COMPARING A FIXED-PANEL SAMPLE DESIGN WITH A ROTATING-PANEL SAMPLE DESIGN FOR MONTHLY TRADE SURVEYS

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ABSTRACT

The Bureau of the Census currently uses a rotating-panel sample design for monthly surveys of retail and wholesale trade. Most of the sample firms belong to one of three rotating panels. They are contacted every third month and report data for the two most recent months. The use of composite estimation reduces the variance of estimates, but also requires us to revise the estimates one month after the data are first available. Unfortunately, the revisions have been undesirably large in many months. We now plan to implement a fixed-panel design when we introduce the next sample in early 1997. All sample units would report each month. When measuring month-to-month trend under this sampling plan, the total overlap in consecutive months compensates for the fact that we obtain only one month of data from each sample contact. Further, the revisions are expected to be small, due mainly to corrections to the microdata. In this paper we compare a fixed-panel design with the current rotating-panel design, addressing sampling variability, revisions to the estimates, data quality, and other issues.

KEY WORDS

Revisions, Composite Estimation, Panel Imbalance, Response Bias

1. INTRODUCTION

In the Census Bureau's monthly surveys of retail and wholesale trade, we use a rotating-panel design. Larger firms are asked to report sales or inventories each month. Smaller firms belong to one of three rotating panels. They are contacted only every third month and report data for the two most recent months. Under this design we obtain eight months of data from the smaller firms through only four contacts per year, potentially reducing costs. By compositing data from the current and the prior month, we reduce the variance of estimates of monthly level significantly, and estimates of month-to-month trend slightly.

Because the data for a given month are collected during two separate periods, the Bureau first releases a preliminary estimate for monthly level and month-to-month trend. A month later we provide the final estimate, incorporating sample units that report later. The difference between the preliminary and the final estimates is called the revision to the estimate. Through analysis and our estimation methods, we hope to keep the monthly revisions as small as possible. Yet they have been too large in many months, and for some kinds of business tend to follow a clear cyclical pattern.

We are now investigating the implications of implementing a fixed-panel design when we introduce the next sample, planned for March 1997. All sample units would report each month for only the current month. In this paper we compare a fixed-panel design with the current rotating-panel design. We examine the issues of sampling variability, revisions, panel imbalance, response bias, cost, respondent burden, and data quality.

Section 2 describes the design of our monthly surveys of retail and wholesale trade, while Section 3 details the system of estimation and other important operations. The main problem with the current procedure, large revisions, is demonstrated in Section 4. Here, we portray the sources of the revisions--panel imbalance and differential response bias--and what we have done recently to address the problem.

In Section 5, the fixed-panel design is introduced. Its effects on variances and revisions are discussed in Section 6. The variance of monthly level increases significantly under the new sampling plan. However, the variance of month-to-month trend remains about the same. Although we obtain less information per sample contact, all units report in the two months. Section 7 covers some of the effects on operations and data quality. These are more difficult to assess, but offer arguments for changing to a fixed-panel sample. Concluding remarks are made in Section 8.

2. BACKGROUND ON THE SURVEY DESIGN

The Bureau of the Census conducts four monthly surveys in retail and wholesale trade. The Monthly Retail Trade Survey (MRTS) measures sales in the kinds of business designated by Standard Industrial Classification (SIC) codes 52 through 59. The Retail Inventory Survey (RIS) measures inventory in these businesses. The Advance Monthly Retail Trade Survey (MARTS) is a subsample of the MRTS, conducted only a few days after the end of the data month. Although the MARTS canvasses a smaller number of retailers and reports on fewer major SICs than the MRTS, it provides an early estimate of retail sales about one month *before* the MRTS estimate is available. In the Monthly Wholesale Trade Survey (MWTS) the Census Bureau collects sales and inventory data from merchant wholesalers in SICs 50 and 51.

This paper focuses on the rotating-panel design used in the MRTS and MWTS. Sample units in the MARTS do not rotate in and out of sample, but report every month. Because the RIS follows the same design as the MRTS sample, we will not discuss it again in this paper.

In the 1940's, the Sample Survey of Retail Stores measured retail levels and trends on a monthly basis (U.S. Bureau of the Census 1953). At that time, sample units selected from the Economic Census list reported each month. The list frame was supplemented by an area sample which was divided into 12 equal panels. The sample units in these panels reported once a year, supplying their sales for the current month and the prior month. Composite estimation was introduced at the end of the 1940's to take advantage of the rotating panels in the area sample (Woodruff 1963). Variances--particularly for measuring monthly level--are reduced by using the partial overlap in the sample.

The area frame was eliminated in the early 1990's as the Census Bureau has obtained more complete administrative records from the Internal Revenue Service (IRS). Over time, the number of rotating panels has been reduced, until we now rotate three panels in and out of sample.

The current designs of the MRTS and the MWTS are similar in most aspects except the industries and the geographic areas they cover. The monthly samples for estimating retail sales and wholesale sales and inventories are selected every five years from the Standard Statistical Establishment List. The list is a register of establishments that report quarterly payroll data to the Internal Revenue Service. Before selecting the sample, we group together establishments belonging to the same

company, and assign a major kind of business to the company according to its SIC. Within each major SIC, the largest companies are designated as "certainties," that is, placed in sample with probability one. These companies report their sales *every month* shortly after the end of the month. In 1992, when the Census Bureau last reselected their samples, about 3500 companies were selected with probability 1 in the MRTS and about 1800 in the MWTS.

The establishments in all remaining companies are then identified by their Employer Identification Number (EIN), and placed together with any other establishment in the same trade area and with the same EIN. Within major SIC and trade area, the EINs are stratified according to their total annual sales. We select a simple random sample from each stratum, and assign weights inversely proportional to the probabilities of selection.

To extract more information from fewer sample cases, we select three times as many noncertainty sampling units as the design calls for, and systematically divide these cases into three rotating panels. The firms in a given panel are contacted *only every third month*, and report their sales or inventories from the most recent two months. This two-level, three-panel design is depicted in Table 1.

Table 1. Source of Monthly Data From the Three Rotating Panels

	PANEL[1]		
	1	2	3
January	current	prior[2]	
February		current[2]	prior
March	prior		current
April	current	prior	
May		current	prior
June	prior		current
July	current	prior	
August		current	prior
September	prior		current
.	.	.	.
.	.	.	.
.	.	.	.

[1] Certainty units report every month.

[2] Panel 2 rotating units provide these current- and prior-month data at the same time. Other panels respond analogously in the appropriate months.

For example, early in March sample units in Panel 2 report their "current month" sales for February and their "prior month" sales for January. These firms in Panel 2 are contacted again three months later to provide sales figures for May and April, and so on. In retail, each panel has about 9000 sample units covering the various SICs. This number is about 1700 in the wholesale survey.

Under this design, each panel reports four times a year, giving us eight months of data through only

four contacts, potentially reducing costs. Thus, for any specific month, we collect sales or inventory data from two of the three rotating panels (in two successive monthly data collections) in addition to the certainties, which report every month. For more information on the design of the Monthly Retail Trade Survey, see U.S. Bureau of the Census (1996). As we stated above, the design of the Monthly Wholesale Trade Survey is similar.

3. ESTIMATION AND OPERATIONS

3.1 Composite Estimation

To estimate total sales, we start by summing the weighted sales values. However, because we rotate three panels of noncertainty units in and out of sample, we might see considerable differences in the measures of monthly levels due merely to the different constitutions of the panels. To benefit from the rotating panel design, we apply a composite estimator--a linear combination of estimates using data from the current month and earlier months. This estimator, as applied in the MRTS and the MWTS, is described in Woodruff (1963) and Wolter (1979). They demonstrate how composite estimation reduces the variance of estimates of monthly level significantly, and estimates of month-to-month trend slightly, compared to the usual weighted estimator.

Let $U_{t,i}$ be the "unbiased" sample weighted estimator of sales from the certainty units and from the panel reporting for month t, where i = 1 (current-month estimator) or 2 (prior-month estimator) and t = 1, 2, 3, ... (The panel reporting is Panel $\text{mod}_3(t+i+1)+1$.) The weight for any sample unit is the inverse of its probability of selection.

Shortly after month t ends, the units in the designated panel report (i) current-month sales for month t (yielding, along with responses from the certainties, $U_{t,1}$) and (ii) prior-month sales for month t-1 ($U_{t-1,2}$). After the responses are processed, edited, and combined with data from the previous month, the Census Bureau releases a "preliminary" estimate for month t, defined recursively as

$$P_t = (1-\beta)\, U_{t,1} + \beta\, (U_{t,1} / U_{t-1,2})\, P_{t-1}, \qquad \textbf{(1)}$$

where β = .75 in MRTS and .65 in MWTS.

One month later, we collect prior-month data *for month t* from the next panel, yielding $U_{t,2}$. (Additional data collected from this panel also produce a current-month estimate, $U_{t+1,1}$, for data month t+1.) Combining these responses with those obtained earlier, we publish a "final" estimate for month t:

$$F_t = (1-\alpha)\, U_{t,2} + \alpha\, P_t\,, \qquad \textbf{(2)}$$

where α = .80 in MRTS and .70 in MWTS. The demand for the data as soon as they are available makes it necessary to release the preliminary estimate before data from the second panel are processed. Because the certainties report every month for current-month sales, they typically do not report a prior-month figure unless there is a correction to make or a revised sales figure.

We call the change from P_t to F_t, that is, $F_t - P_t$, the "revision" in sales for monthly level.

3.2 Birth Processing

In the monthly surveys of retail and wholesale, the Census Bureau attempts to include the contribution of companies that are newly formed or reorganized as well as those that cease operations. Each quarter a representative sample of cases recently assigned employer identification numbers (EINs) by the IRS are selected from the latest available IRS mailing list of FICA tax payers. These new cases, or *births*, are selected using a two-phase procedure. In the first phase, births are stratified by kind of business and a measure of size based on expected employment or quarterly payroll. A relatively large sample is drawn and canvassed to obtain a more reliable measure of size (sales), and a more detailed kind-of-business code, if needed.

Using this more reliable information, the births selected in the first phase are subjected to a second phase of sampling so that the overall probabilities are equivalent to those used in drawing the initial sample. Because of the lag in reporting births to the IRS and the time needed to accomplish the sampling, births are added to the sample six to nine months after they begin operation. During this lag, data from the existing sample account for the month-to-month changes; later we benchmark the monthly level estimates to be consistent with the prior annual survey.

Sample units that go out of business or are assumed under the organization of another company, *deaths*, are tracked as well. Their status is investigated to determine whether they have merely changed their name and EIN. If so, the successor is retained in the sample.

This birth process is conducted once each quarter, but the effects are brought in gradually. Because most of the births and deaths are smaller units, they tend to be noncertainties assigned to one of the rotating panels. Each panel reports only once each quarter, so the births are brought in and deaths are removed from sample over three months. We would prefer to incorporate births and eliminate deaths at the moment they occurred; this would better reflect the true level of trade. But the births are not canvassed for the first time until well after they begin operations. As we are actually measuring activity more than six months later, we feel it best to spread this effect over three months. The rotating-panel design does this automatically.

3.3 Large Observation Procedures

We currently employ two procedures to lessen the influence of noncertainty observations with unexpectedly large sales. Both procedures lead to unbiased estimates with reduced variance.

The first procedure is known as the temporary monthly noncertainty (TMNC) procedure. This procedure reduces the impact of noncertainty sampling units with occasional or temporary increases in sales. Current month data for each sampling unit in the previous month's rotating panel are tested against a large observation cutoff corresponding to the month and the unit's kind-of-business. Any unit with sales exceeding the cutoff is enumerated for an additional month. After the current month enumeration, prior-month data for all units in the current month are also compared against the previous month cutoff. All units in the current and prior month rotating panels which exceeded the previous month cutoff are tabulated in the current month with half their usual monthly weight. All remaining units are tabulated with their full monthly weight.

The second large observation procedure is known as the permanent monthly noncertainty (PMNC)

procedure. This procedure treats noncertainty sampling units which have undergone such significant growth that their measure of size at the time of sample selection is no longer representative of the unit's current size.

In January and June of each year, all sampling units in each of the three rotating panels are tested for PMNC status. If a sampling unit had sales exceeding the TMNC cutoff in each of the preceding six months, then it qualifies as a PMNC. The case is placed in a separate fixed panel (Panel 5), enumerated every month, and tabulated with one-third its previous monthly weight. Table 2 gives the full picture of the sample units and their reporting schedules. Panel 0 contains all units originally selected with probability 1; Panel 5 contains the PMNCs. (There is no Panel 4.)

Table 2. Source of Monthly Data From the Fixed and Rotating Panels

	PANEL				
	0[1]	1	2	3	5[2]
January	current	current	prior[3]		current
February	current		current[3]	prior	current
March	current	prior		current	current
April	current	current	prior		current
May	current		current	prior	current
June	current	prior		current	current
July	current	current	prior		current
August	current		current	prior	current
September	current	prior		current	current
.		.	.		.
.		.	.		.
.		.	.		.

[1] Panel 0 cases are the certainties. (Probability of selection equals 1.)

[2] In Panel 5 are cases that have grown uncharacteristically large compared to their original measure of size.

[3] Panel 2 rotating units provide these current- and prior-month data at the same time. Panels 1 and 3 respond analogously in the appropriate months.

Note: All units *except those originally in Panel 2* report in the annual survey.

4. REVISIONS TO THE DATA

Too often in recent years our retail and wholesale data have been plagued by occasional large revisions from the preliminary to the final estimate. For example, since April 1992, when the Census Bureau started releasing estimates from a new sample, most of the revisions for the U.S. total in retail sales have been upward, that is, the final estimate has been greater than the preliminary. More important, some revisions have been as large as .3% or .4% of the total value. The average percent

revision over this period has been +.15% for sales, and .26% for inventories. Table 3 presents the revisions for sales from April 1992 to August 1995.

Table 3. Monthly Revisions (Volume and Percent) in Retail Sales, U.S. Total

YR MO	$F_t - P_t$[1]	(F/P-1)%	YR MO	$F_t - P_t$[1]	(F/P-1)%	YR MO	$F_t - P_t$[1]	(F/P-1)%
92 04	-116	-.07%	92 05	371	.23%	92 06	216	.13%
92 07	144	.09%	92 08	-32	-.02%	92 09	-109	-.07%
92 10	723	.43%	92 11	401	.24%	92 12	304	.15%
93 01	136	.09%	93 02	494	.34%	93 03	-291	-.18%
93 04	458	.27%	93 05	731	.42%	93 06	369	.21%
93 07	305	.17%	93 08	225	.13%	93 09	122	.07%
93 10	212	.12%	93 11	530	.29%	93 12	-79	-.04%
94 01	253	.16%	94 02	461	.29%	94 03	439	.24%
94 04	377	.21%	94 05	739	.39%	94 06	214	.11%
94 07	20	.01%	94 08	646	.33%	94 09	253	.14%
94 10	82	.04%	94 11	633	.33%	94 12	-138	-.06%
95 01	153	.09%	95 02	298	.18%	95 03	-263	-.14%
95 04	196	.10%	95 05	190	.09%	95 06	200	.10%
95 07	94	.05%	95 08	671	.33%			

[1] In millions of dollars.

In addition to an upward trend in these revisions, one notices a cyclical pattern. The largest revisions tend to be in cycle 2 (the months of February, May, August, and November), while most of the downward revisions are in cycle 3 (March, June, September, and December).

This problem of large and somewhat predictable revisions is not confined to retail sales. In wholesale, the cyclical pattern is even more pronounced at the U.S. total for sales and inventories, as Table 4 demonstrates. The revisions are displayed for April 1992 through October 1995. For all months beginning with October 1993, two numbers are given. As we will discuss in Section 4.3, at that time the Census Bureau started to adjust the preliminary composite estimates in some wholesale SICs to rectify the problem of panel imbalance. The numbers in parentheses represent the revisions that would have occurred had we made no adjustments. The second number in the table cell is the revision based on the adjusted preliminary estimate.

Small revisions in the estimates are expected because of the rotating design of the surveys and the use of composite estimation. But the cyclical pattern and (for retail) the consistent upward direction of the revisions are due mainly to phenomena we call panel imbalance and differential response bias.

4.1 Panel Imbalance

When we select the noncertainties within each SIC and size stratum for the retail and wholesale surveys, we draw a sample three times the designated size and assign the units systematically to the three panels. Before the first contact, each unit is re-examined to make sure that the early estimate of sales used to stratify the units is as accurate as possible. In this way, as the new sample is phased

in, the three panels have essentially the same number of units and, we hope, about the same total volume of sales.

Table 4. Monthly Revisions (Percent) in Wholesale Sales and Inventories, U.S. Total (With Adjustments Applied Starting in 93 10)

SALES

YR MO	(F/P - 1)%	YR MO	(F/P - 1)%	YR MO	(F/P - 1)%
92 04	1.77	92 05	-0.32	92 06	-1.14
92 07	1.68	92 08	-0.39	92 09	-1.49
92 10	1.56	92 11	-0.56	92 12	-0.79
93 01	1.12	93 02	-0.42	93 03	-0.98
93 04	1.63	93 05	0.07	93 06	-0.60
93 07	1.09	93 08	-0.75	93 09	-1.17
93 10	(1.82) 0.93	93 11	(-0.96) -0.67	93 12	(-0.52) 0.06
94 01	(1.36) 0.25	94 02	(-0.29) 0.07	94 03	(0.04) 0.67
94 04	(2.07) 1.09	94 05	(-0.40) -0.02	94 06	(-0.18) 0.42
94 07	(1.64) 0.66	94 08	(-0.03) 0.36	94 09	(-0.88) -0.30
94 10	(1.80) 0.88	94 11	(0.14) 0.50	94 12	(-0.32) 0.32
95 01	(1.88) 0.97	95 02	(-0.12) 0.26	95 03	(-0.46) 0.18
95 04	(1.68) 0.34	95 05	(0.10) 0.71	95 06	(-0.70) -0.03
95 07	(1.36) 0.14	95 08	(-0.26) 0.23	95 09	(-0.60) 0.10
95 10	(1.56) 0.38				

INVENTORIES

YR MO	(F/P - 1)%	YR MO	(F/P - 1)%	YR MO	(F/P - 1)%
92 04	0.56	92 05	-0.70	92 06	-0.28
92 07	0.35	92 08	-0.10	92 09	-0.47
92 10	1.46	92 11	0.13	92 12	-0.02
93 01	0.60	93 02	-0.26	93 03	-0.54
93 04	0.79	93 05	-0.21	93 06	-0.41
93 07	0.84	93 08	-0.31	93 09	-0.66
93 10	(1.01) 0.53	93 11	(-0.12) -0.01	93 12	(-0.52) -0.14
94 01	(1.26) 0.42	94 02	(-0.23) -0.08	94 03	(-0.12) 0.39
94 04	(1.19) 0.68	94 05	(-0.14) -0.02	94 06	(-0.15) 0.35
94 07	(1.41) 0.79	94 08	(-0.54) -0.43	94 09	(-0.30) 0.24
94 10	(1.51) 0.87	94 11	(-0.67) -0.54	94 12	(-0.24) 0.28
95 01	(1.55) 0.96	95 02	(-0.54) -0.42	95 03	(-0.62) -0.14
95 04	(1.51) 0.29	95 05	(-0.09) 0.33	95 06	(-0.43) 0.38
95 07	(1.61) 0.37	95 08	(-0.90) -0.47	95 09	(-0.08) 0.74
95 10	(1.38) 0.09				

Unfortunately, several things can happen to upset this balance *as measured by the volume of sales*, either at the phase-in of the sample or during the subsequent five years. Even before our first contact with new sample units, the dollar volumes of the panels may differ due simply to random chance in assigning units to the three panels or to an inaccurate measure of size used to stratify and select the units. Then, during the five years the firms are asked to report, sample births and deaths can further upset the balance among the three panels. We assign births to panels in a way that tries to balance the number of sample units across panels within sampling strata. There is no guarantee, however, that the dollar volume of sales is balanced as well.

The effects of panel balance on the consistency between the preliminary and final estimates--and thus on the revisions--was studied in Cantwell, Caldwell, Hogan, and Konschnik (1995). They showed that, when one panel is much larger or smaller than the others, and panel imbalance dominates other potential factors, the result can be *large revisions occurring in specific cycles*. See the appendix for a brief mathematical derivation of this result. This pattern is summarized in Table 5.

Table 5. Likely Results of Panel Imbalance on Revisions by Cycle

Relative sizes of panels	Cycle 1 Months 1, 4, 7, 10	Cycle 2 Months 2, 5, 8, 11	Cycle 3 Months 3, 6, 9, 12
Panel 1 > 2 > 3	?	negative revisions	positive revisions
Panel 1 > 3 > 2	negative revisions	?	positive revisions
Panel 2 > 1 > 3	positive revisions	negative revisions	?
Panel 2 > 3 > 1	positive revisions	?	negative revisions
Panel 3 > 1 > 2	negative revisions	positive revisions	?
Panel 3 > 2 > 1	?	positive revisions	negative revisions

Where the question marks appear in the table, the revisions may tend to go in either direction, depending on the actual differences in the sizes of the panels. As an example of what might occur, suppose that panel 2 is much larger than panel 3, which in turn is larger than panel 1. If panel imbalance is the main effect, we might expect to see large positive revisions in cycle 1 and large negative revisions in cycle 3. This is indeed what has happened in several SICs that are responsible for a significant part of total sales and inventories in the MWTS. Thus it is not surprising that panel 2 is the largest when aggregated to the U.S. total for wholesale. The revisions as shown in Table 4 follow.

4.2 Differential Response Bias

A different problem can arise if the rotating sample units report their sales figures differently for the current month and the prior month. Reasons for differences in the reporting practices of sample firms have been proposed and studied for many years. Perhaps the brief period given to determine the sales figure after the data month ends allows some respondents only enough time to provide a rough estimate. But for the prior month, these same respondents have had plenty of time to complete

their accounts and give us a good "book value." How prevalent this phenomenon is might depend on the size of the company, the kind of business, the recent level of price changes, and the availability of computerized accounting systems.

Waite (1974) investigated the bias due to early reporting in responses to the MRTS. Based on data collected in 1973, he observed that (p. 604) “This bias does seem to differ for the two reporting periods. ... The current month's sales seem to be underestimated to a greater degree than the previous month's sales.” Although several theories have been offered, it is not known why early estimates tend to be lower than book values.

When current-month responses tend to be biased downward more so than prior-month responses and this response bias is the dominant effect, it is easy to show that the preliminary and final estimates tend to be biased downward, and *the revisions from preliminary to final tend to be positive*. Details are in the appendix.

In this section and 4.1, we've seen what can happen if panel imbalance or differential response bias alone are present in the design or the data collection. In reality, these effects often occur together. Then, the revisions are generally driven by the stronger factor which--data have shown--is usually panel imbalance (Cantwell et al. 1995). Thus, in many SICs where the response effect is strongly significant, the more powerful influence of panel imbalance dominates the three-month cycle of revisions. Across the three cycles, we see both upward and downward revisions. Still, in this situation the *average revision over all months* tends to be positive. See, for example, Table 2, for the revisions in U.S. total for retail sales.

4.3 A Mathematical Remedy to Reduce the Revisions

Several times in the 1970's and 1980's the Census Bureau has adjusted the preliminary estimates in a survey to address the problem of panel imbalance. The Monthly Wholesale Trade Survey is currently being adjusted in several SICs. Since April 1992, the Bureau's wholesale estimates have been based on a new sample. As we described in section 4.1, a cyclical pattern of revisions emerged in several wholesale SICs and in the U.S. total for sales and inventories (Table 3).

In October 1993, the Census Bureau began adjusting the MWTS preliminary estimates for sales and inventories in several SICs. The SICs affected--501, 506, 508, 514 (sales only), and 517--were chosen according to the size and consistency of the revisions observed. By modeling the recent revisions as a time series with a three-month cycle, the adjustment predicted the value of the next revision. This method produced a factor which, when applied to the preliminary estimate, would bring the preliminary more in line with the final estimate to be computed one month later. Greater detail about the adjustment can be found in Caldwell, Monsell, Piesto, and Shimberg (1994). The paper describes the selection of the new sample, the Census Bureau's efforts to determine and correct the source of the imbalances in the panels, the seasonal adjustment technique used, and some early results of the procedure.

Since that paper was written, more data have been collected. Now comparisons are available for 25 months (starting in October 1993) between the revisions based on the unadjusted and the adjusted preliminary estimates. These are shown in Table 4 for the U.S. total in wholesale. This table includes the estimates without adjustment (in parentheses) and with adjustment as published. By

adjusting the preliminary estimates in several problem SICs, the revisions for the U.S. total sales and inventories in wholesale have been consistently reduced in the problem cycle, cycle 1 (January, April, July, October). In the other cycles, the revisions have decreased more often than not, usually by relatively small amounts.

Although adjusting the preliminary estimates has greatly reduced revisions in wholesale and removed much of their cyclical pattern, this solution cannot be counted on to resolve the problem in general. The problem is that this method requires many months of preliminary and final estimates based on the new sample to determine the pattern of revisions and to model the three-month time series. This is usually too long to wait, leading to many large revisions before the adjustment can be implemented.

5. A FIXED-PANEL DESIGN

Rotating units in and out of sample can reduce variances. But other factors such as panel imbalance and reporting bias can induce large or cyclical revisions from the preliminary to the final estimate. An alternative is a fixed-panel design. Here, all units would report only current-month sales every month for the life of the sample. As this design can eliminate large revisions, it is worth considering despite some increases in variance.

Under the new design, large companies (certainties) would again be selected with probability 1 in the various kinds of business (SICs) and assigned to Panel 0. Then two panels would be selected from the remainder of the frame, each representing the entire SIC. Panel 1 would report in the annual survey *and* every month in the monthly survey; Panel 2 would report *only in the annual survey*. The intent is to double the number of noncertainty units in the annual survey to reduce the sampling variance of estimates of annual sales and inventories. The noncertainty units have their weights cut in half for the purpose of estimation in the annual survey.

Our current plans call for selecting about the same number of certainty companies into the samples for the monthly retail and wholesale surveys as under the old design. Similarly, the number of noncertainties reporting each month will be about the same as had been in each of the three rotating panels. In this way, the annual surveys will have the same sample size as before the change in design.

From the data for month t in the fixed panel, we derive an unbiased weighted estimate, denoted here by U_t. The sample weights are simply the inverse of the probabilities of selection. With sample rotation eliminated, composite estimation no longer reduces variances and thus is not considered. One month after its release, the published estimate U_t would be revised only to reflect data corrections or revised sales figures, births and deaths just being tabulated, and perhaps other minor changes. Our research has shown that, while it is not unusual for reporting units to correct their sales or inventories given 30 additional days, this should not cause major revisions in the published totals.

Note, however, that in our current rotating procedure, the final estimate reflects the inclusion of an entire panel not covered in the preliminary estimate. As shown in the last section, this additional panel may well be considerably larger or smaller in size than the one that reported earlier. There is no such additional panel to affect the revision under a fixed-panel design. Thus, we expect to see revisions much smaller than those we currently experience.

6. EFFECTS ON VARIANCE (CVs) AND BIAS

6.1 Variances (CVs) of Monthly Level and Trend

Along with cost, one of the most important features of any design is the level of the resulting sample variances or coefficients of variation (CVs). As we indicated in the last section, we retain the same sample size in the fixed panel (deriving U_t) as we had in the rotating design (P_t, equation (1)). But the variance of P_t is smaller than that of U_t due to the use of composite estimation. Further, after the next panel reports for month t in the rotating design, additional independent observations (noncertainties) are available, giving a final estimate F_t whose variance is smaller still.

To compare CVs under the two designs, other conditions are kept the same wherever possible. Formulae for the CVs of the composite estimators are found in Wolter (1979, section 3.2). We insert $\beta = .75$ and $\alpha = .80$, coefficients used in the composite estimates in the MRTS. For this example, the correlations between unbiased estimates from the same panel 1, 3, 6, 9, and 12 months apart are assumed to be .90, .80, .75, .70, and .80, respectively. These numbers are used only for this demonstration; the actual correlations vary according to SIC.

We assume further that the one-month correlation remains the same (.90, here) if we implement a fixed panel. Whether this actually holds is uncertain. With rotating panels, the one-month correlation is measured on $U_{t,1}$ and $U_{t-1,2}$. For rotating units, the pertinent sales figures are reported at the same time; this may induce an artificially high correlation between the estimates. It has also been suggested that the estimate of this correlation is increased because of our imputation procedure. With a fixed panel, the sales figures in U_t and U_{t-1} are reported a month apart and likely would yield a slightly smaller (but more realistic) correlation. Nevertheless, imputation for missing months may still keep the estimated correlation higher than the true value.

With the parameters as given, we observe the following results for estimates of retail sales:

- $CV(U_t) \approx 1.2476\ CV(P_t)$,
- $CV(U_t) \approx 1.4007\ CV(F_t)$, but
- $CV(U_t/U_{t-1}) \approx 1.0174\ CV(P_t/F_{t-1})$. ($P_t/F_{t-1}$ is the best measure of trend under the rotation design.)

The third result--very little difference between the two designs in the CVs for trend--follows because all respondents report in consecutive months in the fixed-panel design.

It should be noted that (1) the results given depend on the strengths of the correlations of the estimates across months, which vary among the kinds of business; and (2) other trends are also estimated and published each month: current month to the month one year ago, current quarter to previous quarter, current quarter to the quarter one year ago, etc.; here we focus on the two simplest and most important estimates.

When the Census Bureau began rotating panels in and out of sample, a greater emphasis was placed on estimates of monthly level than on estimates of month-to-month trend (Woodruff 1963, p. 455). Since that time, however, the Census Bureau has instituted a system by which the estimates of monthly level are benchmarked to the annual surveys, which are in turn benchmarked to the Economic Census (taken every five years). Because the benchmarking operations take advantage of the greater sample sizes and mandatory reporting in the annual surveys and the Economic Census, the importance of estimates of monthly level has diminished relative to that of estimates of month-to-month trend.

It should be noted that the CVs for monthly levels as computed here are based on the estimates before benchmarking to the annual surveys and Economic Census. If benchmarking is considered in determining the CVs for monthly level, we believe the CVs will decrease but leave a similar difference in CVs between the rotating and fixed-panel designs. The CVs for trend are not affected by the benchmarking.

6.2 Eliminating Panel Imbalance

Sampling via a fixed panel cannot eliminate all adverse effects. For example, the single panel itself may well over- or underrepresent the frame. That is, if all sample units in the panel reported their true value of sales, the weighted sum of these units might still show a difference somewhat above (or below) the true frame total for the SIC. But this is a smaller problem under a fixed-panel design. When measuring month-to-month trend, the excess (or deficit) essentially cancels. This does not happen when estimating monthly level. But if the level is benchmarked effectively, it is brought more in line with the frame total.

6.3 Eliminating Differential Response Bias

Data have shown that in retail sales current-month estimates appear to be biased downward much more so than prior-month estimates. With a fixed panel, all sample units would report only the biased current-month sales. But with rotating panels, all noncertainty units report for current- and prior-month sales, the latter being incorporated into the final composite estimate (F_t). The question then arises: If only the current-month estimate is biased, which design is to be preferred?

To simplify the answer, we ignore the effects of panel imbalance. Suppose (1) the current-month estimate is biased downward, that is, $E(U_{t,1}) = r \times$(true monthly total), where $r<1$; but (2) the prior-month estimate is unbiased, that is $E(U_{t,2})$ = (true monthly total). It is then easy to show that the preliminary *and* the final composites (under the rotating-panel design) tend to exhibit a *greater downward bias* than the current-month "unbiased" estimator (under the fixed-panel design). (See the appendix.) That is, typically

$$P_t < F_t < U_t < \text{true monthly total}$$

This result can be explained by recalling the definitions of P_t and F_t in (1) and (2):

$$P_t = (1-\beta)\, U_{t,1} + \beta\, (U_{t,1}/U_{t-1,2})\, P_{t-1}, \quad \text{and} \quad F_t = (1-\alpha)\, U_{t,2} + \alpha\, P_t.$$

Under these conditions, $U_{t,1}$ and $U_{t,1}/U_{t-1,2}$ are biased downward, edging P_t downward. Further, in

the formula for F_t the unbiased estimate from prior-month reporters ($U_{t,2}$) has a small coefficient, 1-α, while P_t is more heavily weighted (α is 80% in MRTS, 70% in MWTS).

Table 6 demonstrates what happens to the approximate values of the estimators in retail sales for different values of r under these idealistic conditions. Although the fixed-panel "unbiased" estimate is biased downward, its bias is less than that of the rotating panels' composite estimators.

Table 6. Comparison (Approximate Values) of Several Estimators Relative to the True Monthly Total When Current-Month Responses are Biased Downward (r<1)

	Preliminary Composite P_t	Final Composite F_t	Fixed Panel Estimate U_t
r = .9999	.9996	.9997	.9999
r = .999	.9960	.9968	.9990
r = .995	.9803	.9842	.9950
r = .99	.9612	.9689	.9900
r = .98	.9245	.9396	.9800
r = .97	.8899	.9119	.9700
r = .95	.8261	.8609	.9500

7. EFFECTS ON OPERATIONS AND DATA QUALITY

7.1 New Procedures for Births and Outliers

Ironically, the rotating design handles births and deaths more simply than the does the fixed-panel design. As we saw in section 3, births cannot be incorporated immediately. It takes about six to nine months to learn of changes in company status from tax records, to conduct the two-stage sampling for births, and to start processing the data from the new companies.

Once these sample births are ready to report, all except the very largest are assigned to one of the three rotating panels. For example, new births selected through the quarterly birth processing procedure--as well as the recent deaths--are determined and ready for sample in February, again three months later in May, etc. In the first case, their total contribution for the quarter is split over February, March, and April as the panels report individually.

With a fixed panel, we could have all births begin reporting as soon as they are available, and remove all deaths once their status is known. In the current example, this would occur in February. But we would then attribute the total change--the volume of the births minus that of the deaths--to February. This would inject a component of abrupt change into the January-to-February trend, and later to the April-to-May trend, etc.

Since we must incorporate the true effect of births and deaths many months after the real changes, we prefer at the least to spread the effect across the three months when they are finally brought in.

In this way, there will be no additional components in the trend estimates for February, May, August, and November for company changes that took place many months earlier.

Implementing a fixed panel also requires a change to the strategy to address large outliers. Recall that, when implementing a fixed panel, we would select two panels of noncertainties. Only Panel 1 reports in the monthly survey, while Panels 1 and 2 report in the annual. The TMNC (temporary monthly noncertainty) procedure used to monitor units more often than every third month would no longer be useful; the monthly noncertainties will be reporting every month already.

However, we still face the problem of units with a large weight whose size (in sales or inventories) is no longer representative of their original stratum. Currently we are considering two procedures. The first would take all units in Panels 1 and 2 that exceed a specified high cutoff and place them in a new PMNC (permanent monthly noncertainty) panel. The weights for these units would be cut in half and they--including those that originated in Panel 2--would report every month.

Although this procedure is unbiased, it has several drawbacks. First, because we enumerate units in Panel 2 only once a year, we may feel less certain that their reported sales or inventories on the annual survey represents their true, high level. Our current TMNC procedure allows us to monitor units every month for half a year before any change is made. But, as indicated, this would be impossible here. Perhaps analysts could contact the company to verify the reported value.

More important though is that the solution could make the problem worse. Because we publish at levels as fine as 4-digit SIC, there may be some kinds of business where there are typically few potential PMNC cases. In half of these SICs, all or most of the cases moved to the PMNC panel could originate in Panel 2. If so, the month-to-month trend jumps artificially in the month the Panel 2 units are moved to the PMNC panel, *even if nothing changed in Panel 1*.

A second approach is biased, but reduces the variance and eliminates the problem just described. Under this procedure, if a unit in Panel 1 exceeds the specified cutoff for a number of months, it is placed in the PMNC panel. At the same time a unit in Panel 2 randomly selected from the same SIC and size stratum is also assigned to the PMNC panel. Each of these units then reports every month. Their weights are cut to one-half the weight originally assigned to sample units in that stratum. For operational simplicity, this procedure might be implemented twice a year.

This scheme biases the totals for the monthly surveys downwards. After cutting the sample weights in half for PMNC units originating in Panel 1, unusual growth in the sample units (above their original measure of size) is not properly represented. Because of the random selection of the accompanying unit from Panel 2, its overall chance of representing the unusual growth is reduced below what is required for an unbiased total.

Though biased, the second procedure may work well. The overall variance is decreased because of the reduction in the weights. Most important, for measuring month-to-month trend, units always move from Panels 1 and 2 to the PMNC panel in pairs, with their weights appropriately cut in half. We do not run the risk of having large units move individually from Panel 2 to the PMNC panel, creating a problem where none existed before. Further, in many cases we see that grow beyond the original measure of size, the growth is not characteristic of the other units being represented by the sample. For example, occasionally a unit with a small measure of size acquires a chain of

establishments. This sample unit is now many times the original size. Although each unit in the stratum could conceivably grow in a similar manner, attributing such change to all units represented generally overestimates the true total for the stratum. A final decision on how to treat such cases will be made soon.

7.2 Analysis of Data

Operating with a fixed panel will make analysis of microdata and aggregates much simpler. First, we will have twelve months of data per year (assuming complete response) rather than eight months. This will allow analysts to better monitor the microdata series and check for unusual or suspect responses. Second, with no composite estimator, we can more easily measure an individual firm's effect on the total estimate. Similarly, the effect of births and deaths will be easier to gauge. Removing the confounding effects of panel imbalance and response bias will simplify the analysis of estimates by kind of business.

Third, reconciliation with the annual surveys will be easier. As a check on data quality, at the end of the year the estimates of the monthly retail (MRTS) and wholesale (MWTS) surveys--summed over the twelve months--are compared by kind of business to those from the annual surveys. The differences are reconciled where possible. For individual units, we collect eights months of data from the monthly surveys and project a year's estimate for comparison with the reported value from the annual survey. Any difference arises from a combination of sampling error--having only eight out of twelve months--and reporting error. With a fixed panel, there will be reports from all twelve months. Any differences can be attributed strictly to reporting error.

A similar reconciliation is done monthly between the MRTS and the Advance (MARTS) survey, whose data are published earlier for the same data month. Currently, the different designs of the surveys makes this reconciliation more difficult. All units in MARTS report every month. But, although the MARTS is a subsample of the MRTS sample, many MARTS reporters fall in the MRTS sample only every third month. When comparing weighted totals for analogous kinds of business, the differences are often due to different units in the two samples, as well as reporting differences from units in both surveys.

Under a fixed-panel design, all MARTS units will be in the MRTS sample each month. This should increase the consistency between the surveys and reduce the revision from the Advance estimate to the MRTS estimate. Further, there will be a more complete history of data for each firm. This information will allow subject matter specialists to perform more thorough analyses for individual firms and by kind of business.

7.3 Unresolved Issues

Finally, we address three important areas. In all three, no firm conclusions between the two designs can be made at this time.

Cost. Since we do not plan to change the size of the monthly samples as we move to a fixed-panel design, the cost should decrease just slightly. The price for mailing out questionnaires, processing data as they arrive, following nonresponding cases, and analyzing data should be about the same.

The main difference may be in the start-up costs, that is, the additional cost of first introducing a unit into sample. For some units, there is no additional cost, because they respond as we intend immediately. For others, there is some initial correspondence--usually by telephone--to give the respondent information or instructions, to get him to subsample his establishments properly, to make alternate reporting arrangements, etc. These are usually measured in staff time. Although the two designs have the same number of sample units in any month, the fixed panel has only one-third as many noncertainty units. (Most certainty cases continue when the sample is reselected; their start-up costs then are relatively small.)

Unfortunately, attempts to measure start-up costs--even relative to the monthly cost per sample unit--have been unsuccessful. Overall costs are not broken out well over their several components. Although the fixed-panel design will likely cost less than the current rotating-panel design, the difference is expected to be very small.

Response burden. Response burden can be considered in two ways: as it applies to the individual respondent, and the total burden for the survey. For the former, we ignore certainty companies, since they report as before. But for noncertainty units, it is difficult to anticipate how the respondent will react to the new design. Will they prefer to report once every three months, giving us their current sales value and looking up the value for the prior month? Or is it easier to report once each month, never going back to prior months? The answer probably depends on who is responding to the survey, whether he or she prefers to pull the sales figure the same time each month, or what type of accounting system he has. Without canvassing many respondents, we will not pretend to know.

The overall survey burden, however, should be smaller with a fixed panel. Each month about 9000 noncertainty reporters in retail and about 1700 in wholesale will be providing only current-month sales, as opposed to both current- and prior-month sales under the current design.

Response rates. What will happen to response rates when all respondents are asked to report every month? Obviously, the response rate is related to the response burden. How much so is undetermined.

We have studied the response rates of PMNC cases--originally reporting every third month, but later placed in Panel 5, where they respond every month. There was no significant difference in the response rates before and after their move to Panel 5. It is difficult to make any conclusions, however, because these cases have experienced unusual growth and may not be typical of other respondents. Another approach might be to compare the response rates of the smallest certainty units in the MRTS or the MWTS with those of the largest noncertainty (rotating) units. Or one could compare the response rates of units in the MARTS--who report every month--to those of the MRTS or MWTS. A problem here is that response is already lower in the MARTS, due to the shorter time allowed for response. Currently we are investigating several strategies.

8. CONCLUSION

The Census Bureau plans to move from rotating panels to a single fixed panel in its monthly surveys of retail and wholesale trade with the introduction of new samples in early 1997. The chief drawback is the expected increased variance in estimates of monthly level. However, for month-to-month trend, the variance is not expected to change noticeably.

Yet the main reason for changing the design is to reduce the size of the projected revisions. Revisions will no longer be dependent on which panels report for the current and prior months, and how badly the panels are out of balance. Differences due to the way respondents report their current- and prior-month data will be nullified, and downward response bias will have a smaller effect on the final estimates. Smaller factors--data corrections, and recent births and deaths--will determine the size of the revisions.

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APPENDIX

For these derivations, we use the following notation and result. From the definition of the preliminary estimate in (1),

$$P_t = (1-\beta)\, U_{t,1} + \beta\, \Delta_t\, P_{t-1}, \quad \text{where } \Delta_t \text{ is defined here as } U_{t,1} / U_{t-1,2}\,.$$

Continuing recursively,

$$\begin{aligned} P_t &= (1-\beta)\, U_{t,1} + \beta\, \Delta_t\, [\, (1-\beta)\, U_{t-1,1} + \beta\, \Delta_{t-1}\, P_{t-2}\,] \\ &= (1-\beta)\, U_{t,1} + (1-\beta)\, \beta\, \Delta_t\, U_{t-1,1} + \beta^2\, \Delta_t\, \Delta_{t-1}\, [\, (1-\beta)\, U_{t-2,1} + \beta\, \Delta_{t-2}\, P_{t-3}\,] \\ &= \ldots \\ &= (1-\beta)\, \{\, U_{t,1} + \beta\, \Delta_t\, U_{t-1,1} + \beta^2\, \Delta_t\, \Delta_{t-1}\, U_{t-2,1} + \beta^3\, \Delta_t\, \Delta_{t-1}\, \Delta_{t-2}\, U_{t-3,1} \\ &\qquad + \beta^4\, \Delta_t\, \Delta_{t-1}\, \Delta_{t-2}\, \Delta_{t-3}\, U_{t-4,1} + \ldots \,\} \end{aligned} \qquad \textbf{(3)}$$

The revision in monthly level can be expressed as

$$F_t - P_t = (1-\alpha)\, U_{t,2} + \alpha\, P_t - P_t = (1-\alpha)\, (\, U_{t,2} - P_t\,)$$

To show the result in Section 4.1:

When panel imbalance dominates other factors, we can express the unbiased estimate as $U_{t,i} \approx m_t \times p_{j(t,i)}$, where m_t is the true, unknown value of sales for month t; and $p_{j(t,i)}$ is (for j = 1, 2, or 3) the "panel effect"--the average value of the estimate from the reporting panel j *above (p_j>1) or below (p_j<1) the true monthly value* m_t. As noted in Section 3.1, the panel subscript j(t,i) is actually the function $\text{mod}_3(t+i+1)+1$. For simplicity, we drop the implicit t and i, and label this effect p_j. In actuality, other random and nonrandom sources also help determine $U_{t,i}$, but this approximation demonstrates the effects of panel imbalance here.

Under these idealistic conditions, $\Delta_t = U_{t,1}/U_{t-1,2} \approx (m_t\, p_j) / (m_{t-1}\, p_j) = m_t/m_{t-1}$

(because j(t,1)) and j(t-1,2) denote the same panel), and

$$\Delta_t\, \Delta_{t-1}\, \Delta_{t-2} \ldots \Delta_{t-h} \approx (m_t/m_{t-1})\, (m_{t-1}/m_{t-2})\, (m_{t-2}/m_{t-3}) \ldots (m_{t-h}/m_{t-h-1}) = m_t/m_{t-h-1}$$

Then, for cycle 1 (t = 1, 4, 7, 10, ...), the preliminary estimate in (3) is approximately

$$\begin{aligned} P_t &\approx (1-\beta)\, \{\, (m_t\, p_1) + \beta\, (m_t/m_{t-1})\, (m_{t-1}\, p_3) + \beta^2\, (m_t/m_{t-2})\, (m_{t-2}\, p_2) \\ &\qquad + \beta^3\, (m_t/m_{t-3})\, (m_{t-3}\, p_1) + \beta^4\, (m_t/m_{t-4})\, (m_{t-4}\, p_3) + \ldots \,\} \\ &= m_t\, (1-\beta)\, \{\, p_1 + \beta\, p_3 + \beta^2\, p_2 + \beta^3\, p_1 + \beta^4\, p_3 + \ldots \,\} \\ &= m_t\, (\, p_1 + \beta\, p_3 + \beta^2\, p_2\,) \,/\, (1+\beta+\beta^2) \end{aligned}$$

The revision is then approximately

$$\begin{aligned} F_t - P_t &= (1-\alpha)\, (\, U_{t,2} - P_t\,) \approx (1-\alpha)\, (\, m_t\, p_2 - P_t) \\ &\approx m_t\, (1-\alpha)\, \{\, p_2 - (\, p_1 + \beta\, p_3 + \beta^2\, p_2\,) / (1+\beta+\beta^2)\,\} \end{aligned}$$

$$= \quad m_t\,(1-\alpha)\ \{\ (1+\beta)\,p_2\ -\ (p_1 + \beta\,p_3\ )\ \}\ /\ (1+\beta+\beta^2)$$

Comparing the values of p_1, p_2, and p_3, we derive the summary in Table 5. The results for cycles 2 and 3 follow similarly.

To show the result in Section 4.2:

(This parallels the derivation in Waite (1974, pp. 605-606).)

When differential response bias dominates other factors, we can express the unbiased estimate as $U_{t,i} \approx m_t \times r_i$, where m_t is again the true, unknown value of sales for month t; and r_i is the "response effect"--the average value of current-month reporters (i=1) or prior-month reporters (i=2) *above (r_i>1) or below (r_i<1) the true monthly value* m_t. As above, other random and nonrandom sources actually contribute toward $U_{t,i}$.

Then $\Delta_t = U_{t,1}/U_{t-1,2} \approx (m_t\,r_1)\,/\,(m_{t-1}\,r_2)$, and

$$\Delta_t\,\Delta_{t-1}\,\Delta_{t-2} \ldots \Delta_{t-h}$$

$$\approx (m_t\,r_1)/(m_{t-1}\,r_2) \times (m_{t-1}\,r_1)/(m_{t-2}\,r_2) \times \ldots \times (m_{t-h}\,r_1)/(m_{t-h-1}\,r_2)$$

$$= (r_1/r_2)^{h+1}\,(m_t/m_{t-h-1})$$

Inserting into (3),

$$P_t \approx (1-\beta)\ \{\ (m_t\,r_1) + \beta\,(r_1/r_2)\,(m_t/m_{t-1})\,(m_{t-1}\,r_1) + \beta^2\,(r_1/r_2)^2\,(m_t/m_{t-2})\,(m_{t-2}\,r_1)$$
$$+ \beta^3\,(r_1/r_2)^3\,(m_t/m_{t-3})\,(m_{t-3}\,r_1) + \beta^4\,(r_1/r_2)^4\,(m_t/m_{t-4})\,(m_{t-4}\,r_1) + \ldots\ \}$$
$$= (1-\beta)\,m_t\,r_1\ \{\ 1 + \beta\,(r_1/r_2) + \beta^2\,(r_1/r_2)^2 + \beta^3\,(r_1/r_2)^3 + \beta^4\,(r_1/r_2)^4 + \ldots\ \}$$
$$= m_t\,(1-\beta)\,r_1\,/\,(1 - \beta\,r_1/r_2)\ ,\quad \text{if}\ \ \beta\,r_1/r_2 < 1. \qquad \textbf{(4)}$$

$$F_t = (1-\alpha)\,U_{t,2} + \alpha\,P_t \approx (1-\alpha)\,m_t\,r_2 + \alpha\,m_t\,(1-\beta)\,r_1\,/\,(1 - \beta\,r_1/r_2)$$
$$= m_t\ \{\ (1-\alpha)r_2 - (1-\alpha)\,\beta\,r_1 + \alpha\,r_1 - \alpha\,\beta\,r_1\ \}\ /\ (1 - \beta\,r_1/r_2)$$
$$= m_t\ \{\ (1-\alpha)r_2 + (\alpha-\beta)\,r_1\ \}\ /\ (1 - \beta\,r_1/r_2) \qquad \textbf{(5)}$$

The revision is approximately

$$F_t - P_t = (1-\alpha)\ (\ U_{t,2} - P_t\ ) \approx (1-\alpha)\ \{\ m_t\,r_2\ -\ m_t\,(1-\beta)\,r_1\,/\,(1 - \beta\,r_1/r_2)\ \}$$
$$= m_t\ (1-\alpha)(r_2 - r_1)\,/\,(1 - \beta\,r_1/r_2)\ .$$

This is positive for all values of r_1 and r_2 such that $r_1 < r_2$.

To show the result in Section 6.3:

In Section 6.3, we assume that $r_1 = r < 1$ and r_2=1. Then from (4) and (5),

$$P_t \approx m_t\,(1-\beta)\,r\,/\,(1 - \beta\,r)\ ,$$

$$F_t = m_t\ \{\ (1-\alpha) + (\alpha-\beta)\,r\ \}\ /\ (1 - \beta\,r),\ \text{and}$$

U_t (fixed panel estimate) $\approx$ $U_{t,1}$ $\approx$ $m_t r$ (all current-month responses)

To show that $P_t < F_t < U_t <$ true monthly total, we need to show

$m_t (1-\beta) r / (1 - \beta r) < m_t \{ (1-\alpha) + (\alpha-\beta) r \} / (1 - \beta r) < m_t r < m_t$, or

$(1-\beta) r < (1-\alpha) + (\alpha-\beta) r < (1 - \beta r) r < 1 - \beta r$.

The first inequality follows because $(1-\alpha)(1-r)$ is greater than 0 when $r < 1$.

The second inequality follows whenever

$(1 - r) (1-\alpha) < (1 - r) r \beta$, or equivalently, $r > (1-\alpha)/\beta$.

This is true in MRTS when $r > .2666$, and in MWTS when $r > .4615$;

realistic values of r are much greater than these bounds.

The third inequality follows whenever $r < 1$.

Comparing a Fixed-Panel Sample Design With a Rotating-Panel Sample Design For Monthly Trade Surveys

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