EXAMINING THE REVISIONS IN MONTHLY TRADE SURVEYS UNDER A ROTATING PANEL DESIGN

Patrick J. Cantwell, Carol V. Caldwell, Howard Hogan, Carl A. Konschnik, Bureau of the Census*
Patrick J. Cantwell, Bureau of the Census, Washington, DC 20233

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1. Introduction

In the Census Bureau's monthly surveys of retail and wholesale trade, a large proportion of the sample firms rotate in and out of sample. Each of these firms belongs to one of three panels and reports every third month, giving sales or inventory figures for the current month (just completed) and the prior month.

Because the data for a given month are collected during two separate periods, we first release 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 in the estimates. Through our estimation methods we hope to keep the revisions as small as possible.

Several factors can increase the size of the revisions. The panels of sample units can become unbalanced. That is, one panel can become significantly larger or smaller in dollar volume than the others. When this happens, the revisions can become large in absolute value and follow a predictable three-month cycle.

Another problem arises if the respondents report differently for current and prior month sales or inventories. That is, the sales figures for one of these months becomes biased (upwards or downwards) relative to the other. This condition can lead to a constant revision in one direction.

In Sections 2 and 3, respectively, we describe the design of the monthly trade surveys and our system of estimation. The next two sections address the two types of problems introduced above--panel imbalance in Section 4, and differential response bias in Section 5. Series of monthly estimates from several kinds of business help depict what is actually happening with the estimates and the revisions.

To counter the consequences of these problems, we discuss two alternatives in Section 6. The first would adjust the preliminary estimate, as we have done in the survey of wholesale trade for about 18 months. We also offer a more systemic approach, where we would drop the rotating panels in favor of a fixed-panel design. These alternatives present benefits as well as new problems. We focus on how such solutions affect the revisions from the preliminary to the final estimates.

Many more details and results are included in a longer version of the paper available from the authors.

2. Design of the Monthly Trade Surveys

The Bureau of the Census conducts several monthly trade surveys using rotating panels, including the Monthly Retail Trade Survey (MRTS) and the Monthly Wholesale Trade Survey (MWTS). Sales and inventory estimates are published from these surveys. The designs of the two surveys are similar. Their samples are selected every five years from the Standard Statistical Establishment List. Within each major Standard Industrial Classification (SIC) code, the largest firms are selected as "certainties." These companies report their sales every month shortly after the end of the month. The remaining firms are stratified according to their total annual sales. We select a simple random sample from each stratum, and assign weights inversely proportional to the probability of selection.

In order to reduce the burden on reporters and extract more information from fewer sample cases, we select three times as many "noncertainty" sampling units as the design calls for, and systematically divide them into three rotating panels. The firms in a given rotating panel are contacted only every third month, and report their sales or inventories from the most recent two 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. The firms in Panel 2 are contacted again three months later to provide sales figures for May and April, and so on.

Under this design, each panel reports four times a year, giving us eight months of data through only four contacts, potentially reducing costs and response burden. Thus, for any specific month's estimate, 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. Composite Estimation

To benefit from the rotating panel design, we apply a composite estimator--a linear combination of estimates using data from the current month and the prior month. 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 us define $U_{t,i}$ as the "unbiased" sample weighted estimator of sales from the certainties and 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 would be Panel $\text{mod}_3(t+i+1)+1$.)

Generally, in month t+1 we collect current month data for month t from one panel and the certainties, giving us $U_{t,1}$. After the data are processed and edited, we release a "preliminary" estimate. One month after collecting current month data for month t, we collect prior month data *also for month t* from a second panel, yielding $U_{t,2}$. Combining these data with those obtained earlier, we release a "final" estimate. The demand for the data as soon as they are available make it necessary to release the preliminary estimate before data from the second panel are processed.

Both released estimates, the preliminary and the final, are composites. We define the preliminary estimate recursively as

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

Note that $U_{t,1}/U_{t-1,2}$ is an estimate of month-to-month trend from month t-1 to month t based on common respondents. When the next panel reports, we tabulate $U_{t,2}$ and compute a final estimate:

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

(At this time, we also tabulate $U_{t+1,1}$ and compute the preliminary estimate for month t+1, P_{t+1}.) The MRTS uses $\beta = .75$ for the preliminary and $\alpha = .80$ for the final. The corresponding values used in the MWTS are $\beta = .65$ and $\alpha = .70$.

We call the change from P_t to F_t, $F_t - P_t$, the revision in the sales figure for monthly level. F_t uses data from more reporters than P_t--two panels as well as the certainties. Further, responses pertaining to the prior month (those that go into $U_{t,2}$) are more likely to be "book values" rather than early estimates, given the additional 30 days to report. It follows that F_t is statistically the better of the two composite estimates for measuring monthly level. Thus, we wish to produce a preliminary estimate that will be revised as little as possible.

Table 1 presents the revisions in millions of dollars and the relative revisions in the estimates for the U.S. Total sales in retail trade. Most of the revisions since April 1992--when the Bureau started releasing estimates from a new sample--have been upward, i.e., $P_t < F_t$. More important, some revisions have been as large as .3% or .4%. In the next two sections we highlight two problems with the current design that can cause large revisions from the preliminary to the final estimates.

4. Problem One: Panel Imbalance

To understand the sources of problems with rotating-panel designs, we express the unbiased estimates as a sum of several components. In the descriptions below, when we refer to a specific panel reporting in its appropriate month, we implicitly include the certainties that report in that month. Let

$$U_{t,i} = m_t + p_{j(t,i)} + r_i + e_{t,i} , \text{ where}$$

m_t is the true, unknown value of sales for month t;

$p_{j(t,i)}$ is the "panel effect"--the average value of the estimate from panel j *above (+) or below (-) the true monthly value* m_t;

r_i is the "response effect"--the average value of current month reporters (i = 1) or prior month reporters (i = 2) *above or below the true monthly value* m_t; and

$e_{t,i}$ is error term in the model for $U_{t,i}$.

As noted above, $j(t,i) = \text{mod}_3(t+i+1)+1$. For simplicity, we drop the implicit t and i, and label this effect p_j. We assume that $E(e_{t,i}) = 0$. The effects p_j and r_i, however, being defined relative to the true value m_t, need not average to 0.

When we select (within each SIC and size stratum) the noncertainties for the MRTS and the MWTS, we draw a sample three times the designated size, and assign the units systematically to the three panels. 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.

Unfortunately, several things can happen to upset this balance *as measured by the volume of sales*. 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 report, new units are formed--some of which are added to the sample. Meanwhile, some units in sample cease operations or merge with other companies. These births and deaths can further upset the balance among the three panels.

What is the effect of panel imbalance on the estimates--and on the revision from preliminary to final? To speculate, we return to the expression for $U_{t,i}$ and make several assumptions. Suppose

(1) the response effects $r_i = 0$ for $i = 1,2$;

(2) the error terms $e_{t,i}$ are small relative to the panel effects p_j, so that $U_{t,i} \approx m_t + p_j$, and

(3) the panel effects p_j are small relative to the monthly totals m_t, so that $U_{t,1} / U_{t-1,2} \approx (m_t + p_j)/(m_{t-1} + p_j) \approx m_t/m_{t-1}$.

The second assumption is reasonable when the panel effects are substantial because the large sample size induces a relatively small variance for the error terms $e_{t,i}$. In reality, the error terms are likely to embody more than what we've covered with this model, and will represent other sources of variation. The third assumption is plausible because the true monthly totals are very large.

If these conditions are true, it can be shown using simple algebra that for "cycle 1," i.e., data months 1, 4, 7, 10, ..., the revision is approximately

$$F_t - P_t = (1-\alpha) \{ p_2 - (1-\beta) [p_1 + \beta (m_t/m_{t-1}) p_3 + \beta^2 (m_t/m_{t-2}) p_2 + \beta^3 (m_t/m_{t-3}) p_1 + \beta^4 (m_t/m_{t-4}) p_3 + \ldots] \}$$

This series ends with the earliest month in the sequence. For the other two cycles, similar results are determined; only the panel effects p_j change. The revision can then be summarized as:

Data Months	*Dominant terms*
1, 4, 7, 10, ...	p_2 vs. p_1 and p_3
2, 5, 8, 11, ...	p_3 vs. p_2 and p_1
3, 6, 9, 12, ...	p_1 vs. p_3 and p_2

As an example of what might occur, suppose that p_2 is much larger than p_3, which in turn is larger than p_1. If the assumptions given above are roughly true, we might expect to see a large positive revision in cycle 1, months 1, 4, 7, ..., and a large negative revision in cycle 3, months 3, 6, 9, ... This is indeed what has happened in several SICs that are responsible for a significant part of total sales and inventories in wholesale.

For many wholesale SICs, we extracted the unbiased estimates for the two reporting panels for each month from April 1992 (the first month of the current sample) through October 1994. From these estimates we removed the portion due to sample units that report every month, leaving the part due to rotating-panel reporters. We then performed an analysis of variance (ANOVA) on the unbiased estimates according to the model for $U_{t,i}$ using a balanced incomplete design. (Note that we also included an interaction term between the panel effects and the response type effects.)

SIC 501 covers wholesalers in motor vehicles, parts, and supplies. For this SIC, the ANOVA for a panel effect yielded a statistically significant F statistic, 104.2. An examination of the panels themselves shows that the level of Panel 2 is generally much larger than that of the other two, while Panel 1 is usually the smallest of the three. Thus we expect to see large positive revisions in months 1, 4, 7, ..., and moderately large negative revisions in months 3, 6, 9, ...

Table 2 presents the percent revisions from the preliminary estimates to the final estimates in SIC 501 for the months of April 1992 through February 1995. (For all months beginning with October 1993, the revisions are placed in parentheses. As we will discuss in Section 6, at that time we 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.) One can see the large positive revisions in months 1, 4, 7, ..., and the large negative revisions in months 3, 6, 9, ...

This phenomenon, where the second panel is significantly larger than the other two, emerges in a number of the SICs in wholesale. Thus, U.S. Total sales and inventories in the MWTS, like SIC 501, realize a sequence of large positive revisions in months 1, 4, 7, ...

5. Problem Two: Differential Response Bias

A different problem can arise if the noncertainty sample units report their sales figures differently for the current month and the prior month. Reasons for such

differences have been proposed and studied for many years. (See, for example, Waite (1974).) It has been suggested that the current month sales figure for many reporters underestimates the true value. 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 availability of computer-operated accounting systems, and the recent level of price changes.

To see what can happen, we return to the expression for $U_{t,i}$. The assumptions we make now are similar to those in the last section, but focus on the response effects. Suppose

(1′) the panel effects $p_j = 0$ for $j = 1,2,3$;

(2′) the error terms $e_{t,i}$ are small relative to the response effects r_i, so that $U_{t,i} \approx m_t + r_i$, and

(3′) the response effects r_i are small relative to the monthly totals m_t, so that $U_{t,1} / U_{t-1,2} \approx (m_t + r_1)/(m_{t-1} + r_2) \approx m_t/m_{t-1}$.

If these conditions hold, it can be shown that the revision is approximately

$$F_t - P_t = (1-\alpha) \{ r_2 - r_1 (1-\beta) [1 + \beta (m_t/m_{t-1}) + \beta^2 (m_t/m_{t-2}) + \beta^3 (m_t/m_{t-3}) + \beta^4 (m_t/m_{t-4}) + \ldots] \}$$

One can see that this expression depends strongly (although not solely) on the value of $(1-\alpha)(r_2 - r_1)$. This revision, when the response effect dominates, *applies to every month*. This differs from the result in the last section involving a strong panel effect, where the revision exhibits a three-month cycle of positive and negative amounts.

To see what might occur in the presence of differentiable response bias, we examined the unbiased estimates in many important retail SICs for the data months of April 1992 through March 1995. As before, only the rotating-panel reporters are included in these estimates. Table 3 summarizes the modeling of the unbiased estimates, presenting the F statistics for panel and response effects from the ANOVA. Also included is the portion of the unbiased estimates made up by rotating-panel units.

From these results and other analyses, one can make several observations concerning response type and panel effects:

- For many SICs the response effect between current- and prior-month reporting is statistically significant. In every such case, current-month values tend to be significantly *less* than prior-month values.

- With the response effect consistently pointing in the same direction ($r_1 < r_2$), this effect does not cancel when aggregating to higher levels. For example, it is significant in the U.S. Total retail sales. The result is a series of mostly upward revisions. (See Table 1.)

- There seems to be a strong interaction effect between panel and response type. When the response type is statistically significant, the panel effect usually is as well.

- *In volumes of dollars,* the estimated effect for panels is usually much larger than that for response types.

- Serious panel imbalances in the finer SICs can partially cancel when aggregating to higher-level totals if different panels are larger in different SICs. This occurs somewhat in retail. But in the wholesale sample, Panel 2 is larger than the others in many important SICs, leaving the U.S. Total with a serious panel imbalance and a cycle of large revisions.

In Sections 4 and 5, we saw what can happen theoretically if panel or response effects are present in the design or the data collection. In reality, as Table 3 demonstrates, these effects often occur together, and other forces also influence the direction and magnitude of the preliminary-to-final revision.

6. Two Approaches to Address Large Revisions

One approach to consider when there is evidence of panel imbalance or response bias is to adjust the preliminary estimate. This has been done several times in recent decades and is currently being done in selected SICs in the MWTS.

The Bureau's estimates for April 1992 and subsequent months are based on a new sample. As we described in Section 4, a cyclical pattern of revisions emerged in several wholesale SICs and in the U.S. Total for sales and inventories. In October 1993, the

Bureau began adjusting the MWTS preliminary estimates for sales in five SICs and for inventories in four of these five SICs. Greater detail about the adjustment can be found in Caldwell, Monsell, Piesto, and Shimberg (1994).

At the level of U.S. Total sales (see Table 4) and inventories for wholesale, the adjustments in the affected SICs have produced consistently smaller revisions in months 1, 4, 7, ... In the other months, the revisions have decreased more often than not, usually by relatively small amounts. We have recently applied the same type of adjustment in several other SICs to further reduce the revisions there and at the U.S. Total level.

A second approach would eliminate the rotating panels in favor of one fixed panel, where all units report every month for the life of the sample. For month t, we obtain an unbiased weighted estimate, U_t. Under a rotating design, the same number of respondents contribute toward P_t. 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, additional independent observations are available in the rotation design, giving a final estimate F_t whose variance is even smaller. Still, in eliminating large preliminary-to-final revisions while simplifying many of the processing and correction routines, the fixed panel may be an option to consider.

To compare variances under the two designs, we keep sample sizes and other conditions the same. For estimates of retail sales, $Var(U_t)$ is about 25% larger than $Var(P_t)$ and 40% larger than $Var(F_t)$. However, for month-to-month trend, $Var(U_t/U_{t-1})$ is only about 2% greater than $Var(P_t/F_{t-1})$. (P_t/F_{t-1} is the best measure of trend under the rotation design.) The latter follows because all respondents report in consecutive months in the fixed-panel design.

When the Census Bureau began rotating panels in and out of sample, a greater emphasis was placed on estimates of monthly level (Woodruff 1963). Since then, however, the 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 is apparent that sampling via a fixed panel cannot eliminate all adverse effects. The single panel itself may be unbalanced, or, with all units reporting only current month sales, the estimate might possess a nontrivial response effect. When measuring month-to-month trend, the effects should essentially cancel. This would not happen when estimating monthly level. But if the levels are benchmarked effectively, the biases should be vastly reduced.

We are now considering whether to switch from rotating panels to a single fixed panel in our monthly surveys of retail and wholesale trade. In addition to cost and variance, the size of the projected revisions will be an important factor in making our decision.

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REFERENCES

CALDWELL, C.V., MONSELL, B.C., PIESTO, N.A., and SHIMBERG, M.Z. (1994). "Using Seasonal Adjustment Models to Correct for Panel Imbalance in the Monthly Wholesale Trade Survey," *Proceedings of the Section on Business and Economic Statistics, American Statistical Association,* pp. 83-88.

U.S. Bureau of the Census (1996). Current Business Reports, *Monthly Retail Trade: Sales and Inventories, January 1996,* BR/96-01, Washington, DC.

WAITE, P.J. (1974). "An Evaluation of Nonsampling Errors in the Monthly Retail Trade Sales Data," *Proceedings of the Section on Business and Economic Statistics, American Statistical Association,* pp. 602-607.

WOLTER, K.M. (1979). "Composite Estimation in Finite Populations," *Journal of the American Statistical Association, 74,* pp. 604-613.

WOODRUFF, R.S. (1963). "The Use of Rotating Samples in the Census Bureau's Monthly Surveys," *Journal of the American Statistical Association, 58,* pp. 454-467.

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Table 1. Monthly Revisions in Retail Sales, U.S. Total

YR MO	F/P%	YR MO	F/P%	YR MO	F/P%
92 04	-.07	92 05	.23	92 06	.13
92 07	.09	92 08	-.02	92 09	-.07
92 10	.43	92 11	.24	92 12	.15
93 01	.09	93 02	.34	93 03	-.18
93 04	.27	93 05	.42	93 06	.21
93 07	.17	93 08	.13	93 09	.07
93 10	.12	93 11	.29	93 12	-.04
94 01	.16	94 02	.29	94 03	.24
94 04	.21	94 05	.39	94 06	.11
94 07	.01	94 08	.33	94 09	.14
94 10	.09	94 11	.33	94 12	-.06
95 01	.09	95 02	.18	95 03	-.14

Table 2. Monthly Revisions in Wholesale Sales for SIC 501: Motor Vehicles, Parts, and Supplies

YR MO	F/P%	YR MO	F/P%	YR MO	F/P%
92 04	3.78	92 05	-0.91	92 06	-1.09
92 07	3.73	92 08	0.02	92 09	-2.36
92 10	4.14	92 11	-1.22	92 12	-1.65
93 01	3.73	93 02	0.25	93 03	-2.68
93 04	3.60	93 05	0.23	93 06	-2.87
93 07	4.85	93 08	-1.24	93 09	-5.30
93 10	(4.79)	93 11	(-2.28)	93 12	(-1.72)
94 01	(2.06)	94 02	(-0.97)	94 03	(-1.83)
94 04	(4.11)	94 05	(-0.53)	94 06	(-2.04)
94 07	(3.76)	94 08	(-1.60)	94 09	(-3.24)
94 10	(4.05)	94 11	(-1.05)	94 12	(-2.45)
95 01	(5.76)	95 02	(-0.84)		

Table 3. Summary of Modeling Results for Sales by SIC (Retail)

SIC		Rotating Portion	F Statistics	
			Panel	Response
	U.S. Total	47.5%	9.73	8.39
5211	Lumber	42.8%	1.15	0.62
5231	Paint, glass, wallpaper	48.8%	40.71	20.38
5251	Hardware	78.0%	22.72	11.40
5411	Grocery	32.9%	15.93	10.25
5511	New and used car dealers	86.3%	2.54	2.38
5521	Used car dealers	81.5%	112.25	56.99
5531	Auto & home supply	59.6%	35.34	18.12
5541	Gasoline service stations	62.2%	153.78	77.13
5712	Furniture	61.2%	26.22	13.82
5731	Radio, TV, & electronics	20.7%	1.63	0.94
5734	Computer & software	23.7%	17.40	4.49
			$F_{2,32,.01} = 5.34$	$F_{1,32,.01} = 7.50$

Table 4. Monthly Revisions in Wholesale Sales, U.S. Total -- Adjustments Applied Starting in 93 10

YR MO	F/P%	YR MO	F/P%	YR MO	F/P%
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	0.18