November 1982 civilian noninstitutional population (in thousands), and the entry 173,199, the CPS estimate of the December 1982 civilian noninstitutional population (in thousands). Net population growth between November and December 1982 is estimated at 141,000 individuals. This equals the difference between inflow of 360,000 and outflow of 219,000. If all of the missing classifications arose from legitimate movement into and out of the civilian noninstitutional population, then the gross inflow to the population would be estimated as 8,404,000. Similarly, the gross outflow from the civilian noninstitutional population would be estimated as 8,298,000. Clearly, most of the missing classifications must be the result of transitions into and out of the CPS sample, and not the population. Since the CPS ultimate sampling units are physical residences and not households, movement of families from domicile to domicile as well as movement of individuals from household to household can cause missing employment status classifications. If the employment status changes of individuals who move into and out of the CPS sample differ from the employment status changes of individuals who remain in the sample, systematic exclusion of the partially classified individuals will result in biased estimates of the gross flows.

In addition to the basic CPS, a subsample of the CPS households are reinterviewed each month. The labor-force status of each individual as of the CPS survey week is determined from the reinterview survey. Discrepancies between the reinterview labor-force status and the original interview status are resolved for 80% of the reinterview respondents by the use of additional respondent information. These reinterview surveys are used to estimate the classification error rate in labor-force status. It is important to note that the type of classification error measured is relative to the standard Census Bureau definitions of employment status. The reinterview survey measures interviewer errors, coding errors, and changes in the respondents' answers. In principle a respondent household that answers the CPS employment status questions and the reinterview employment status questions identically should have the same labor-force status determined by either survey. Errors in determining labor-force status that are due to respondent misinformation or survey ambiguity will not, in principle, be captured by the reinterview process.

The problem that classification errors present for gross flow estimation depends on the extent to which such errors are serially correlated. If the classification errors were perfectly, positively correlated, then the same classification error would be made in each period. Under these conditions, there would be no bias in the estimated gross flows arising from spurious changes in classification. With perfect correlation, the classification errors only affect the reported levels of employment, unemployment, and nonparticipation. If the classification errors were serially independent, then they would tend to increase the number of reported changes and decrease the number of reported continuations of the previous state. In general, this means that the observed proportions moving between states would be overestimates of true proportions.

In the next section, we present a method for adjusting the gross flow data that allows for missing data that are not missing at random and for serially independent classification errors. To implement our procedure, we need gross change data and some supplemental data. We used data from CPS gross change table 1 (identicals uninflated) to estimate the unadjusted flows of persons between labor-force states—employed, unemployed, and not in the labor force—and data from CPS gross change table 1B (nonidenticals uninflated) to estimate the unadjusted flows of persons between the labor-force states and missing. Published CPS estimates of total employed, unemployed, and not in the labor force persons were employed to estimate the current- and previous-month population employment status proportions. Monthly data cover the period December 1976–December 1982. All CPS and Census Bureau data, including unpublished data, are based on the revised 1980 Census time series except for the unadjusted gross flows (see Bureau of Labor Statistics 1982b), which are not available on a 1980 Census basis. All data are seasonally unadjusted and disaggregated by sex.

We constructed an estimate of the population inflow and outflow for each month. The components of the population inflow are (a) individuals who become age 16 during the month, (b) net immigration, (c) individuals who return to the civilian population from the military, and (d) individuals who return to the noninstitutional population from institutions. Components (a) and (b) of population inflow were provided by the Census Bureau from unpublished tables. We estimated components (c) and (d), using published population components, nonconfidential military turnover data, and institutional population turnover data. The components of population outflow are (a) deaths, (b) individuals who enter the military, and (c) individuals who enter institutions. Component (a) of population outflow was provided by the Census Bureau from unpublished data. There are apparently no reliable estimates of gross immigration and emigration. We included the net immigration in population inflow. We estimated components (b) and (c) of population outflow, using published population components, nonconfidential military turnover data, and institutional turnover data.

To estimate the classification error model, we used reinterview data constructed in the following manner. For each quarter from 1976:1 to 1982:4, all responses from reinterview surveys conducted during the months covered by the quarter were aggregated. (Reinterview data are not available for some months within some quarters.) Only reconciled reinterviews were used. We considered the original interview report from the CPS to be the reported labor-force state. We considered the final labor state after reconciliation to be the true state. (Poterba and Summers 1984 considered alternatives to this definition.) Our recommendations include some new procedures that can improve the usefulness of the reinterview data for estimating classification error rates. The procedure adopted here is a reasonable compromise between assuming temporal constancy in the error rates and using monthly data with considerable sampling variability. All data are seasonally unadjusted and disaggregated by sex. (All unadjusted data, unpublished supplementary data, and adjusted data are available from the authors on request. Month-by-month summaries of the unadjusted and adjusted gross labor-force flows are contained in an addendum to this article, which is available on request from the authors.)

3. MODELS FOR GROSS FLOW ADJUSTMENT

In this section, we describe our method for adjusting the gross flow data when missing classifications are not missing at random (Rubin 1976) and classification errors are independent from period to period. Our method assumes that for each month, the raw gross flows, population employment status margins, population inflow, population outflow, and classification error rates are observed. We model the relationship between the unobserved adjusted gross flows and the observables, allowing for missing classifications resulting from movement into and out of the CPS sample. We estimate the unknown parameters of our adjustment model, assuming parameter stationarity over the sample period. Our estimation objective is to minimize the weighted squared deviation of the adjusted gross flow margins from the observed population margins. We call this procedure the *margin error adjustment.* We use the estimated parameters to calculate margin-adjusted gross flows for the period January 1977–December 1982. Next, we use data from the quarterly reinterview survey to estimate classification error rates. We call this procedure the *classification error adjustment.* Estimated classification error rates are used to calculate classification- and margin-adjusted gross flows for the period January 1977–December 1982.

To facilitate the discussion of our procedures, we define the following symbols for the various employment states:

E employed (standard Census definition)
U unemployed (standard Census definition)
N not in the labor force (standard Census definition)
A inflow of population between months, when used as a row index
outflow of population between months, when used as a column index
M missing employment status

We define the following symbols for the various data constructs:

$n_{ij}(t)$ unadjusted count of individuals in labor-force state i at date $t-1$ and in labor-force state j at date t, from CPS gross change table 1 (uninflated), where $i, j =$ E, U, N (using period t weights)
$n_{i\mathrm{M}}(t)$ unadjusted count of individuals in labor-force state i at date $t-1$ and missing labor-force state at date t, from CPS gross change table 1B (uninflated), where $i =$ E, U, N (using period $t-1$ weights)
$n_{\mathrm{M}j}(t)$ unadjusted count of individuals with missing labor-force state at date $t-1$ and in labor-force state j at date t, from CPS gross change table 1B (uninflated), where $j =$ E, U, N (using period t weights)
$z_{ij}(t)$ unadjusted proportion of gross flows between states i and j, where $i, j =$ E, U, N, M $[= n_{ij}(t)/n_{++}(t)]$
$\pi_{ij}(t)$ margin-adjusted proportion of gross flows between states i and j, where $i, j =$ E, U, N, A
$\beta_{i|j}(t)$ proportion of individuals whose true labor-force state in period t is j but who have been classified as state i, where $i, j =$ E, U, N, A
$\mu_{ij}(t)$ classification- and margin-adjusted proportion of total population, including inflow and outflow in state i in period $t-1$ to state j in period t, where $i, j =$ E, U, N, A
$x_{i+}(t)$ CPS estimate of the proportion of individuals in labor-force state i at date $t-1$ as a proportion of the civilian noninstitutional population at date t (including outflow), where $i =$ E, U, N, A
$x_{+j}(t)$ CPS estimate of the proportion of individuals in labor-force state j at date t as a proportion of the civilian noninstitutional population at date t (including outflow), where $j =$ E, U, N, A

A subscript + denotes a margin over the dimension subscripted. We describe our margin-adjustment procedure in Section 3.1. Then we describe the classification-adjustment procedure in Section 3.2.

3.1 The Multiplicative Model for Gross Flow Margin Adjustment

Our margin-adjustment procedure is most easily described by considering the natural logarithm of each margin-adjusted proportion as a function of the natural logarithm of the corresponding unadjusted proportion and the natural logarithms of the proportions in the cells that are only partially classified. The equations relating the margin-adjusted to the unadjusted proportions are as follows:

$$\ln \pi_{ij}(t) = \ln z_{ij}(t) + \theta_{ij|i\mathrm{M}} \ln z_{i\mathrm{M}}(t) + \theta_{ij|\mathrm{M}j} \ln z_{\mathrm{M}j}(t) - \ln \Delta(t) \quad (1)$$

$$\ln \pi_{iA}(t) = (1 - \theta_{iE|iM} - \theta_{iU|iM} - \theta_{iN|iM}) \times \ln z_{iM}(t) - \ln \Delta(t) \quad (2)$$

$$\ln \pi_{Aj}(t) = (1 - \theta_{Ej|Mj} - \theta_{Uj|Mj} - \theta_{Nj|Mj}) \times \ln z_{Mj}(t) - \ln \Delta(t) \quad (3)$$

for $i, j = \text{E, U, N}$. The function $\Delta(t)$ depends on all θ's and $z_{ij}(t)$'s; it is constructed so that the adjusted proportions sum to 1. Equation (1) is interpreted as an allocation of $\ln z_{iM}(t)$ and $\ln z_{Mj}(t)$ to $\ln \pi_{ij}(t)$. Equation (2) is interpreted as allocating to $\ln \pi_{iA}(t)$ the unallocated portion of $\ln z_{iM}(t)$. Equation (3) is interpreted as allocating to $\ln \pi_{Aj}(t)$ the unallocated portion of $\ln z_{Mj}(t)$. The parameters $\theta_{ij|iM}$ and $\theta_{ij|Mj}$ have unknown values and must be estimated from the data. The parameters $\theta_{ij|iM}$ may be interpreted as the allocations from $\ln z_{iM}(t)$ to $\ln \pi_{ij}(t)$. Similarly, the parameters $\theta_{ij|Mj}$ may be interpreted as the allocation from $\ln z_{Mj}(t)$ to $\ln \pi_{ij}(t)$.

Before describing the method for estimating the allocation parameters in (1)–(3), we will discuss the use of the multiplicative method instead of more conventional additive methods for making the allocations. In an additive model, allocation parameters are used to allocate directly from z_{iM} and z_{Mj} to π_{ij}. The most common method of margin adjusting the gross flow data is to apply the unadjusted proportions $z_{ij}(t)$ to an estimate of the population that excludes inflows (in t) or outflows (in $t - 1$). This is equivalent to a missing-at-random model in which the information in the partially classified observations is ignored. In all of our discussions and comparisons, we refer to the gross flow estimates produced by this procedure as "unadjusted." *Unadjusted gross flows, then, are equivalent to estimates generated by a missing-at-random model for the partially classified observations.* In either an additive or multiplicative framework, the missing-at-random procedure is time stationary (allocation parameters do not vary over time) and parameter free (all allocation parameters are equal to 0). For multiplicative and additive adjustment procedures that are not missing at random, one must specify and estimate allocation parameters.

The choice of functional form for the allocation scheme (additive, multiplicative, or other) is difficult. There are few external consistency checks that can be applied (see Sec. 5 for more about this). We chose the multiplicative, time-stationary form based on internal consistency checks as compared with additive time-stationary and nonstationary models. For U.S. data there are no estimates of the labor-force status of population inflows and outflows. Hence any allocation process that is not missing at random—including, and in particular, conditional missing-at-random models (Rubin 1976) whether or not they are time stationary—must also produce estimates of the labor-force status of population inflows and outflows. Additive time-stationary allocation models have consistently produced negative estimates of these components in our past calculations. This is a failure of an internal consistency check that we find compelling. Additive nonstationary allocation models require a window of stationarity to estimate the labor-force status of the inflows and outflows. For all of the windows we tried (4 months to 5 years), the additive nonstationary models produced negative estimates of some inflow and outflow labor-force status components. Again, we find this lack of internal consistency a compelling reason for rejecting additive models. The absence of labor-force status estimates of the inflow and outflow components also presents difficulties for other nonadditive procedures (e.g., Statistics Canada 1979, Fienberg and Stasny 1982, and Stasny 1983). The multiplicative allocation model that we propose for the margin-adjustment part of our procedure has always produced well-behaved estimates of the labor-force status of population inflows and outflows in our calculations. This internal consistency is the basis for discussing only multiplicative allocation schemes. Issues of time stationarity and external consistency are discussed in Section 5.

The expressions for the multiplicative adjusted proportions as functions of the unadjusted proportions are given by

$$\pi_{ij}(t) = \frac{z_{ij}(t) z_{iM}(t)^{\theta_{ij|iM}} z_{Mj}(t)^{\theta_{ij|Mj}}}{\Delta(t)} \quad (4)$$

$$\pi_{iA}(t) = \frac{z_{iM}(t)^{(1-\theta_{iE|iM}-\theta_{iU|iM}-\theta_{iN|iM})}}{\Delta(t)} \quad (5)$$

$$\pi_{Aj}(t) = \frac{z_{Mj}(t)^{(1-\theta_{Ej|Mj}-\theta_{Uj|Mj}-\theta_{Nj|Mj})}}{\Delta(t)}. \quad (6)$$

Since the denominator function $\Delta(t)$ is constructed so that the proportions (the π's) sum to 1, our adjustment model has 18 unrestricted θ parameters. It is important to note that although we assume that the θ's are constant over an estimation period, this is not equivalent to assuming that the monthly adjustments are constant. Our procedure allows the monthly adjustments to vary. In general, we expect $\pi_{iA}(t) < z_{iM}(t)$ and $\pi_{Aj}(t) < z_{Mj}(t)$, since most of the missing data arise from management into and out of the sample, but not the population. This requires that $(1 - \theta_{iE|iM} - \theta_{iU|iM} - \theta_{iN|iM}) > 1$ and $(1 - \theta_{Ej|Mj} - \theta_{Uj|Mj} - \theta_{Nj|Mj}) > 1$. In general, the θ's must be negative, although a few may be positive without causing problems with the adjustment of the inflow and outflow proportions.

The adjustment parameters may be interpreted by considering several interesting special cases. First, when all θ's are 0, the model reduces to missing at random. That is, when the partially classified cases are missing at random, each adjusted proportion $\pi_{ij}(t)$ equals the unadjusted proportion $z_{ij}(t)$ for all i and j. A second interesting case can be illustrated by considering the ratio of any two adjusted proportions in the same row or column:

$$\frac{\pi_{ij}(t)}{\pi_{ik}(t)} = \frac{z_{ij}(t) z_{iM}(t)^{\theta_{ij|iM}} z_{Mj}(t)^{\theta_{ij|Mj}}}{z_{ik}(t) z_{iM}(t)^{\theta_{ik|iM}} z_{Mk}(t)^{\theta_{ik|Mk}}}. \tag{7}$$

If $\theta_{ij|Mj} = \theta_{ik|Mk} = 0$, then (7) reduces to

$$\frac{\pi_{ij}(t)}{\pi_{ik}(t)} = \frac{z_{ij}(t)}{z_{ik}(t)} z_{iM}(t)^{\alpha_{jk|iM}}, \tag{8}$$

where $\alpha_{jk|iM} = (\theta_{ij|iM} - \theta_{ik|iM})$. When $\alpha_{jk|iM}$ is positive, relatively more of $z_{iM}(t)$ is allocated to $\pi_{ik}(t)$ than would be allocated using the missing-at-random model ($\alpha_{jk|iM} = 0$). Alternatively, when $\alpha_{jk|iM}$ is negative, relatively more of $z_{iM}(t)$ is allocated to $\pi_{ij}(t)$ than would be allocated using the missing-at-random model. The special case in (8), then, represents a simple multiplicative adjustment to the missing-at-random allocation. A third interesting case occurs if in (7), $\theta_{ij|Mj} = \theta_{ik|Mk}$ and $\theta_{ij|iM} = \theta_{ik|iM}$; then the expression reduces to

$$\frac{\pi_{ij}(t)}{\pi_{ik}(t)} = \frac{z_{ij}(t)}{z_{ik}(t)} \left[\frac{z_{Mj}(t)}{z_{Mk}(t)}\right]^{\beta_{jk}}, \tag{9}$$

where $\beta_{jk} = \theta_{ij|Mj} = \theta_{ik|Mk}$. In the special case represented by (9), the relative deviation of the adjustment away from missing at random depends on the interaction of the conditions $z_{Mj}(t)/z_{Mk}(t) \lesseqgtr 1$ and $\beta_{jk} \lesseqgtr 0$. When $z_{Mj}(t)/z_{Mk}(t) > 1$, the proportion of individuals initially missing who appear in state j exceeds that of those who appear in state k. In this case, if β_{jk} is positive, the multiplicative model allocation to $\pi_{ij}(t)$ exceeds the allocation of $\pi_{ik}(t)$ relative to the allocation from the missing-at-random model. The multiplicative model, under this data and parameter configuration, allocates more of the missing observations to $\pi_{ij}(t)$ than would be allocated with the missing-at-random model. When $z_{Mj}(t)/z_{Mk}(t) > 0$ and β_{jk} is negative, the reverse is true. *The special case represented by (9) is the multiplicative equivalent of conditional missing-at-random models.* Allocations only depend on the state that is observed, and not on the state that is unobserved. That is, the same allocation parameter is used to allocate to the cells π_{iE}, π_{iU}, and π_{iN} from the cell z_{iM} for all i and to the cells π_{Ej}, π_{Uj} and, π_{Nj} from the cell z_{Mj} for all j. We refer to the restricted model of (9) as the *conditional missing-at-random model.* It imposes 12 linear restrictions on the 18 free parameters. These restrictions form the basis of our test for the appropriateness of the conditional missing-at-random model.

In general, (7) allows a very flexible set of potential adjustments, including missing at random, conditional missing at random, and other interesting special cases. Equation (7), however, does not give us any guidance concerning the appropriate set of θ's for the gross flow data. To choose an appropriate set of θ's, we must specify an objective. In the case of the gross flow data, a natural objective is suggested by the existence of full CPS estimates of the employment status proportions at a point in time. As Table 1 makes clear, once individuals in the missing cells have been allocated, the margins from the gross flow proportions should agree with the employment status proportions estimated from the full CPS. Since the gross flow data use only the common CPS rotation groups, there is some scope for discrepancy between the marginal proportions of the gross flow data and the CPS employment proportions. Nevertheless, the gross flow marginal employment status proportions and the CPS employment status proportions do estimate the same quantities from common data. Therefore, a reasonable adjustment procedure ought to allocate those individuals with missing classifications to gross flow cells to minimize the discrepancy between the two measures of employment status proportions at a point in time. We adopt this as our estimation criterion and hence the name *margin adjustment* for this part of our procedure.

To estimate the adjustment parameters, we construct a six-equation nonlinear system. In each equation the dependent variable is the CPS estimate of the employment status proportion. Three of the proportions [$x_{i+}(t)$, i = E, U, N] correspond to the previous-month employment states. The other three proportions [$x_{+j}(t)$, j = E, U, N] correspond to the current-month employment states. The excluded category for the previous month is inflow (i = A). The excluded category for the current month is outflow (j = A). Each CPS proportion is set equal to its marginal counterpart from the adjusted gross flow table plus an error term. A typical equation for the previous month's margin is given by

$$x_{i+}(t) = \pi_{iE}(t) + \pi_{iU}(t) + \pi_{iN}(t) + \pi_{iA}(t) + u_{i+}(t) \tag{10}$$

for i = E, U, and N, with the π's as given in (4)–(6). A typical equation for the current month's margin is given by

$$x_{+j}(t) = \pi_{Ej}(t) + \pi_{Uj}(t) + \pi_{Nj}(t) + \pi_{Aj}(t) + u_{+j}(t) \tag{11}$$

for j = E, U, and N, with the π's as given in (4)–(6). Writing (10) and (11) for the six unconstrained margins creates a system with a vector of error terms, $u(t)' = [u_{E+}(t), u_{U+}(t), u_{N+}(t), u_{+E}(t), u_{+U}(t), u_{+N}(t)]$. We assume that $u(t)$ has the following statistical properties:

$$E[u(t)] = 0,$$

$$E[u(t)u(t)'] = \Omega$$

(where Ω is a 6×6 pds matrix), and

$$E[u(t)u(s)'] = 0$$

(for $t \neq s$). Under these assumptions, the system of six equations defined by substituting (4), (5), and (6) into (10) and (11) is a nonlinear seemingly unrelated regression (NSUR) model. It is important to note that the equations in the estimating system do not have additive constants. The model, therefore, does not automatically fit the average CPS margins. Values of the adjustment parameters must be chosen to make the model fit the data well. We estimate the adjustment parameters by minimizing the NSUR criterion,

$$\sum_{t=1}^{T} u(t)'\Omega^{-1}u(t).$$

This criterion involves minimization of the deviations of the CPS margins from the unadjusted gross flow margins in the metric of Ω. See the Appendix for a detailed algebraic analysis of the margin-adjustment procedure.

3.2 Adjusting for Independent Classification Error

We illustrated in Section 2 the error arising from independent classification errors in the labor status. In this section, we provide a statistical model for adjusting the gross flows to correct for classification error. Since the types of classification error we are modeling are interviewer error, coding error, and respondent changes in answers, we assume independent classification errors. This permits the direct use of CPS reinterview data for the adjustment. Fuller and Chua (1983) suggested a similar procedure that uses information from the reinterview data and the individual CPS data from two consecutive months. In the Fuller and Chua procedure, the observed labor-force state is known for both the current and previous months. The unreconciled reinterview state is known for either the current or the previous month. They measure error classification rates conditional on the pair of observed states given the single reinterview state. Although this procedure uses additional information, an ideal procedure requires periodic reinterview surveys with the same individuals reinterviewed in the current and previous months. (We discuss this issue in greater detail in Sec. 6.)

Our statistical model for the effect of classification error is based on the formula for the expected observed gross flow proportions (margin adjusted) as a function of the true gross flow proportions and the error classification probabilities:

$$E[\pi_{ij}(t)] = \sum_{k}\sum_{l} \phi_{ij|kl}(t)\mu_{kl}(t) \qquad k,l = \mathrm{E,U,N,A}, \quad (12)$$

where $\phi_{ij|kl}(t)$ is the conditional probability of being observed in i, j when the true $t-1$ to t labor-force status is k, l. With independent classification errors, the conditional error probablity $\phi_{ij|kl}$ simplifies to

$$\phi_{ij|kl}(t) = \beta_{i|k}(t-1)\beta_{j|l}(t) \qquad i,j,k,l = \mathrm{E,U,N,A}, \quad (13)$$

where $\beta_{i|k}(t)$ is the probability of observing i when the correct labor-force status is k. The probability $\beta_{i|k}(t)$ is the error classification rate estimated by the CPS reinterview procedure. Our classification error adjustment solves (12) for $\mu_{kl}(t)$ as a function of the margin-adjusted $\pi_{ij}(t)$ and the classification error rates $\beta_{i|k}(t-1)$ and $\beta_{j|l}(t)$:

$$\mathrm{vec}[\mathrm{M}(t)] = [B(t-1) \otimes B(t)]^{-1}\mathrm{vec}[\Pi(t)], \quad (14)$$

where $\mathrm{M}(t) = \{\mu_{ij}(t)\}$, $B(t) = \{\beta_{i|j}(t)\}$, $\Pi(t) = \{\pi_{ij}(t)\}$.

To apply the classification error adjustment, we need an estimate of $\beta_{i|k}(t)$ for each month from December 1976 to December 1982. Although the reinterview survey is conducted monthly, we use the quarterly aggregated reinterview data. These quarterly aggregated interview–reinterview data are available from the Census Bureau in unpublished tables (monthly tables are not available). The quarterly tables refer to the reconciled reinterview sample (see Bureau of the Census 1978). The assumption that the reconciled reinterview state is correct allows calculation of a time series of estimates of $\beta_{i|k}(t)$. These estimates permit solution of Equation (14) month by month. Since the CPS reinterview survey does not measure classification error rates for population inflows and outflows, and since these are a relatively small proportion of the total, we have assumed that the monthly classification error rates for inflows and outflows are 0. The Census Bureau instituted the reinterview program to detect poor interviewer performance. Since we are using these data for a different purpose, the possibility exists that better estimates of the error classification rates could be developed by redesigning the reinterview procedure (discussed in Sec. 6).

4. RESULTS OF THE GROSS FLOW ADJUSTMENT PROCEDURES

To apply the margin-adjustment procedure described in Section 3.1, we must estimate the unknown allocation parameters, the θ's. We can then solve (4)–(6) for the margin-adjusted gross labor-force flow proportions. To apply the classification-adjustment procedure described in Section 3.2, we must estimate the classification error rates $\beta(\mathrm{t})$. We can then solve (14) for the classification- and margin-adjusted gross flow proportions. Multiplying the estimated gross flow proportions by the current civilian noninstitutional population (plus outflow) provides our estimate of the gross labor-force flows for the model, including population inflows and outflows. Conditioning the unadjusted, margin-adjusted, and margin and classification error adjusted gross flow proportions on current and previous labor-force states of employed, unemployed, or not in the labor force provides our estimate of the flow proportions applicable to the population common to the consecutive months. Multiplying the estimated conditional gross flow proportions by the current civilian noninstitutional population (less inflow) provides our estimate of the gross labor-force flows for the model, excluding population inflows and outflows. In this section, we discuss the results of each of these estimation and conditioning steps.

We begin by discussing the estimation results for our missing-data model. The NSUR system developed in Section 3.1 was estimated separately for the total, male, and female samples. Our margin-adjustment procedure is based on these parameter estimates. Table 2 contains the estimated allocation parameters for the total, male, and female civilian noninstitutional populations. Each row of Table 2 contains the estimates for one of the 18 free allocation parameters; each column contains the estimates for one of the population groups. For each sample, the estimated allocation parameters are predominantly negative. Predominantly negative parameter estimates are required for a sensible multiplicative adjustment model if most of the missing employment status data result from movement into and out of the CPS sample, but not into and out of the civilian noninstitutional population. For each sample, the implied allocation parameters for the allocation from the missing-data cells to the inflow and outflow cells are greater than 1. This means that all estimates of the labor-force status of inflow and outflow proportions are positive and less than the corresponding missing-classification proportion.

For the total sample, the negative allocation parameter estimates range from −.033 to −.504. Most of the negative allocation parameter estimates are substantially more than twice their standard errors regardless of the method used to compute the standard errors. There are five positive allocation parameters, ranging between .004 and .059. None is quantitatively or statistically important. We could have made all five of the positive parameter estimates zero without affecting any of the subsequent results in any way. We chose not to do so for two reasons. First, the theoretical model does not require all allocation parameters to be negative. Second, the pattern of small positive allocation parameter estimates does not correspond to any of the interpretable special cases discussed in Section 3.

For the male sample, the negative allocation parameter estimates range from −.039 to −.635. Most are

Table 2. Estimated Multiplicative Adjustment Coefficients for Total, Male, and Female Civilian Noninstitutional Population Age 16 and Over Estimated Over the Period January 1977–December 1982

Allocation Parameter	Total	Male	Female
Employed–Employed from Employed–Missing, θ for EE | EM	−.242 (.035)	−.285 (.045)	−.288 (.038)
Employed–Unemployed from Employed–Missing, θ for EU | EM	−.478 (.100)	−.635 (.030)	−.462 (.086)
Employed–Not in LF from Employed–Missing, θ for EN | EM	−.457 (.066)	−.537 (.069)	−.232 (.089)
Unemployed–Employed from Unemployed–Missing, θ for UE | UM	.004 (.050)	.039 (.016)	−.048 (.063)
Unemployed–Unemployed from Unemployed–Missing, θ for UU | UM	−.208 (.021)	−.170 (.013)	−.161 (.026)
Unemployed–Not in LF from Unemployed–Missing, θ for UN | UM	.059 (.048)	.001 (.032)	.069 (.056)
Not in LF–Employed from Not in LF–Missing, θ for NE | NM	−.213 (.055)	−.188 (.049)	−.081 (.069)
Not in LF–Unemployed from Not in LF–Missing, θ for NU | NM	−.491 (.064)	−.329 (.053)	−.721 (.063)
Not in LF–Not in LF from Not in LF–Missing, θ for NN | NM	−.284 (.037)	−.236 (.034)	−.476 (.073)
Employed–Employed from Missing–Employed, θ for EE | ME	−.238 (.037)	−.207 (.047)	−.192 (.043)
Employed–Unemployed from Missing–Unemployed, θ for EU | MU	.023 (.058)	.094 (.021)	−.005 (.047)
Employed–Not in LF from Missing–Not in LF, θ for EN | MN	−.033 (.060)	.019 (.047)	−.206 (.087)
Unemployed–Employed from Missing–Employed, θ for UE | ME	−.476 (.083)	−.554 (.022)	−.397 (.107)
Unemployed–Unemployed from Missing–Unemployed θ for UU | MU	−.089 (.024)	−.129 (.012)	−.143 (.032)
Unemployed–Not in LF from Missing–Not in LF, θ for UN | MN	−.504 (.070)	−.365 (.044)	−.566 (.091)
Not in LF–Employed from Missing–Employed, θ for NE | ME	−.259 (.056)	−.274 (.062)	−.377 (.075)
Not in LF–Unemployed from Missing–Unemployed, θ for NU | MU	.034 (.042)	−.039 (.037)	.160 (.036)
Not in LF–Not in LF from Missing–Not in LF, θ for NN | MN	−.120 (.037)	−.114 (.034)	.013 (.063)
Large-sample χ^2 for conditional-missing-at-random model vs. unrestricted multiplicative model (df = 12)	461.39	1270.19	217.78

NOTE: Parameter estimates are based on the six-equation NSUR model for the multiplicative gross flow adjustment procedure. Asymptotic standard errors are within parentheses. The standard errors assume arbitrary heteroscedasticity and serial correlation.

substantially more than twice their respective standard errors. There are four positive allocation parameter estimates. They range from .001 to .094. The only statistically important positive allocation parameter estimate is the one in row 11. The estimated magnitude of .094, however, is still not large enough to affect our results materially. In addition, the theoretical model does not require all allocation parameter estimates to be negative. As with the model for the total sample, we have chosen not to impose any zero restrictions on the estimated allocation parameters for the male sample, since the pattern of small positive estimates does not correspond to any of the interpretable special cases discussed in Section 3.

For the female sample, the negative allocation parameter estimates range from −.005 to −.721, and most are substantially more than twice their respective standard errors. There are three positive allocation parameter estimates, ranging from .013 to .160. The only statistically important positive allocation parameter estimate is the one in row 17. Restricting this parameter would affect the results slightly. The existence of this positive parameter does not, however, result in any inflow or outflow allocations that exceed the corresponding missing-classification cell. As with the models for the total and male samples, we have not imposed any zero restrictions on the estimated allocation parameters.

Table 2 also presents standard errors for all parameter estimates. Lee et al. (1977) demonstrated that equation system models for flow proportions are likely to exhibit heteroscedasticity arising from changes in the expected flow proportions and in the underlying CPS sample size. MacRae (1977) demonstrated that similar models are also likely to exhibit serially correlated errors when the margin proportions are estimated from a sample of the population, and not from population totals. Finally, since the equations for the labor-force status margins from the current month at date t become the equations for the labor-force status margins from the previous month at date $t + 1$ (except for inflows and outflows), errors are likely to follow a low-order moving average process. We found evidence of both heteroscedasticity and serial correlation in the estimated residuals from our margin-adjustment equations. Since the resulting parameter estimates are consistent and since generalized least squares corrections for serial correlation in proportion models are parametrically restrictive, we chose to correct the asymptotic standard errors rather than estimate the system and include a correction for both heteroscedasticity and serial correlation. The standard errors in each column are computed from the appropriate system generalization of the formula provided by White and Domowitz (1984). These standard errors are asymptotically valid in the presence of arbitrary heteroscedasticity and low-order moving average–type serial correlation. The reported standard errors cut off the serial correlation after two lags, but the conclusions are unaffected by using up to four lags. The procedure is not computationally stable for longer lags.

We showed in Section 3.1 that the multiplicative version of the conditional missing-at-random model is nested in our general model through 12 linear restrictions. Table 2 reports the asymptotic chi-squared statistic for the Wald test of the null hypothesis that the conditional missing-at-random model is true versus the alternative hypothesis that our general multiplicative model is true. For any reasonable decision rule using the calculated chi-squared statistics, the data soundly reject the conditional missing-at-random model. The reported chi-squared statistics are based on the robust asymptotic parameter covariance matrix. The conclusions are unaffected by the use of the conventional asymptotic covariance matrix. We computed summary analyses for the conditional missing-at-random model. In view of the evidence from the test of the parameter restrictions, we have not reported any of these results.

To facilitate interpretation of the allocation parameter estimates, we calculated the margin-adjusted gross flow proportions for the sample period by using in Equations (4)–(6) the parameter estimates from Table 2. Averages for the monthly data from January 1977 to December 1982 appear under Adjusted LF Status: Margin Error Only in Table 3. (Standard deviations for the monthly data over the same period appear in the comparable panel of table B1 of the addendum to this article, available on request from the authors.) The average percentage changes implied by the margin adjustment relative to the unadjusted data appear under % change: Margin Error Only to Unadjusted in Table 3. The results are based on the model including population inflow and outflow. Table 4 shows results for the model excluding population inflow and outflow under the same panel labels.

Table 3 shows that our margin-adjustment procedure using the multiplicative adjustment model does indeed resolve the first major problem with the gross flow data discussed in the introduction. The Margin row and column under Adjusted: Margin Error Only match the equivalent CPS row and column almost exactly. This means that the allocation parameters for the total sample and for the male and female samples separately are able to allocate missing data in a manner consistent with the CPS estimates of the labor-force status of the appropriate population. Neither the stationary missing-at-random model nor the stationary conditional missing-at-random model could fit the margins as well as the general multiplicative adjustment model. For example, in the total sample, the CPS estimate of the percentage of the population employed in the current month is 58.71 (Employed row, Published CPS Margin column). Under Margin Error Only, our adjusted estimate of this percentage is 58.71 (Employed row, Margin column). Under Unadjusted LF Status, the unadjusted gross flow estimate of this percentage is 54.58 (Em-

Table 3. Summary of Gross Labor-Force Flows, Including Population Inflow and Outflow: Monthly Averages

Status Last Month	Adjusted LF Status, Current Month										Unadjusted LF Status, Current Month				
	Classification & Margin Error					Margin Error Only									
	E	U	N	Outflow	Margin	E	U	N	Outflow	Margin	E	U	N	Missing[a]	Margin
All Persons															
Employed	57.11	.82	1.20	.03	59.16	55.78	.89	2.02	.03	58.71	47.69	.86	1.64	4.39	54.58
Unemployed	1.05	3.15	.66	.07	4.92	1.08	2.48	.95	.06	4.58	.96	2.02	.79	.50	4.27
Not in LF	1.03	.85	33.79	.01	35.68	1.88	1.12	33.46	.02	36.48	1.46	.83	28.86	2.46	33.61
Inflow[b]	.06	.13	.05		.24	.06	.12	.06		.24	4.44	.54	2.56		7.54
Margin	59.24	4.96	35.70	.11		58.79	4.61	36.50	.11		54.55	4.24	33.84	7.36	
CPS	58.79	4.59	36.52	.11		58.79	4.59	36.52	.11		58.79	4.59	36.52	.11	
Male															
Employed	70.09	1.15	.97	.02	72.24	69.00	1.24	1.65	.02	71.91	59.05	1.12	1.33	5.29	66.79
Unemployed	1.26	3.75	.49	.09	5.59	1.33	3.04	.79	.08	5.25	1.17	2.43	.65	.58	4.83
Not in LF	.86	.61	20.43	.01	21.92	1.55	.90	20.12	.02	22.59	1.16	.69	17.30	1.61	20.76
Inflow[b]	.07	.13	.06		.26	.07	.11	.07		.26	5.36	.61	1.65		7.62
Margin	72.28	5.64	21.95	.12		71.96	5.29	22.63	.12		66.73	4.84	20.93	7.49	
CPS	72.03	5.26	22.58	.12		72.03	5.26	22.58	.12		72.03	5.26	22.58	.12	
Female															
Employed	45.60	.67	1.05	.03	47.35	44.06	.70	2.00	.03	46.80	37.47	.62	1.92	3.58	43.58
Unemployed	.90	2.63	.73	.06	4.32	.90	2.00	1.02	.05	3.96	.78	1.64	.91	.43	3.76
Not in LF	.92	.90	46.29	.00	48.11	1.91	1.16	45.94	.01	49.02	1.72	.97	39.27	3.23	45.19
Inflow[b]	.03	.14	.05		.22	.04	.12	.06		.22	3.61	.47	3.38		7.46
Margin	47.46	4.34	48.11	.09		46.91	3.99	49.02	.09		43.59	3.70	45.47	7.24	
CPS	46.89	3.98	49.03	.09		46.89	3.98	49.03	.09		46.89	3.98	49.03	.09	

[a] Column includes outflow data. [b] Row includes missing data for Unadjusted LF Status columns.

ployed row, Margin column). Similarly, the CPS estimate of the percentage of the total population unemployed in the current month is 4.55 (Unemployed row, Published CPS Margin column). Under Margin Error Only, margin-adjusted estimate of this percentage is 4.58 (Unemployed row, Margin column). The unadjusted estimate is 4.27%. The CPS estimate of the percentage of the total population that is not in the labor force averages 36.50 (Not in LF row, Published CPS Margin column). Our margin-adjusted estimate is 36.48 (Not in LF row, Margin column). The unadjusted estimate is 33.61%. The estimates of the marginal percentages in each labor-force state last month show a similar pattern of agreement after our margin adjustment. Compare the Margin row under Adjusted: Margin Error Only to the same row under Unadjusted and to the CPS row under both. The conclusion that the multiplicative adjustment procedure corrects the defect in the gross flow margins on average also holds for the male and female samples.

Most users of the gross flow data implicitly assume that the individuals with missing labor-force classifications are missing at random. They do this by ignoring the labor-force status information of individuals who were not matched and calculating proportions based on counts of persons who were employed, unemployed, or not in the labor force in both periods. This procedure also assumes that there are no legitimate transitions into and out of the population of interest. Tables 4 and 5 compare our adjusted gross flow data to unadjusted data based on excluding all nonmatching individuals.

The Margin Error Only and Unadjusted LF Status sections of Table 4 compare the multiplicative adjustment model for the missing data to a missing-at-random model of the type just discussed. This table excludes population inflow and outflow. Individuals must be in the relevant population in both the current and previous months. For all three samples, Table 4 shows that our missing-data model generates a better margin adjustment than the missing-at-random model. It should be noted that the problem of disparity between the unadjusted gross flow margins and the published CPS margins is not as severe for the three-state model of Table 4 as for the four-state model of Table 3. Nevertheless, comparison of our adjusted margins with the unadjusted margins and the appropriate CPS margins reveals that the adjustment substantially improves the agreement between the gross flow margins and the CPS margins. Our margin-adjustment procedure is based on the four-state model. When we apply it to the three-state model, the results are based on the appropriate conditional block of our estimated four-state gross flow matrices. Therefore, the estimation procedure did not force the agreement we find in Table 4. The finding that the three-state margins fit so well is an internal consistency check that lends credibility to our margin-adjustment procedure.

We next discuss the results of our classification error adjustment procedure. Our estimates of the monthly classification error rates are based on quarterly reinterview data. Table 6 summarizes this quarterly data for the period from 1977:1 to 1982:4. The table shows that for all persons, the labor-force status classification error rate for the employed state is 1.22%. Of all persons who should have been classified as employed, .19% were improperly classified as unemployed and 1.03% were improperly classified as not in the labor force. Table 6 also shows that the classification error rate for all per-

for January 1977–December 1982 Civilian Noninstitutional Population Ages 16 and Over (% of total)

Published CPS Margin	% Change											
	Classification & Margin Error to Unadjusted				Classification & Margin Error to Margin Error Only				Margin Error Only to Unadjusted			
	E	U	N	Outflow	E	U	N	Outflow	E	U	N	Outflow
58.71	19.78	−5.41	−28.03	−99.36	2.39	−8.32	−41.64	−3.65	16.98	3.21	23.26	−99.34
4.55	8.40	60.99	−16.69	−86.31	−3.57	27.93	−31.22	13.10	12.40	25.55	21.09	−87.90
36.50	−30.84	1.64	17.19	−99.60	−46.28	−24.62	.97	−41.93	28.67	34.73	16.06	−99.32
.24	−98.78	−74.98	−98.16		−3.87	13.02	−21.99		−98.73	−77.88	−97.65	
71.99	18.71	1.80	−29.92	−99.65	1.59	−7.93	−43.45	−10.74	16.86	10.50	23.86	−99.61
5.22	6.93	61.20	−25.45	−84.26	−6.39	24.60	−39.24	11.61	14.17	28.96	22.46	−85.90
22.54	−28.30	−11.99	18.48	−99.22	−46.44	−33.18	1.55	−36.74	33.85	31.61	16.66	−98.77
.26	−98.71	−79.07	−96.41		−3.98	11.37	−14.32		−98.65	−81.21	−95.82	
46.78	21.84	7.99	−46.56	−99.10	3.49	−5.49	−48.61	−.90	17.72	14.45	3.90	−99.09
3.96	15.84	63.07	−20.14	−87.21	.20	32.06	−28.45	14.91	15.69	23.30	11.62	−88.88
49.04	−47.48	−7.72	17.95	−99.91	−52.49	−23.32	.75	−74.14	10.41	20.18	17.07	−99.70
.22	−99.08	−70.77	−98.66		−4.89	14.90	−26.78		−99.03	−74.58	−98.18	

sons properly classified as unemployed is 11.43%. Of all persons properly classified as unemployed, 1.91% were improperly classified as employed and 9.53% were improperly classified as not in the labor force. The table also shows that the classification error rate for all persons properly classified as not in the labor force is .79%. Of all persons properly classified as not in the labor force, .50% were improperly classified as employed and .29% were improperly classified as unemployed. The separate results for each sex display a similar pattern. For males and females separately, the classification error rates for the employed and not in the labor force states are relatively low (<1% to <2%). However, the classification error rate for the unemployed state is 10.08% for males and 12.92% for females. For either sex, the improperly classified unemployed person is more likely to be classified as not in the labor force than as employed.

Table 3 also contains a detailed analysis of the incremental adjustment due to the classification error model and the total adjustment due to the combined effects of both models. The % Change: Classification & Margin Error to Unadjusted section shows the average percentage adjustment resulting from applying both adjustment procedures to the unadjusted gross flow proportions. The % Change: Classification & Margin Error to Margin Error Only section shows the average percentage adjustment resulting from applying the classification error adjustment procedure to the margin-adjusted gross flow data. The % Change: Margin Error Only to Unadjusted section shows the average percentage adjustment resulting from applying the margin error adjustment procedure to the unadjusted data. All show results for all persons, males, and females. The data in Table 3 refer to gross flows as a percentage of the current population (plus outflow since last month).

Consider first the percentage of all persons employed in both the current and previous months. Our classification and margin error adjusted estimate of the monthly average for this percentage is 57.11% (Employed row, E column under Adjusted LF Status: Classification & Margin Error). This estimate begins with the unadjusted estimate of 47.69% (Employed row, E column under Unadjusted LF Status). The estimate is adjusted upward by 16.98% (Employed row, E column under % Change: Margin Error Only to Unadjusted) on average, by using the margin-adjustment model. The resulting estimate is 55.78% (Employed row, E column under Adjusted LF Status: Margin Error Only). The classification error adjustment increases this estimate by an additional 2.39% (Employed row, E column under % Change: Classification and Margin Error to Margin Error Only) on average. The resulting final estimate is 57.11%, which is 19.78% (Employed row, E column under % Change: Classification and Margin Error to Unadjusted) larger than the unadjusted percentage on average. The classification and margin error adjusted estimate of the percentage of males employed in both the current and previous months is 70.09% (Employed row, E column under Adjusted LF Status: Classification and Margin Error). The comparable estimate for females is 45.60%. The sex-specific adjusted gross flow percentages can be decomposed by using the % Change section. All figures in Table 3 are averages of the monthly results. (Standard deviations are reported in table B1 in an addendum available on request from the authors.)

Consider next the flow from employed in the previous month to unemployed in the current month. Our adjusted monthly average estimate for all persons is

Table 4. Summary of the Gross Labor-Force Flows, Excluding Population Inflow and Outflow: Monthly Averages for January 1977–December 1982 Civilian Noninstitutional Population Ages 16 and Over (% of total)

Status Last Month	Adjusted LF Status, Current Month: Classification & Margin Error				Adjusted LF Status, Current Month: Margin Error Only				Unadjusted LF Status, Current Month				Published CPS	% Change: Classification & Margin Error to Unadjusted			% Change: Classification & Margin Error to Margin Error Only			% Change: Margin Error Only to Unadjusted		
	E	U	N	Margin	E	U	N	Margin	E	U	N	Margin	CPS	E	U	N	E	U	N	E	U	N
All Persons																						
Employed	57.31	.82	1.21	59.34	55.97	.89	2.03	58.88	56.04	1.01	1.93	58.98	58.85	2.27	−19.22	−38.58	2.39	−8.32	−41.64	.12	−11.88	5.25
Unemployed	1.05	3.16	.66	4.87	1.08	2.49	.96	4.53	1.13	2.36	.93	4.42	4.56	−7.46	37.30	−28.86	−3.57	27.93	−31.22	−4.03	7.11	3.39
Not in LF	1.03	.86	33.90	35.79	1.88	1.13	33.58	36.59	1.71	.98	33.91	36.60	36.59	−41.00	−13.26	.05	−46.28	−24.62	.97	9.86	15.03	−.92
Margin	59.39	4.84	35.77		58.94	4.50	36.56		58.89	4.35	36.76											
CPS	58.85	4.59	36.56		58.85	4.59	36.56		58.85	4.59	36.56											
Male																						
Employed	70.36	1.15	.98	72.49	69.26	1.25	1.65	72.16	69.58	1.32	1.57	72.46	72.17	1.16	−13.22	−40.32	1.59	−7.93	−43.45	−.43	−5.82	5.55
Unemployed	1.26	3.77	.49	5.52	1.34	3.05	.80	5.18	1.37	2.86	.77	5.00	5.23	−8.89	37.18	−36.53	−6.39	24.60	−39.24	−2.70	9.77	4.30
Not in LF	.87	.61	20.51	21.99	1.56	.90	20.20	22.65	1.37	.81	20.37	22.54	22.60	−38.97	−25.09	.90	−46.44	−33.18	1.55	14.03	12.08	−.65
Margin	72.49	5.53	21.98		72.16	5.20	22.64		72.32	4.98	22.70											
CPS	72.12	5.27	22.61		72.12	5.27	22.61		72.12	5.27	22.61											
Female																						
Employed	45.74	.67	1.05	47.46	44.20	.71	2.00	46.91	43.92	.72	2.25	46.90	46.89	4.21	−7.60	−54.32	3.49	−5.49	−48.61	.69	−2.11	−11.13
Unemployed	.91	2.64	.73	4.28	.90	2.00	1.02	3.93	.91	1.92	1.07	3.90	3.97	−.93	39.36	−31.66	.20	32.06	−28.45	−1.06	5.41	−4.51
Not in LF	.93	.90	46.43	48.26	1.91	1.17	46.08	49.16	2.03	1.13	46.04	49.20	49.15	−55.12	−21.08	.89	−52.49	−23.32	.75	−5.56	2.83	.14
Margin	47.57	4.22	48.21		47.02	3.88	49.11		46.86	3.77	49.37											
CPS	46.94	3.99	49.08		46.94	3.99	49.08		46.94	3.99	49.08											

.82% (Employed row, U column under Adjusted LF Status: Classification and Margin Error). The comparable estimate for males is 1.15% and for females .67%. The adjusted gross flow from employed to unemployed for all persons is 5.41% less than the unadjusted percentage. For males the adjusted percentage is 1.80% greater than the unadjusted percentage. For females the adjusted percentage is 7.99% larger than the unadjusted percentage. For both males and females, the margin error adjustment increased the estimated flow from employed to unemployed by more than the classification error adjustment reduced the estimated flow on average. (See the % Change section of Table 3).

The classification- and margin-adjusted monthly average flow from employed to not in the labor force is 1.20% for all persons, .97% for males, and 1.05% for females. This result is one of the few inconsistencies between our adjustments for all persons and the adjustments for males and females separately. We performed all adjustments separately on the all persons, males, and females samples. Consequently, the estimate for all persons is not the simple weighted average of the males and females estimates. Rather, the estimate for all persons is the best estimate using only the data for all persons. The estimate for males is the best estimate using only the data for males, and the estimate for females is the best estimate using only the data for females. The discrepancies between the all persons estimates and the weighted average of males and females estimates arise because the weighted average of the multiplicative missing-data adjustments does not equal the multiplicative adjustment of the weighted average of the unadjusted data. This appears to be a cost of the multiplicative adjustment procedure. One can eliminate the discrepancy by performing the missing-data adjustment at the disaggregated sex-specific level and then aggregating to the all persons level. Since the disaggregated model has twice as many parameters, when applied to the aggregated data, it is not clear that a researcher interested in only the all persons data should prefer the aggregation of males and females models to the best fitting model using only the all persons data. In general, the preference will depend on the researcher's intended use of the data. For the purpose of publication of monthly adjusted gross flow estimates, estimating the aggregates by summing the disaggregated models may be preferable to publication of inconsistent aggregates.

Table 3 also shows the effects of both the margin adjustment and the classification error adjustment on the flow from unemployment to other states, not in the labor force to other states, and population inflows and outflows. It is particularly interesting to note that some of the missing-data adjustments are substantially different for males and females. Consider % Change: Margin Error Only to Unadjusted: For example, the male adjustment to the flow from employed to not in the labor

Table 5. *Summary of the Gross Labor-Force Transition Rates, Excluding Population Inflow and Outflow: Monthly Averages for January 1977–December 1982 Civilian Noninstitutional Population Ages 16 and Over (% of row)*

Status Last Month	Adjusted LF Status, Current Month: Classification & Margin Error			Margin Error Only			Unadjusted LF Status, Current Month			% Change: Classification & Margin Error to Unadjusted			Classification & Margin Error to Margin Error Only			Margin Error Only to Unadjusted		
	E	U	N	E	U	N	E	U	N	E	U	N	E	U	N	E	U	N
All Persons																		
Employed	96.58	1.39	2.03	95.05	1.51	3.44	95.02	1.71	3.26	1.64	−19.70	−38.96	1.61	−9.02	−42.09	.02	−11.75	5.40
Unemployed	21.72	64.65	13.63	24.19	54.51	21.29	26.06	52.67	21.27	−16.48	23.42	−35.73	−10.45	18.75	−36.10	−6.78	3.85	.44
Not in LF	2.87	2.39	94.73	5.14	3.08	91.78	4.69	2.68	92.63	−39.67	−11.40	2.26	−45.09	−22.95	3.22	9.90	15.02	−.92
Male																		
Employed	97.06	1.60	1.34	95.98	1.73	2.28	96.02	1.82	2.16	1.08	−13.33	−40.34	1.12	−8.36	−43.70	−.04	−5.48	5.95
Unemployed	23.04	67.95	9.01	26.13	58.28	15.59	28.32	55.97	15.70	−18.18	22.19	−42.88	−12.22	16.72	−42.83	−6.90	4.58	−.40
Not in LF	3.93	2.78	93.29	6.87	3.97	89.16	6.09	3.58	90.33	−37.57	−23.51	3.27	−44.87	−31.23	4.64	13.38	11.33	−1.30
Female																		
Employed	96.37	1.42	2.22	94.22	1.50	4.28	93.65	1.54	4.81	2.90	−8.64	−54.86	2.28	−6.59	−49.21	.61	−2.18	−11.17
Unemployed	21.25	61.55	17.19	23.08	50.84	26.09	23.57	48.81	27.62	−9.85	26.54	−37.73	−8.01	21.20	−34.25	−1.98	4.35	−5.34
Not in LF	1.92	1.87	96.21	3.88	2.38	93.74	4.11	2.31	93.58	−54.24	−19.65	2.81	−51.61	−21.89	2.64	−5.47	2.81	.17

force averages 23.86% (Employed row, N column), whereas the female adjustment averages only 3.90% (same row and column). This difference is also apparent in the comparable percentages in Table 4 (5.55% for males and −11.13% for females) using the three-state model, which excludes population inflows and outflows. The sex-related difference in missing-data allocations probably reveals an underlying sex-related difference in the pattern of movement into and out of the CPS sample. In particular, if systematically more women than men are recorded Employed–Missing when Employed–Employed is correct, then a simple missing-at-random model will both overstate the Employed–Not in LF adjustment and the Employed–Unemployed adjustment.

A behavioral model of female labor-force mobility might explain this result by establishing that Employed–Not in LF flows are both more likely for women and less likely to generate missing data than are Employed–Employed flows. Females in families may generate more observed Employed–Not in LF flows. Unmarried individuals may be more likely than married individuals to generate Employed–Missing observations. If the unmarried individuals are primarily Employed–Employed, the observed sex difference in missing-data adjustments would obtain. Notice that essentially the same pattern of sex-related differences holds for Not in the LF–Employed transitions. The male gross flow proportions are adjusted upward by the margin adjustment substantially more than the female proportions (33.85% for males vs. 10.41% for females in Table 3, and 14.03% for males vs. −5.56% for females in Table 4). The same behavioral model of sex-related differences in the generation of missing initial employment states would explain this finding. Married women generating Not in the LF–Employed observations are not producing as much missing data as more mobile single women who would have been recorded as Employed–Employed. The smaller sex-related difference in the percentage change in the Employed–Employed cell is consistent with this explanation, since the level of the unadjusted Employed–Employed cell (which forms the base for the percentage change) is an order of magnitude larger than the level of either the unadjusted Employed–Not in the LF or Not in the LF–Employed cell.

Table 7 shows the effects of the margin adjustment and the classification error adjustment on the gross labor-force transition rates among employment, unemployment, and not in the labor force, including population inflow and outflow. The left three panels show monthly average percentages of individuals in each labor-force status given the labor-force status in the previous month (row percentages). The right three panels show the percentage change due to each of the adjustments. This table is based on the same four-state adjustment procedure summarized in Table 3. The row percentage summary represents an additional way of

Table 6. Summary of Quarterly Reinterview Data From the CPS for 1977:1-1982:4, Civilian Noninstitutional Population Age 16 and Over (%)

Original Interview Status	Status Determined on Reinterview E	U	N	Margin
All Persons				
Employed	98.78	1.91	.50	56.81
Unemployed	.19	88.57	.29	4.35
Not in LF	1.03	9.53	99.21	38.85
Male				
Employed	99.16	2.30	.66	69.49
Unemployed	.19	89.92	.41	4.91
Not in LF	.65	7.78	98.93	25.60
Female				
Employed	98.26	1.47	.42	45.61
Unemployed	.20	87.08	.24	3.84
Not in LF	1.54	11.46	99.34	50.55

NOTE: 1978:2 data are missing.

describing our results. (Monthly standard deviations for the transition rate summaries are presented in table B2 in the addendum, available on request from the authors.)

Most of the interest in the CPS-based estimates of gross labor-force flows centers on movements among employment, unemployment, and not in the labor force. Population inflows and outflows are of less interest and are estimated based on ancillary information not contained in the CPS. Tables 4 and 5 summarize the results of our adjustment procedures, excluding population inflow and outflow. These tables are based on the same adjusted and unadjusted labor-force status data as are Tables 3 and 7; however, being in the relevant population in both the current and previous months is a condition for calculating the summaries in Tables 4 and 5. Table 4 presents the monthly average percentage of the population flowing among the three labor-force states. Table 5 presents the monthly average percentage employed, unemployed, and not in the labor force in the current month expressed as a percentage of the number in each employment status in the last month (row percentages).

Table 5 reveals the effects of our adjustment procedures most vividly. For all persons, 96.58% of the individuals employed last month are employed in the current month, 64.65% of the individuals unemployed last month are unemployed in the current month, and 94.73% of the individuals not in the labor force last month are not in the labor force in the current month. These estimates are adjusted for both missing data and classification errors. The comparable unadjusted estimates are 95.02%, 52.67%, and 92.63%, respectively. For all persons employed last month, we estimate that 1.39% are unemployed and 2.03% are not in the labor force in the current month. The comparable unadjusted estimates are 1.71% and 3.26%, respectively. For all persons unemployed last month, we estimate that 21.72% are employed and 13.63% are not in the labor force in the current month. The comparable unadjusted estimates are 26.06% and 21.27%, respectively. For all persons not in the labor force last month, we estimate that 2.87% are employed and 2.39% are unemployed in the current month. The comparable unadjusted estimates are 4.69% and 2.68%, respectively. The right three panels of Table 5 show the monthly average percentage change in the unadjusted estimates arising from each part of the adjustment procedure. For all persons, the largest adjustments to the row percentages arising from the margin adjustment for missing data (% Change: Margin Error Only to Unadjusted) occur in the Employed–Unemployed (−11.75%) and Not in the LF–Unemployed (15.02%) cells. The other adjustments due to the margin-adjustment procedure are

Table 7. Summary of Gross Labor-Force Transition Rates, Including Population Inflow and Outflow: Monthly

Status Last Month	Adjusted LF Status, Current Month: Classification & Margin Error E	U	N	Outflow	Margin Error Only E	U	N	Outflow	Unadjusted LF Status, Current Month E	U	N	Missing[a]
All Persons												
Employed	96.53	1.39	2.03	.05	95.00	1.51	3.44	.05	87.38	1.58	3.00	8.04
Unemployed	21.41	63.74	13.44	1.42	23.86	53.79	21.00	1.35	22.90	46.42	18.71	11.96
Not in LF	2.87	2.39	94.70	.03	5.14	3.08	91.74	.05	4.34	2.48	85.85	7.33
Inflow[b]	23.03	56.88	20.09		23.94	50.43	25.63		58.86	7.17	33.97	
Male												
Employed	97.03	1.60	1.34	.03	95.95	1.73	2.28	.03	88.42	1.68	1.98	7.92
Unemployed	22.65	66.83	8.86	1.66	25.71	57.36	15.34	1.59	24.79	49.16	13.75	12.30
Not in LF	3.92	2.78	93.24	.06	6.86	3.97	89.08	.09	5.60	3.30	83.31	7.79
Inflow[b]	27.22	49.46	23.32		28.31	44.53	27.15		70.21	8.05	21.74	
Female												
Employed	96.30	1.42	2.21	.07	94.15	1.50	4.27	.07	85.96	1.41	4.41	8.22
Unemployed	20.97	60.76	16.97	1.29	22.79	50.22	25.77	1.23	20.80	43.20	24.41	11.59
Not in LF	1.92	1.87	96.20	.01	3.88	2.38	93.72	.02	3.82	2.14	86.90	7.15
Inflow[b]	15.35	63.67	20.98		16.12	55.47	28.41		48.43	6.36	45.21	

[a] Column includes outflow data. [b] Row includes missing data for Unadjusted LF Status columns.

below 10%. On the other hand, the incremental adjustments to the row percentages arising from the classification error adjustment (% Change: Classification & Margin Error to Margin Error Only) are generally substantial. All row percentages involving changes in labor force status are adjusted downward substantially. The row percentage Unemployed–Unemployed is adjusted upward substantially. For all persons, the incremental classification error adjustment to the Unemployed–Unemployed row percentage increases the estimate by 18.75%. For all persons, the incremental classification error adjustment to the Unemployed–Employed row percentage decreases the estimate by 10.45%. For all persons, the incremental classification error adjustment to the Unemployed–Not in the LF row percentage decreases the estimate by 36.10%.

The pattern of row percentages and adjustments for males and females is similar to the pattern for all persons. Sex-related differences in the margin adjustments for missing data have already been discussed.

Figures 1–5 present graphical summaries of some of the adjustments. We have illustrated the adjustments for all cells involving unemployment. Each figure shows the monthly time series plots for the total, male, and female adjusted and unadjusted gross labor-force flows (in thousands of persons). In addition, each figure shows the time series plot of the ratio of adjusted to unadjusted flows. Adjusted counts were estimated by applying the estimated percentage of the total population (excluding inflow and outflow) adjusted for both classification and margin errors to a monthly estimate of the population common to the consecutive months based on CPS information and unpublished inflow and outflow estimates from the Census Bureau. Unadjusted counts were estimated by applying the comparable unadjusted percentages (excluding all missing-data categories) to the same population estimate. Unadjusted count estimates are equivalent to missing-at-random count estimates. (The graphs summarize the data displayed in the monthly tables in an addendum, available on request from the authors.)

Some general comments apply to all five figures. First, our margin adjustment for missing data depends only on current- and previous-month data. It naturally preserves the seasonal patterns in the original data, although it may enhance or attenuate the seasonal peaks and troughs. Second, our classification error adjustment uses quarterly estimates of the classification error rates. This procedure could induce an artificial seasonal effect at the months separating the quarters; however, we find no evidence of such behavior. In general, the adjusted series have the same seasonal patterns as the unadjusted series. Finally, there are no trends in the ratios of adjusted to unadjusted series. This appears to be a result of the absence of trends in either the missing-data classifications or the reinterview estimates of the classification error rates.

Figure 1 graphs the monthly estimated counts of persons employed in the last month and unemployed in the current month. Both the adjusted and unadjusted estimates of this count show slight upward trends. Male counts are adjusted downward slightly more than female counts. The adjusted to unadjusted ratio for the total count exceeds the comparable ratio for either sex.

Figure 2 graphs the monthly estimated counts of persons unemployed in the last month and employed in the current month. There are no trends apparent in these graphs. Males and females have similar seasonal troughs (in January). The seasonal trough in male movements is enhanced by the adjustment process.

Figure 3 graphs the monthly estimated counts of persons unemployed in the last month and unemployed

Averages for January 1977–December 1982 for Civilian Noninstitutional Population Ages 16 and Over (% of row)

% Change											
Classification & Margin Error to Unadjusted				*Classification & Margin Error to Margin Error Only*				*Margin Error Only to Unadjusted*			
E	*U*	*N*	*Outflow*	*E*	*U*	*N*	*Outflow*	*E*	*U*	*N*	*Outflow*
10.49	−12.72	−33.63	−99.41	1.62	−9.01	−42.09	−4.39	8.73	−4.07	14.57	−99.38
−6.48	38.30	−28.04	−88.21	−10.51	18.67	−36.14	4.94	4.46	16.43	12.54	−88.76
−34.88	−4.39	10.33	−99.62	−45.08	−22.93	3.23	−40.64	18.54	24.06	6.87	−99.37
−60.98	702.36	−41.11		−3.87	13.02	−21.99		−59.43	609.46	−24.75	
9.75	−5.92	−35.22	−99.68	1.12	−8.36	−43.70	−11.15	8.53	2.61	15.03	−99.64
−8.27	37.12	−35.94	−86.54	−12.29	16.63	−42.88	4.55	4.44	17.42	11.78	−87.12
−32.29	−17.07	11.94	−99.26	−44.85	−31.21	4.67	−34.89	22.84	20.63	6.94	−98.87
−61.46	524.94	7.01		−3.98	11.37	−14.32		−59.91	460.56	24.72	
12.06	−.54	−50.83	−99.17	2.28	−6.59	−49.21	−2.06	9.56	6.52	−3.27	−99.15
.65	41.36	−30.48	−88.90	−8.07	21.12	−34.30	5.43	9.53	16.63	5.75	−89.47
−50.69	−13.46	10.73	−99.92	−51.61	−21.88	2.65	−73.68	1.81	10.69	7.87	−99.72
−68.36	910.05	−53.88		−4.89	14.90	−26.78		−66.76	778.98	−37.36	

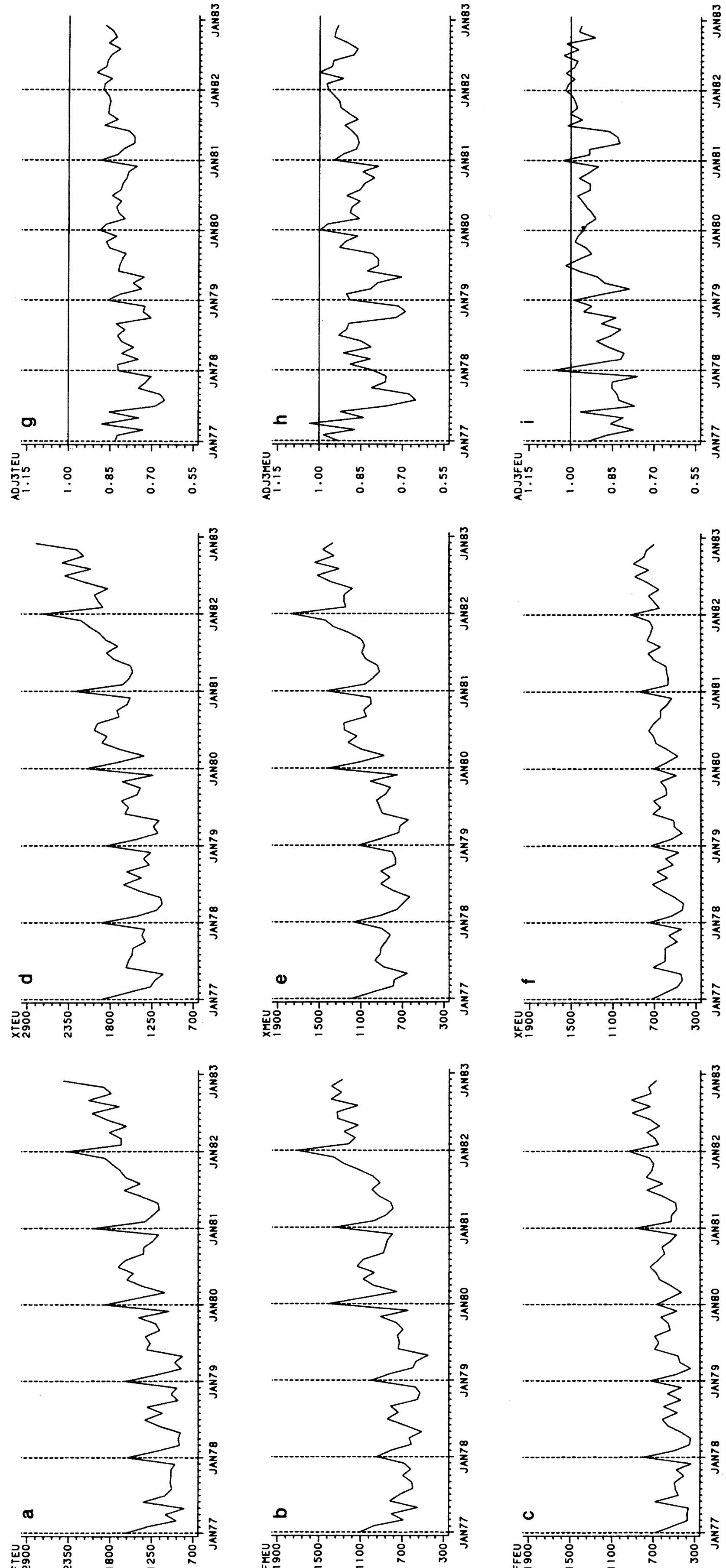

Figure 1. Employed to Unemployed, January 1977–December 1982. Top row, total employed last month to unemployed current month; middle row, males employed last month to unemployed current month; bottom row, females employed last month to unemployed current month. a–c, Adjusted; d–f, unadjusted; g–i, ratio of adjusted to unadjusted.

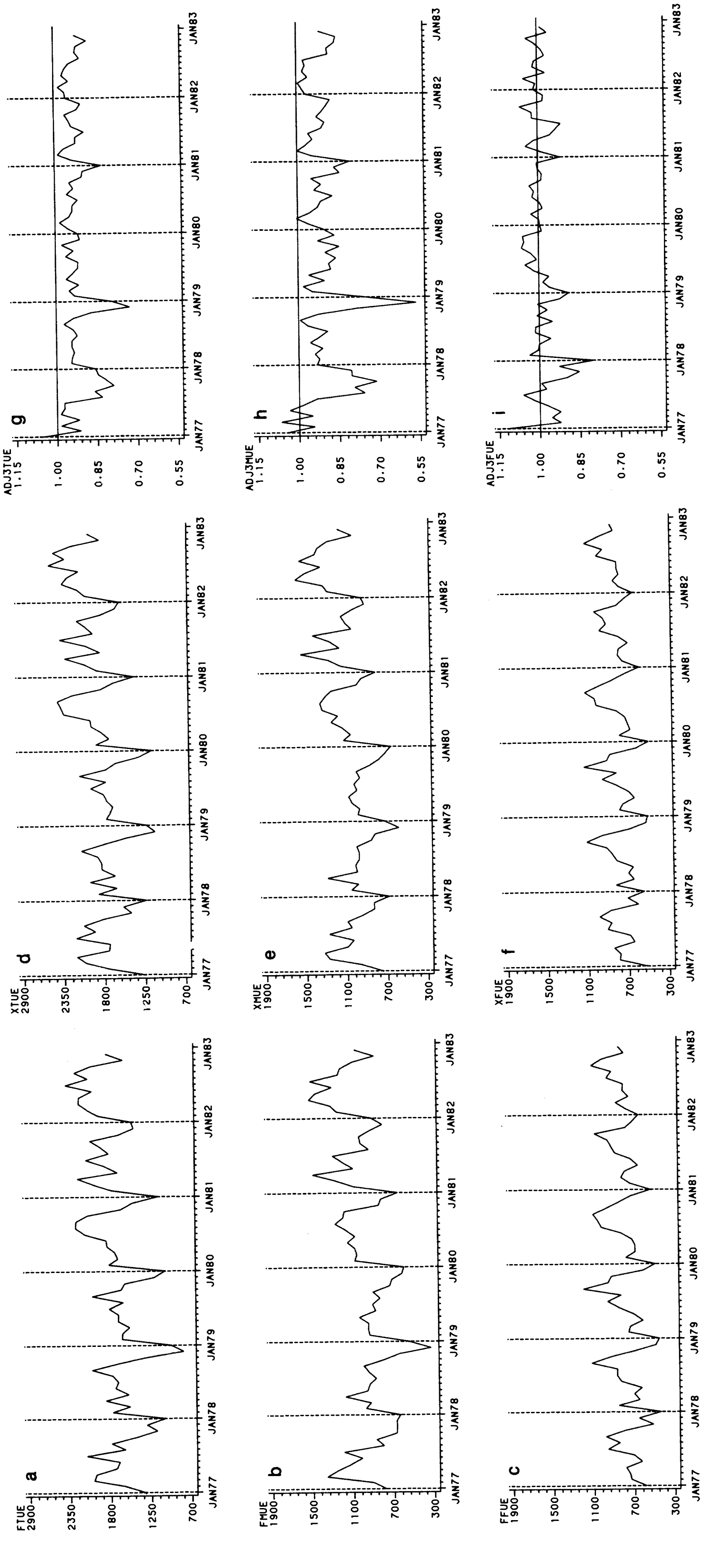

Figure 2. Unemployed to Employed, January 1977–December 1982. Top row, total unemployed last month to employed current month; middle row, males unemployed last month to employed current month; bottom row, females unemployed last month to employed current month. a–c, Adjusted; d–f, unadjusted; g–i, ratio of adjusted to unadjusted.

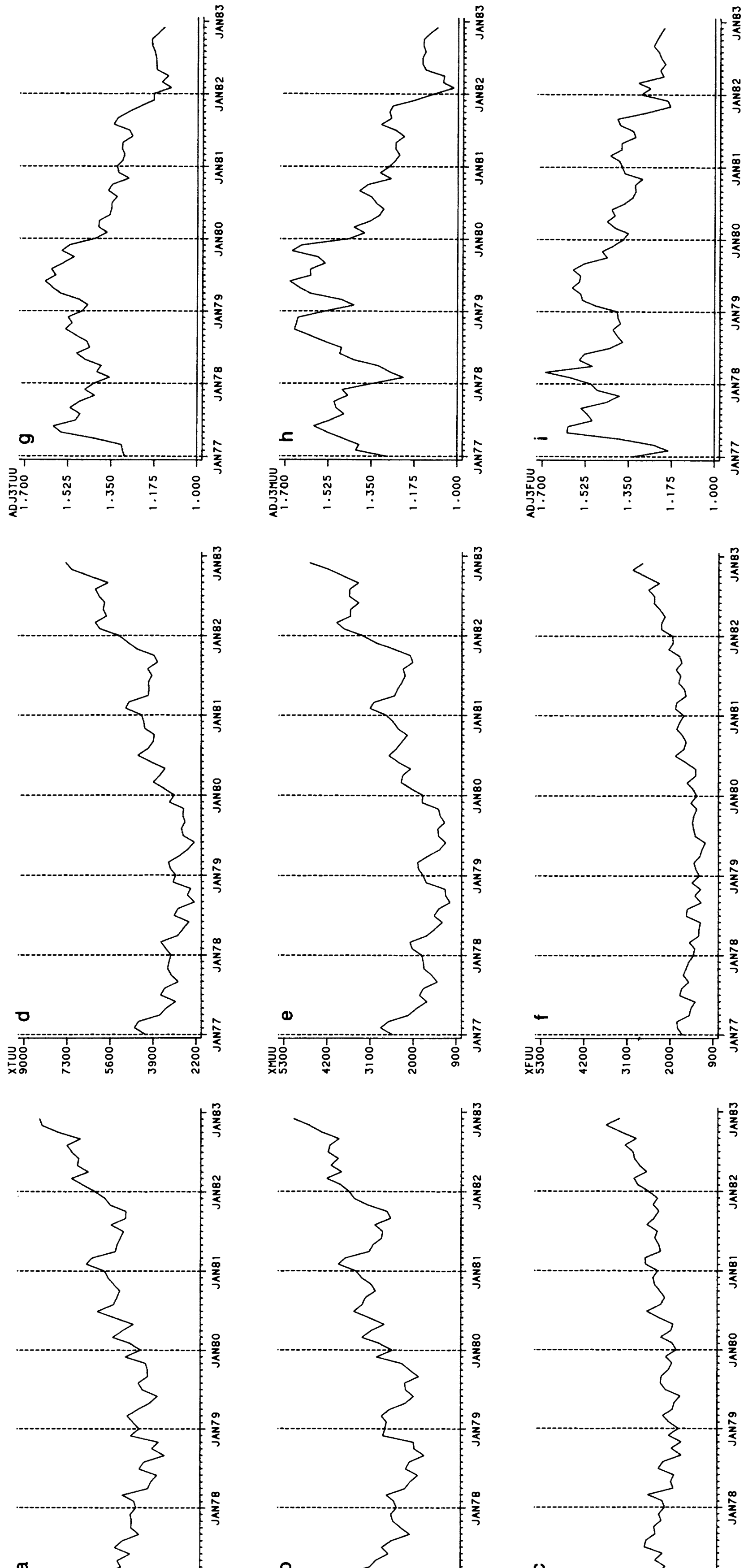

Figure 3. Unemployed to Unemployed, January 1977–December 1982. Top row, total unemployed last month to unemployed current month; middle row, males unemployed last month to unemployed current month; bottom row, females unemployed last month to unemployed current month. a–c, Adjusted (thousands); d–f, unadjusted (thousands); g–i, ratio of adjusted to unadjusted.

in the current month. Both adjusted and unadjusted counts show a decline in early months and a rise in later months. The adjustment process attenuates this slightly. There is no pronounced seasonal trend in this series for either sex.

Figure 4 graphs the monthly estimated counts of persons unemployed in the last month and not in the labor force in the current month. There is a large initial adjustment for males that arises primarily from the classification error rates in 1976:4. There are no other unusual adjustments in this series.

Figure 5 graphs the monthly estimated counts of persons not in the labor force in the last month and unemployed in the current month. This series has a strong early-summer seasonal peak that is slightly enhanced by the adjustment process. Females also have a seasonal trough in the early winter that is unaffected by the adjustment process.

The preceding discussion focused on the relationship between the adjusted and unadjusted estimates of the gross labor-force flows. Figures 6 and 7 show the sources of unemployed persons in the current month from employment, unemployment, and nonparticipation last month for males and females, respectively. These figures, based on our adjusted gross flow data, show how the composition of the unemployed changed over the six analysis years (1977–1982).

In each figure the denser crosshatching represents individuals who were unemployed in the last month and remain unemployed in the current month. For males (Fig. 6) the share of the unemployed last month (in total unemployment of males this month) declined between January 1977 and January 1979, stayed constant until mid-1980, and then rose until the end of the sample. The females (Fig. 7) show a much less pronounced change in composition. In each figure, the unhatched area represents individuals who entered unemployment from outside the civilian labor force last month. These individuals represent the "added workers" whose contribution to total unemployment may be countercyclical (when real production is high relative to trend, added workers should be low relative to trend). Countercyclical added worker effects should appear as a fatter unhatched band in periods when the total unemployment is high; this pattern is evident in both figures. Finally, the less dense crosshatching in each figure represents individuals who were employed in the last month. In each figure, the amount of total unemployment arising from individuals who were employed in the last month is less cyclically variable than total unemployment. This establishes that major changes in total unemployment occur through changes in both the incidence and duration of unemployment spells.

Figures 8 and 9 show the allocation of unemployed persons in the last month to each of the labor force states in the current month: denser crosshatching represents unemployment, no hatching represents not in the labor force, and less dense crosshatching represents employment as the destination. In Figures 8 and 9, the unhatched area represents what is sometimes called the *discouraged-worker* effect. The discouraged worker exits the labor force to end a spell of unemployment. Discouraged-worker effects are also thought to be countercyclical. Our adjusted gross flow data confirm this hypothesis. When total unemployment is high, the number of individuals who exit the labor force to end the unemployment spell is relatively high. This pattern is very evident for men (Fig. 8) and less evident, but still present, for women (Fig. 9).

5. DIAGNOSTIC ANALYSIS OF THE GROSS FLOW ADJUSTMENTS

In this section, we consider the results of two diagnostic analyses of our adjustment procedures. First, we analyze whether the assumption of temporal stationarity in the missing-data adjustment process is reasonable. Second, we compare our adjusted estimates of the flow from employed to unemployed with administrative data based on the number of new claims for unemployment insurance. Both diagnostic analyses provide support for our procedure.

The issue of temporal stationarity of the allocation parameters in the missing-data model has important practical consequences. To apply our adjustment procedure to the entire historical record of gross flow data, the issue of how often to reestimate the allocation parameters must be addressed. We studied this question by estimating the missing-data model over the two subperiods January 1977–December 1979 and January 1980–December 1982.

There is some statistical evidence of parameter nonstationarity. For the total sample, the likelihood ratio statistic (assuming iid distributed normal error vectors for the six-equation system) for the split-sample estimates as compared with the full-sample estimates in Table 2 is 155.5 with 18 df. For the male sample, the statistic is 105.7; for the female sample, the statistic is 140.88. As we noted in Section 4, the residuals for the missing-data model are both heteroscedastic and serially correlated. Hence these likelihood ratio statistics may be seriously biased. Since the effect of these two departures on the asymptotic standard errors of the parameter estimates was, however, not large, we tentatively interpret these statistics as evidence of parameter nonstationarity.

We next consider the practical importance of the parameter nonstationarity. For all three samples, the changes in the estimated allocation parameters between the two subperiods are unimportant. (A complete table of parameter estimates is available from the authors on request.) We summarize the parameter changes as follows. The general pattern of negative, small, and positive estimated allocation parameters is identical for the

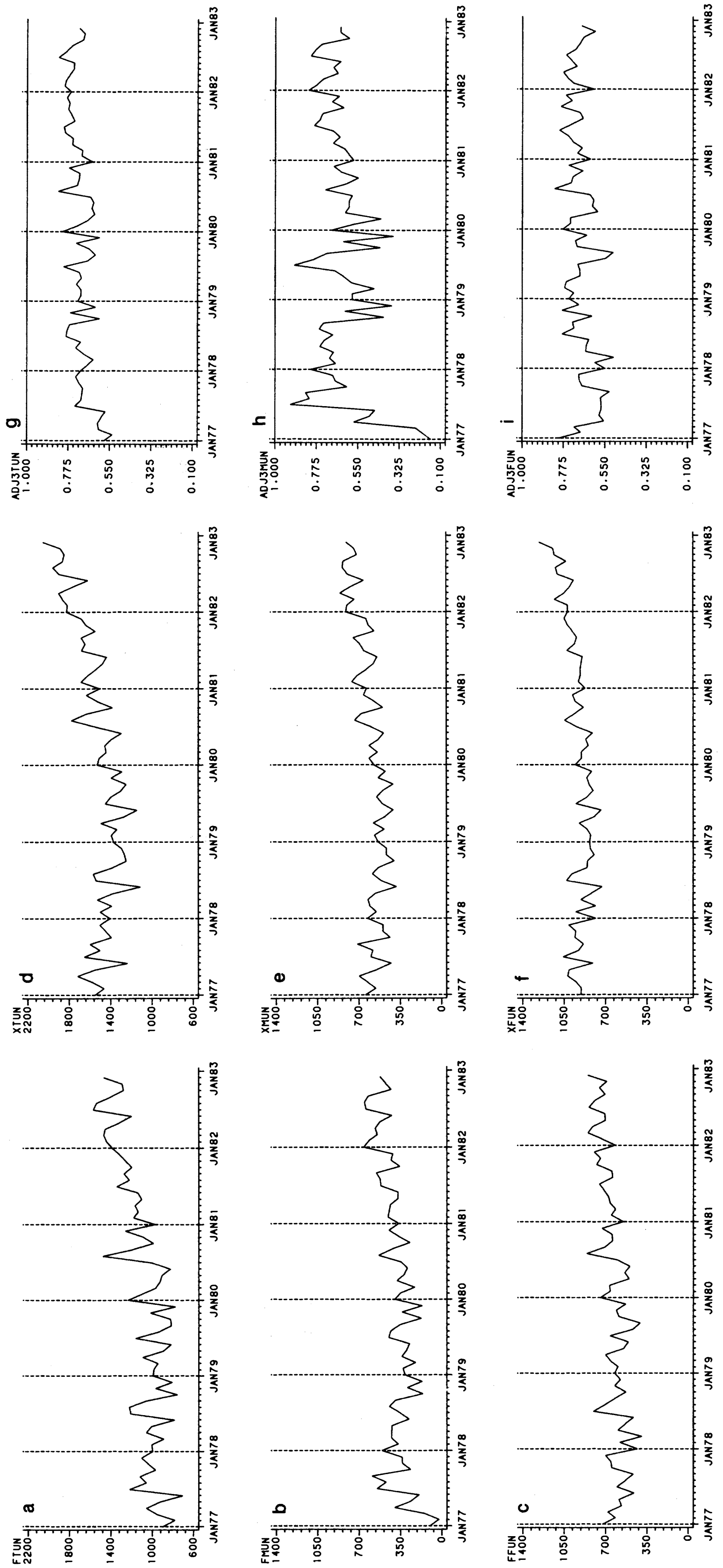

Figure 4. Unemployed to Not in LF, January 1977–December 1982. Top row, total unemployed last month to not in LF current month; middle row, males unemployed last month to not in LF current month; bottom row, females unemployed last month to not in LF current month. a–c, Adjusted (thousands); d–f, unadjusted (thousands); g–i, ratio of adjusted to unadjusted.

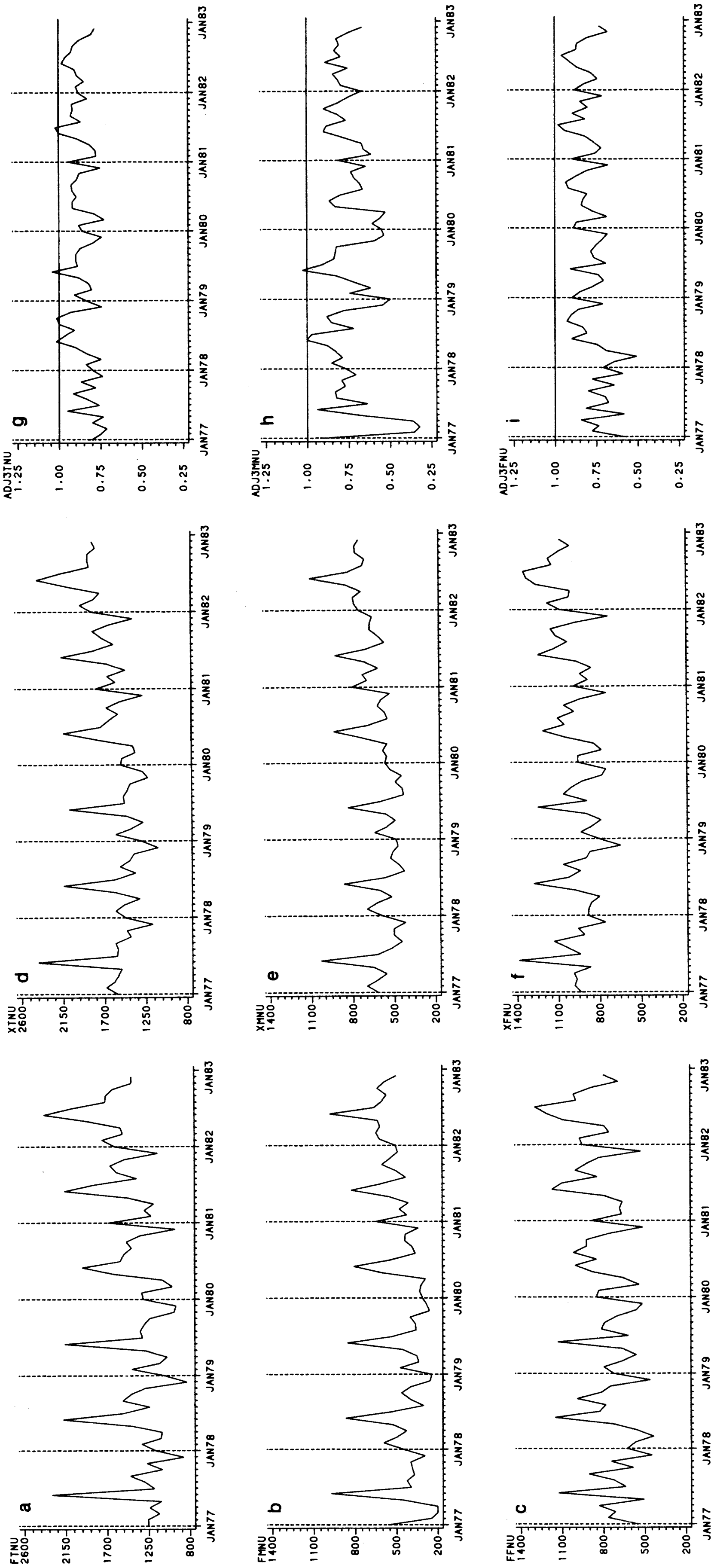

Figure 5. Not in LF to Unemployed, January 1977–December 1982. Top row, total not in LF last month to unemployed current month; middle row, males not in LF last month to unemployed current month; bottom row, females not in LF last month to unemployed current month. a–c, Adjusted (thousands); d–f, unadjusted (thousands); g–i, ratio of adjusted to unadjusted.

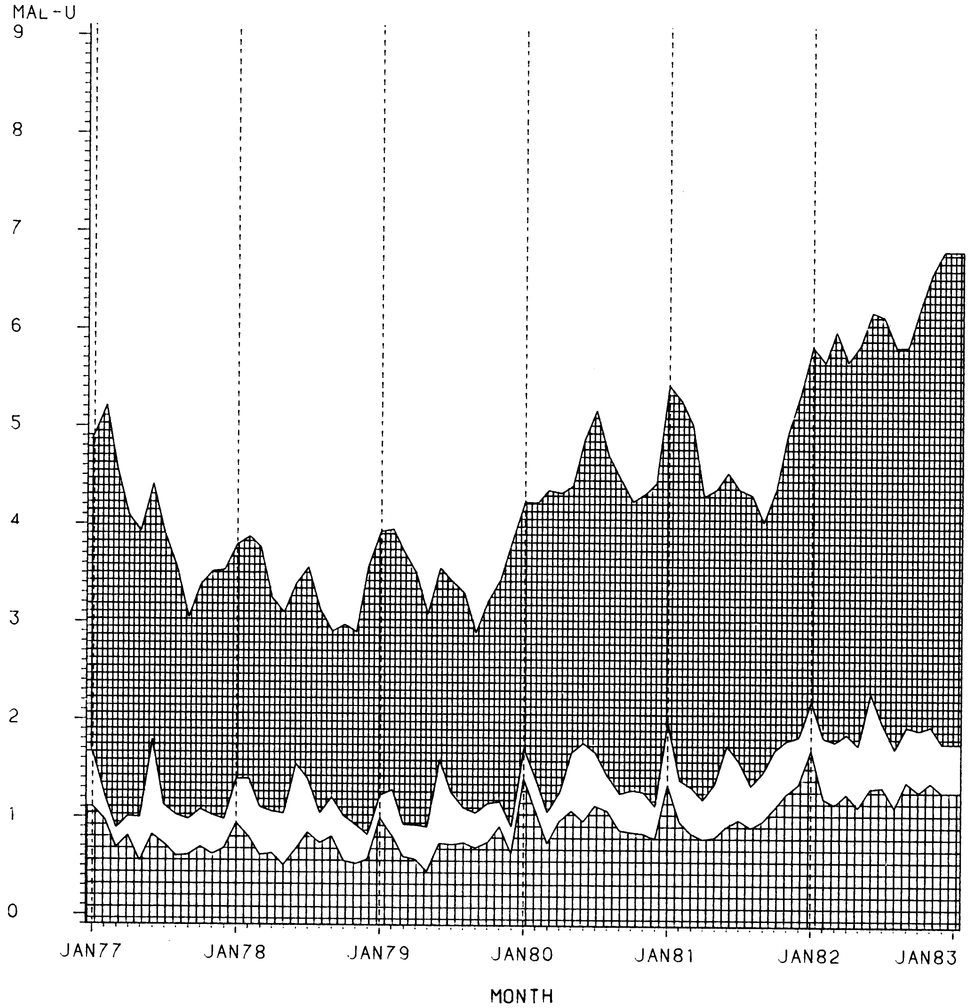

Figure 6. Sources of the Unemployed, Using Adjusted Gross Flows: Males Unemployed Current Month From All Classifications Last Month (millions of persons). Less dense crosshatching represents employed last month; denser crosshatching represents unemployed last month; no crosshatching represents not in LF last month.

two subperiods and is the same as reported for the entire analysis period in Table 2. The derived allocation parameters for the population inflow and outflow are all greater than one and very similar between the subperiods. This conclusion holds for all three analysis samples. Because each subperiod is half as long as the complete analysis period, the estimated parameter standard errors are approximately one and one-half times as large as the standard errors reported in Table 2. In general, the lower precision of the subperiod estimates suggests that a three-year window may not be adequate to determine the allocation parameters.

Although the allocation process may not be formally stationary, the choice of the estimation period length does not appear to affect greatly the results of the missing-data adjustment. The qualitative pattern of missing-data adjustments and all of the orders of magnitude in Tables 3 and 4 are very similar in the two subperiods. Using estimation periods of lengths varying between 36 and 72 months, then, does not affect the qualitative properties of the missing-data model at all, nor does it affect the quantitative properties of the model substantially. Estimation periods of 36 months appear too short to determine adequately the allocation parameters. Estimation periods of 60–72 months adequately determine the allocation parameters at the cost of masking some parameter nonstationarity. The practical consequence of the parameter nonstationarity is minimal. We suggest that the missing-data model be estimated on the basis of either 60- or 72-month periods.

Gross labor-force flows involving movements into and out of unemployment have long been of interest. For movements from employment to unemployment, the weekly time series of initial claims for regular state unemployment insurance provides some ancillary evidence on gross labor-force flows. The Bureau of Labor Statistics supplied the weekly seasonally unadjusted data for this series. We calculated a monthly series for the total initial claims for state unemployment insur-

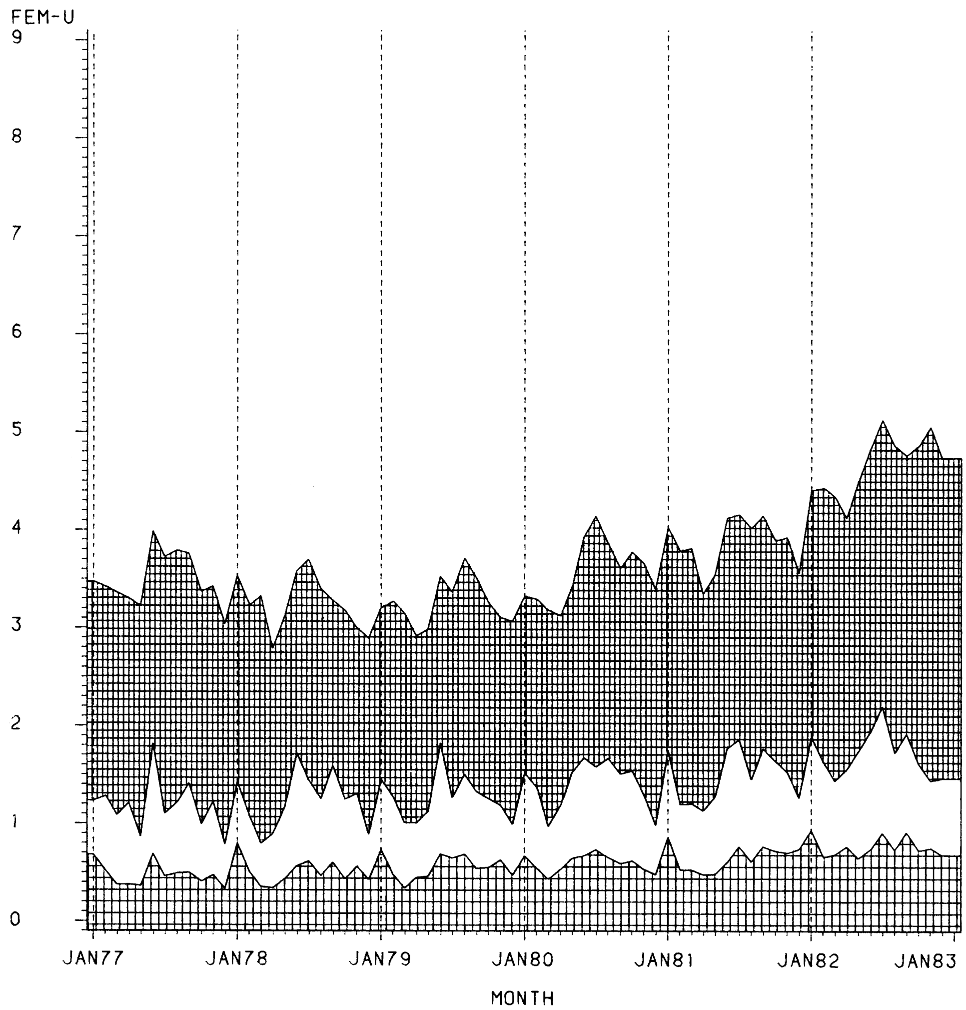

Figure 7. Sources of the Unemployed, Using Adjusted Gross Flows: Females Unemployed Current Month From All Classifications Last Month (millions of persons). Less dense crosshatching represents employed last month; denser crosshatching represents unemployed last month; no crosshatching represents not in LF last month.

ance by summing claims from the CPS information week (the week containing the 12th of the month) and weeks since the last CPS information week. Thus the monthly series on initial unemployment insurance claims covers either four or five weeks as appropriate. To facilitate comparisons with our gross flow proportion of employed to unemployed, we divided the monthly new claims series by the same population measure used to normalize the gross flows.

Table 8 shows summary statistics for the monthly new claims for unemployment insurance, the classification- and margin-adjusted flow from employed to unemployed, the margin-only adjusted flow, and the unadjusted flow, as percentages of the population in the current month (less inflow). The monthly new claims series is an overestimate of the monthly flow from employed to unemployed because it captures short unemployment spells that are not captured by the CPS gross flow from month to month. Both adjusted flows, however, are more highly correlated with the monthly new unemployment insurance claims series than is the unadjusted flow. The differences are not large.

A more discerning test of the reasonableness of our adjustment procedure is summarized in Table 9. In this table, we consider the extent to which the ratio of adjusted to unadjusted flows covaries with the monthly new claims series. The six regressions summarized in Table 9 measure the extent to which there is common information in the movements of the monthly new claims series and various gross flow adjustment ratios. All six regressions provide evidence of this common information. This means that the gross flow adjustment process is capturing some of the additional information about employment to unemployment flows that is contained in the initial unemployment insurance claims but is not contained in the unadjusted gross labor-force flow estimates. When the regression coefficient on the new unemployment insurance claims variable is estimated precisely, relative to its standard error, there is

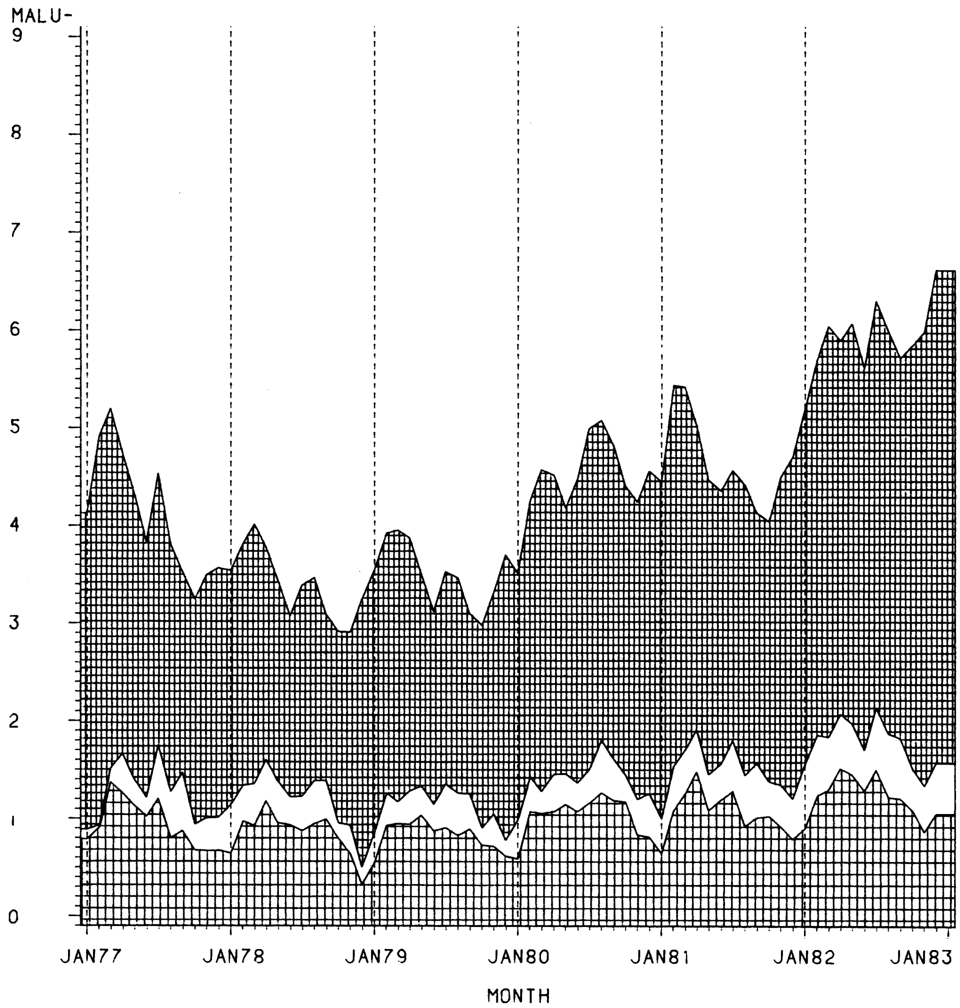

Figure 8. Destinations of the Unemployed Using Adjusted Gross Flows: Males Unemployed Last Month to All Classifications Current Month (millions of persons). Less dense crosshatching represents employed current month; denser crosshatching represents unemployed current month; no crosshatching represents not in LF current month.

common information in the adjustment ratio and the monthly new unemployment insurance claims data. The larger the adjusted R^2, the greater is the magnitude of the common information. The regression could be run with either variable as dependent. The interpretation of adjusted R^2 is relative to no common information.

Rows 1 and 4 of Table 9 show that the margin adjustment contains a relatively small (but still statistically important) element of information that is also contained in the new claims data but is missing from the unadjusted gross flow data. Rows 2 and 5 show that the incremental adjustment due to the classification error model contains a relatively large amount of information that is also contained in the new claims data but is missing from the unadjusted gross flow data. Rows 3 and 6 show that the combined adjustment procedures jointly contain information that is also contained in the new claims data. Table 9 clearly demonstrates that our adjustment procedure corrects the unadjusted gross flow from employment to unemployment in a manner that is consistent with other labor market information on the movement between these states.

6. ALTERNATIVES TO ADJUSTMENT PROCEDURES: NEW INFORMATION SOURCES

Since the gross flow data constitute an important source of labor-force information, it is worth investigating alternatives to adjustment procedures that might be adopted in the future. Our procedure is designed to reduce the potential for bias in the historical gross flow data arising from systematic exclusion of nonrandom missing data and independent classification errors. It may also be possible to make changes to the CPS to reduce the possibility of these biases in future calculations of labor-force flows. Finally, it may be possible to restructure the reinterview survey to provide estimates for nonindependent classification error models.

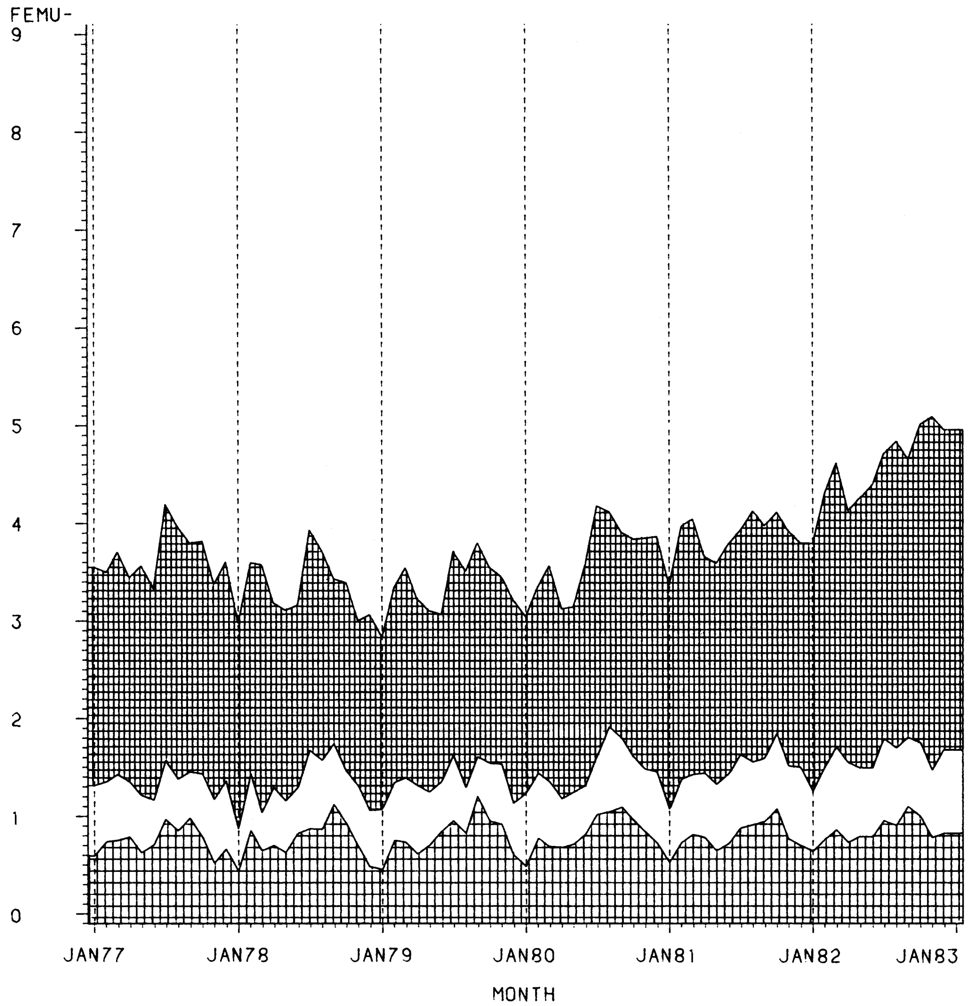

Figure 9. Destinations of the Unemployed, Using Adjusted Gross Flows: Females Unemployed Last Month to All Classifications Current Month (millions of persons). Less dense crosshatching represents employed current month; denser crosshatching represents unemployed current month; no crosshatching represents not in LF current month.

In the current sampling frame of the CPS, we can identify three major sources of lost information on individual respondents from month to month: (a) the family that occupied the household last month has moved, (b) an individual who lived with the family in the sampled household last month has moved out, and (c) an individual who lived in an unsampled household last month has moved into a sampled household. To gather more complete labor-force status change information on individuals or families who would have otherwise generated missing data, it is necessary for an interviewer to be able to identify which of these three cases has occurred. The addition of a question designed to identify a new household (or individual) would allow the interviewer to ask a special set of questions designed to record the last month's labor-force status for such individuals. The set of questions asked of respondents who appear in the sample for the first time after rotation group 1 should be identical to the usual set of questions but asked with respect to the appropriate week one month ago. This information could then be used in calculating the gross flow tables.

Special questions designed to record the last month's labor-force status for individuals who are new to the sample this month would only have to be asked of a relatively small percentage of the respondents (<7.5%). Since these questions would greatly reduce the missing data on these individuals, it would appear worthwhile to use them when necessary.

Individuals and families who leave a sampled residence create a special problem. Since these individuals are no longer part of the CPS sampling frame, no attempt is made to contact them. Although the CPS sample design does not require responses from these individuals, since they are replaced by the individuals who now live in the sampled residence, they are still valuable for calculating gross flows. A short special telephone interview could be administered to these individuals to ascertain their current labor-force status if they could be located. One method to facilitate locat-

Table 8. Summary of Monthly New Claims for Unemployment Insurance and Labor-Force Flows for January 1977–December 1982, Civilian Noninstitutional Population Age 16 and Over

Variable	Mean, %	SD, %	Correlation 2	Correlation 3	Correlation 4
1. Monthly new claims for unemployment insurance*	1.14	.32	.813	.812	.800
2. Classification and margin adjusted flow from employed to unemployed	.82	.21		.979	.980
3. Margin only adjusted flow from employed to unemployed	.89	.18			.997
4. Unadjusted flow from employed to unemployed	1.01	.21			

* Monthly new claims for unemployment insurance include the weekly claims for the week covered by the CPS and all weeks since the last CPS.

ing these individuals, which has worked well in other longitudinal surveys, is to provide individuals with a postcard that can be used to notify the Census Bureau if an individual or family moves out of a sampled residence. Past respondents could then be located and the supplemental information collected. Once again, fewer than 7.5% of the individuals in the survey could be expected to require this special interview.

Considering the importance of reliable gross labor-force flow information and the reduced cost of computerized data management facilities, the Census Bureau should also investigate ways in which the field interviewer can be supplied with more information about the household being interviewed. For example, if the control sheet for all rotation groups except the first contained the names and ages of all individuals included in the interview the last time the household was surveyed, the interviewer could be instructed to be certain to obtain current labor-force and population status information about each of these individuals. In addition, the interviewer would be able immediately to identify any individual currently in the household for whom the last month's labor-force and population status information was missing. This would facilitate gathering additional information on these individuals.

We used a classification error model that assumed that classification errors were independent between the previous and the current month. It is impossible to check this assumption with existing reinterview data. The Census Bureau should redesign the reinterview survey so that some households are reinterviewed in two (or more) consecutive months. Longitudinal data on the classification error rate generated by this panel reinterview survey would permit estimation of a general two-period conditional probability model. The assumption of independent classification errors is very strong. Evidence that this assumption is correct would greatly strengthen the adjustment model. Evidence that this assumption is incorrect would also provide the information required to correct it. This revision to the reinterview process may also shed light on the differences between the reconciled and unreconciled subsamples.

Each of the suggestions in this section provides an

Table 9. Summary of Regression Analysis of the Relationship Between Adjustment Ratios for Employed to Unemployed Flow and Monthly New Claims for Unemployment Insurance: January 1977–December 1982, Total Civilian Noninstitutional Population Age 16 and Over

Dependent Variable	Intercept	New UI Claims*	Adjusted R^2	Durbin–Watson
Ratio of margin adjusted EU to unadjusted EU (proportions)	.868 (.007)	1.172 (.621)	.049	1.270
Ratio of classification and margin adjusted EU to margin adjusted EU (proportions)	.797 (.033)	10.513 (2.249)	.267	1.061
Ratio of classification and margin adjusted EU to unadjusted EU (proportions)	.689 (.027)	10.375 (1.795)	.332	1.284
Ratio of margin adjusted EU to unadjusted EU (transitions)	.876 (.004)	.609 (.312)	.024	2.698
Ratio of classification and margin adjusted EU to margin adjusted EU (transitions)	.789 (.033)	10.564 (2.228)	.271	1.139
Ratio of classification and margin adjusted EU to unadjusted EU (transitions)	.690 (.028)	9.898 (1.952)	.292	1.139

NOTE: Standard errors are given within parentheses and allow for arbitrary serial correlation and heteroscedasticity in the true errors.

* The independent variable is the total new claims for unemployment insurance for the CPS week and the weeks following the previous month's CPS expressed as a percent of the current month's population.

alternative to complicated adjustment procedures for future gross flow data collection. These alternatives should, however, be investigated and implemented in conjunction with a continuing research program designed to monitor and improve the quality of gross labor-force flow data. Now that research interest in historical and future gross flow data has been rekindled, we believe that the Bureau of Labor Statistics and the Census Bureau should jointly ensure that these data are given a significant amount of the research and administrative resources devoted to labor-market data collection.

We believe that the X-11 program for seasonal adjustment provides an appropriate model. Seasonal adjustment procedures were implemented gradually. Once research efforts had identified a workable automatic procedure, that procedure was implemented. As continuing research suggested improvements and refinements, these were evaluated and implemented as appropriate. Even though seasonal adjustment has been institutionalized for many years, research continues to suggest new approaches. Formal statistical models and behavioral economic models are currently productive areas of research in the study of seasonal adjustment.

Current research on gross flow adjustment, including our own research, is largely based on workable, automatic procedures that can be applied to historical data. Future research will no doubt move in the direction of more formal statistical modeling. Eventually, reasonable behavioral models will be developed. There is no reason to delay the production of official gross flow statistics until all research questions have been resolved. Routine adjustment and publication of gross flow statistics should begin immediately. Adjustment methods should be replaced by higher quality original data as the improvements to the data collection effort can be implemented.

7. CONCLUSION

We have developed a model for the adjustment of gross labor-force flow data that does not assume that missing employment status classifications are missing at random and allows for independent employment status classification errors. Our model was implemented by using published and unpublished labor force data for the period January 1977–December 1982. We demonstrated that our procedure corrects the major defects in the historical gross flow data: (a) average marginal employment status proportions no longer differ from the comparable proportions estimated by the full CPS and (b) the potential bias from classification errors has been removed from the estimates of actual labor-force flows. The average adjustment due to the nonrandom missing-data model changes estimated flows by −12%–15% relative to a missing-at-random model. The average adjustment due to the model for classification errors reduces estimates of changes in labor-force status by 8%–49% and increases estimates of consecutive periods of unemployment by 18%. Males and females differ substantially with respect to missing-data adjustments. There are no major sex-related differences in the classification error adjustments. Important seasonal and nonseasonal patterns can be detected in the deviation of adjusted gross flows from the missing at random/no classification error gross flows that have been used in many economic applications of these data.

In principle, one might develop a behavioral model for the underlying movements into and out of the CPS sample that give rise to the missing-data problem in the gross flows and for the sources of classification error. Though we agree that this line of research is desirable, more useful remedies to the defects in the gross flow data would be (a) to improve the tracking of employment status changes in the survey itself and (b) to conduct repeated reinterview surveys so that dependent classification error models can be analyzed. We have offered some suggestions for such improvements. Historical adjustment will still be required for the existing gross flow data and, to a lesser extent, new data collected by using improved survey techniques. We believe that flexible models for the adjustment process such as our combined missing-data and classification error model offer a viable alternative to implicit missing-at-random adjustment. Researchers can always perform additional adjustments if required. For general purposes, however, we have demonstrated that our procedure provides reasonable adjustments that are internally consistent (at the appropriate level of disaggregation) and externally consistent with independent data on labor-force flows.

ACKNOWLEDGMENTS

This article is an extension of the authors' paper presented at the 1983 Annual Meetings of the American Statistical Association. The present version was presented at the Bureau of the Census/Bureau of Labor Statistics Conference on Gross Flows in Labor Force Statistics. Earlier reports on this research were delivered to the Census Advisory Committee of the American Economic Association in April and October 1982. The current research was partially supported by Joint Statistical Agreement 83-6 between the Bureau of the Census and the University of Chicago. Additional research support was provided by the H. G. B. Alexander Research Foundation and the Graduate School of Business. The authors wish to acknowledge the assistance and comments of Charles Brown, John Carlson, Delores Conway, Patrick Flanagan, Richard Freeman, Matthew Goldberg, Gloria Green, Roger Herriot, Carma Hogue, Cary Isaki, Joseph Kadane, Roderick Little, Jennifer Marks, Robert McIntire, Louisa Miller, Roger Moore, Janet Norwood, Kenneth Ricinni, George Tauchen, and Elizabeth Tunstall. Research assistance for this article was provided by Janice McCallum and Kenneth Sutley. Michael Hemler and Brent Moulton provided research assistance for related work on the project.

APPENDIX: MATHEMATICAL FORMULAS

The equation system implied by Equations (4)–(6) in the text may be summarized as follows. For the row margins of the proportion table (including population inflow and outflow) the equation is

$$\pi_{i+}(t) = \left[\sum_{j=\mathrm{E,U,N}} [z_{ij}(t) z_{i\mathrm{M}}(t)^{\theta_{ij|i\mathrm{M}}} z_{\mathrm{M}j}(t)^{\theta_{ij|\mathrm{M}j}}] + z_{i\mathrm{M}}(t)^{(1-\theta_{i\mathrm{E}|i\mathrm{M}}-\theta_{i\mathrm{U}|i\mathrm{M}}-\theta_{i\mathrm{N}|i\mathrm{M}})} \right] \div \left[\sum_{k=\mathrm{E,U,N,M}} \left(\sum_{l=\mathrm{E,U,N}} [z_{kl}(t) z_{l\mathrm{M}}(t)^{\theta_{kl|k\mathrm{M}}} z_{\mathrm{M}l}(t)^{\theta_{kl|\mathrm{M}l}}] + z_{k\mathrm{M}}(t)^{(1-\theta_{k\mathrm{E}|k\mathrm{M}}-\theta_{k\mathrm{U}|k\mathrm{M}}-\theta_{k\mathrm{N}|k\mathrm{M}})} \right) \right] + u_{i+}(t) \quad \text{(A.1)}$$

for i = E, U, N. The equation for $\pi_{\mathrm{A}+}(t)$ is

$$\pi_{\mathrm{A}+}(t) = 1 - \pi_{\mathrm{E}+}(t) - \pi_{\mathrm{U}+}(t) - \pi_{\mathrm{N}+}(t).$$

For the column margins of the proportion table (including population inflow and outflow), the equation is

$$\pi_{+j}(t) = \left[\sum_{i=\mathrm{E,U,N}} [z_{ij}(t) z_{i\mathrm{M}}(t)^{\theta_{ij|i\mathrm{M}}} z_{\mathrm{M}j}(t)^{\theta_{ij|\mathrm{M}j}}] + z_{\mathrm{M}j}(t)^{(1-\theta_{\mathrm{E}j|\mathrm{M}j}-\theta_{\mathrm{U}j|\mathrm{M}j}-\theta_{\mathrm{N}j|\mathrm{M}j})} \right] \div \left[\sum_{l=\mathrm{E,U,N,M}} \left(\sum_{k=\mathrm{E,U,N}} [z_{kl}(t) z_{k\mathrm{M}}(t)^{\theta_{kl|k\mathrm{M}}} z_{\mathrm{M}l}(t)^{\theta_{kl|\mathrm{M}l}}] + z_{\mathrm{M}l}(t)^{(1-\theta_{\mathrm{E}l|\mathrm{M}l}-\theta_{\mathrm{U}l|\mathrm{M}l}-\theta_{\mathrm{N}l|\mathrm{M}l})} \right) \right] + u_{+j}(t) \quad \text{(A.2)}$$

for j = E, U, N. The equation for $\pi_{+\mathrm{A}}(t)$ is

$$\pi_{+\mathrm{A}}(t) = 1 - \pi_{+\mathrm{E}}(t) - \pi_{+\mathrm{U}}(t) - \pi_{+\mathrm{N}}(t).$$

The cell $\pi_{\mathrm{AA}}(t)$ is always 0. The equations for $\pi_{\mathrm{A}+}(t)$ and $\pi_{+\mathrm{A}}(t)$ are redundant. The six-equation system that forms the basis for estimation of the allocation parameters θ may be summarized as:

$$\begin{aligned} \pi_{\mathrm{E}+}(t) &= f_{\mathrm{E}+}(z(t), \theta) + u_{\mathrm{E}+}(t) \\ \pi_{\mathrm{U}+}(t) &= f_{\mathrm{U}+}(z(t), \theta) + u_{\mathrm{U}+}(t) \\ \pi_{\mathrm{N}+}(t) &= f_{\mathrm{N}+}(z(t), \theta) + u_{\mathrm{N}+}(t) \\ \pi_{+\mathrm{E}}(t) &= f_{+\mathrm{E}}(z(t), \theta) + u_{+\mathrm{E}}(t) \\ \pi_{+\mathrm{U}}(t) &= f_{+\mathrm{U}}(z(t), \theta) + u_{+\mathrm{U}}(t) \\ \pi_{+\mathrm{N}}(t) &= f_{+\mathrm{N}}(z(t), \theta) + u_{+\mathrm{N}}(t) \end{aligned} \quad \text{(A.3)}$$

or

$$\pi(t) = f(z(t), \theta) + u(t) \quad \text{(A.4)}$$

where $z(t) \equiv [z_{\mathrm{EE}}(t), z_{\mathrm{EU}}(t), \ldots, z_{\mathrm{MN}}(t)]'$ (15 × 1), $\theta \equiv [\theta_{\mathrm{EE|EM}}, \ldots, \theta_{\mathrm{NN|NM}}, \theta_{\mathrm{EE|ME}}, \ldots, \theta_{\mathrm{NN|MN}}]'$ (18 × 1), $\pi(t) \equiv [\pi_{\mathrm{E}+}(t), \pi_{\mathrm{U}+}(t), \pi_{\mathrm{N}+}(t), \pi_{+\mathrm{E}}(t), \pi_{+\mathrm{U}}(t), \pi_{+\mathrm{N}}(t)]'$ (6 × 1), $f \equiv [f_{\mathrm{E}+}(z(t), \theta), \ldots, f_{+\mathrm{N}}(z(t), \theta)]'$ (6 × 1), and $u(t) \equiv [u_{\mathrm{E}+}(t), \ldots, u_{+\mathrm{N}}(t)]'$ (6 × 1). The parameter estimates in Table 2 were produced by iterative nonlinear least squares with updating of the residual covariance matrix. For iteration 1 the formula is

$$\hat{\theta}^{(1)} \text{ attains: } \min_{\theta} \sum_{t=1}^{T} [\pi(t) - f(z(t), \theta)]'[\pi(t) - f(z(t), \theta)],$$

where T = the total number of time periods used. For all subsequent iterations (l) the formulas are

$$\underset{(6\times 6)}{\hat{\Omega}^{(l)}} \equiv \frac{1}{T} \sum_{t=1}^{T} [\pi(t) - f(z(t), \hat{\theta}^{(l-1)})][\pi(t) - f(z(t), \hat{\theta}^{(l-1)})]'$$

$$\hat{\theta}^{(l)} \text{ attains: } \min_{\theta} \sum_{t=1}^{T} [\pi(t) - f(z(t), \theta)]' \times (\hat{\Omega}^{(l)})^{-1} [\pi(t) - f(z(t), \theta)].$$

Conventional asymptotic standard errors were calculated by using the formula

$$\widehat{\mathrm{var}}[\hat{\theta}] \equiv (\hat{F}^{(L)\prime} [(\hat{\Omega}^{(L)})^{-1} \otimes I_T] \hat{F}^{(L)})^{-1},$$

where

$$\underset{6T\times 18}{\hat{F}^{(L)}} \equiv \left[\frac{\partial f_{\mathrm{E}+}(z(1), \hat{\theta}^{(L)})'}{\partial \theta} \cdots \frac{\partial f_{\mathrm{E}+}(z(T), \hat{\theta}^{(L)})'}{\partial \theta} \cdots \cdots \frac{\partial f_{+\mathrm{N}}(z(1), \hat{\theta}^{(L)})'}{\partial \theta} \cdots \frac{\partial f_{+\mathrm{N}}(z(T), \hat{\theta}^{(L)})'}{\partial \theta} \right]'.$$

The formula for the robust asymptotic standard errors is

$$\widehat{\mathrm{var}}[\hat{\theta}] \equiv (\hat{F}^{(L)\prime} [(\hat{\Omega}^{(L)})^{-1} \otimes I_T] \hat{F}^{(L)})^{-1} \times (\hat{F}^{(L)\prime} \hat{V} \hat{F}^{(L)}) (\hat{F}^{(L)\prime} [(\hat{\Omega}^{(L)})^{-1} \otimes I_T] \hat{F}^{(L)})^{-1},$$

where V is a block-symmetric $6T \times 6T$ matrix with typical block element V_{qr}. The main diagonal elements of V_{qr} are $\hat{u}_q(t)\hat{u}_r(t)$. The first diagonal below the main diagonal has elements $\hat{u}_q(t)\hat{u}_r(t-1)$. The first diagonal above the main diagonal has elements $\hat{u}_q(t-1)\hat{u}_r(t)$. All other elements are zero. For each equation $\hat{u}_q(t) \equiv \pi_q(t) - f_q[z(t), \hat{\theta}^{(L)}]$ and q, r = E+, U+, N+, +E, +U, +N. Fitted values for the margin-adjusted estimates were computed by using the formula

$$\hat{\pi}_{ij}(t) = [z_{ij}(t) z_{i\mathrm{M}}(t)^{\hat{\theta}_{ij|i\mathrm{M}}} z_{\mathrm{M}j}(t)^{\hat{\theta}_{ij|\mathrm{M}j}}] / \hat{\Delta}(t)$$

for i, j = E, U, N, and

$$\hat{\pi}_{i\mathrm{A}}(t) = [z_{i\mathrm{M}}(t)^{(1-\hat{\theta}_{i\mathrm{E}|i\mathrm{M}}-\hat{\theta}_{i\mathrm{U}|i\mathrm{M}}-\hat{\theta}_{i\mathrm{N}|i\mathrm{M}})}] / \hat{\Delta}(t),$$

$$\hat{\pi}_{\mathrm{A}j}(t) = [z_{\mathrm{M}j}(t)^{(1-\hat{\theta}_{\mathrm{E}j|\mathrm{M}j}-\hat{\theta}_{\mathrm{U}j|\mathrm{M}j}-\hat{\theta}_{\mathrm{N}j|\mathrm{M}j})}] / \hat{\Delta}(t),$$

where

$$\hat{\Delta}(t) \equiv \sum_{k=\mathrm{E,U,N,M}} \left[\sum_{l=\mathrm{E,U,N}} [z_{kl}(t) z_{k\mathrm{M}}(t)^{\hat{\theta}_{kl|k\mathrm{M}}} z_{\mathrm{M}l}(t)^{\hat{\theta}_{kl|\mathrm{M}l}}] + z_{k\mathrm{M}}(t)^{(1-\hat{\theta}_{k\mathrm{E}|k\mathrm{M}}-\hat{\theta}_{k\mathrm{U}|k\mathrm{M}}-\hat{\theta}_{k\mathrm{N}|k\mathrm{M}})} \right].$$

Fitted values for classification- and margin-adjusted estimates were computed by using the formula $\mathrm{vec}[\hat{\mathrm{M}}(t)] = [\hat{B}(t-1) \otimes \dot{B}(t)]^{-1}\mathrm{vec}[\hat{\Pi}(t)]$, where $\hat{B}(t) \equiv \{\hat{\beta}_{i|j}(t)\}$ and $\hat{\beta}_{i|j}(t) \equiv$ estimated probability of observing status i when status j is true for month t.

[*Received October 1984. Revised February 1985.*]

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