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BEFORE THE
POSTAL RATE COMMISSION

POSTAL RATE AND FEE CHANGES, 1997	:	DOCKET NO. R97-1

DIRECT TESTIMONY OF
KEVIN NEELS
ON BEHALF OF
UNITED PARCEL SERVICE

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QUALIFICATIONS

My name is Kevin Neels. I am a director at the management and economic consulting firm of Putnam, Hayes & Bartlett, Inc. I have provided economic research and consulting services for more than twenty years. Much of my work has involved the use of econometric analysis and has addressed issues relating to product costing in a wide range of areas.

I have analyzed pricing behavior in the context of allegations of antitrust violations and conducted numerous studies on the pricing of government services in areas ranging from municipal services to air traffic control. In connection with this and other work, I have frequently conducted investigations of costs for purposes of determining the total cost of providing a product or service, the costs associated with a specific product or service in the context of a multi-product firm, or the effects of incremental changes in volume on total profit. I have developed econometric analyses for purposes of estimating damages in civil litigation; of providing clients with forecasting capability; of estimating the effects on sales of changes in product design, pricing, or promotion; and of analyzing the structure of costs. I have also been called upon to provide critical evaluations of econometric analyses developed by others.

Prior to joining Putnam, Hayes & Bartlett, Inc. I held a number of responsible positions in economic research and consulting. I was previously vice president in the Transportation Program at the economic consulting firm of Charles River Associates, Inc., and senior economist at Abt Associates, a policy research firm. I have also served as a senior research associate in the Systems Sciences Division of the Rand Corporation and as an associate in the Transportation Studies Program of the Urban Institute. I hold a Ph.D. and a B.A., both from Cornell University.

NATURE OF MY ASSIGNMENT

In previous proceedings, the Commission has decided that mail processing labor costs are 100 percent volume variable. In this proceeding, Postal Service witness Michael D. Bradley (USPS-T-14) has introduced a study that purports to demonstrate that mail processing labor costs do not vary fully with changes in mail volume. Bradley's study is based on the econometric estimation of a series of cost equations. These cost equations relate the number of labor hours in specific activities, facilities, and accounting periods to the number of times pieces of mail are handled in those activities, facilities, and accounting periods.

For activities at Management Operating Data System (MODS) facilities, Bradley relies on data drawn from the Postal Service's MODS database. For Bulk Mail Centers (BMCs), he relies upon data from the Productivity Information Reporting System (PIRS) database, another operational database maintained by the Postal Service for BMC activities.

I have been asked to review the approach used by Bradley and to determine whether it provides accurate and reliable estimates of the volume variability of mail processing costs that are suitable for use in rate setting. I have also been asked to review Bradley's implementation of his approach and to assess the soundness of the results that he presents. Finally, I have been asked to offer an opinion in the light of all of the available evidence about how mail processing costs should be treated in determining postal rates.

SUMMARY OF MY CONCLUSIONS

Bradley's econometric analysis does not provide a reliable basis for determining the extent to which mail processing labor costs vary with volume. Bradley's econometric equations look not at cost, but at labor hours. Before determining whether labor hours are a suitable proxy for cost, one must either estimate the extent to which compensation per hour varies with volume, or provide some affirmative evidence that compensation per hour is independent of volume. One can advance reasonable arguments to support either the contention that compensation per hour increases with volume or that it decreases with volume. Bradley presents no evidence that would permit a determination of which is the case. In the absence of such evidence, the use of labor hours as a proxy for cost could result in either an underestimate or an overestimate of volume variability.

Also, Bradley's econometric equations look not at volumes, but rather at piece handlings, a measure of mail processing steps that is sensitive not only to changes in volume, but also to changes in routing, sorting technology, error rates, and other factors. Before determining whether piece handlings are a suitable proxy for volume, one must first estimate the extent to which piece handlings vary with volume, or provide some affirmative evidence that the two are directly proportional. Once again, Bradley presents no evidence on this question. In the absence of such evidence, the use of piece handlings as a proxy for volumes could result in either an underestimate or an overestimate of volume variability.

Quite apart from these fundamental issues, there are a number of problems with the implementation of Bradley's approach that raise serious questions about the robustness, reliability, and relevance of his results. These include:

(a) Reliance on a dataset whose ability to provide accurate estimates of piece handlings has been questioned in internal Postal Service investigations;

(b) Bias in volume variability estimates due to errors in the measurement of mail volumes;

(c) Adoption of a set of highly subjective data "scrubbing" procedures that result in the elimination from the analysis of enormous quantities of otherwise usable data and that significantly alter the results of the analysis;

(d) Use of a complex set of time trend variables that produces erratic and counter-intuitive estimates of the effects of technological change.

Also, and perhaps most significant, Bradley's equations cannot provide accurate estimates of the *long-run* response of costs to changes in volume.

These factors lead me to conclude that the new study introduced by Bradley does not justify rejection of the Commission's well-established determination that mail processing labor costs are fully volume variable. Common sense indicates that labor costs should be fully variable. Simple, straight-forward unadorned plots of the raw data tend to confirm this view. Bradley has failed to provide convincing evidence to contradict the Commission's traditional position. I recommend that the Commission stand by its traditional position and treat mail processing labor costs as 100 percent volume variable.

If the Commission does elect to adopt some version of Bradley's econometric analysis, I recommend adoption of his cross-sectional analysis as a starting point. This analysis is better able to provide estimates of long-run volume variability, and it is less subject to downward bias from errors in the measurement of volume.

I recommend a number of changes to the cross-sectional model that Bradley presents in his workpapers. The time trend variables that Bradley includes in his recommended model have little meaning in a cross-sectional context and should therefore be dropped. Also, the cross-sectional analysis needs to be extended to all of the activities that Bradley considers. Furthermore, Bradley's results are based upon a drastically reduced dataset that emerges from his "scrubbing" process. This process results in the loss of an unacceptably large portion of the available data. I have rerun Bradley's cross-sectional analysis on a dataset that uses all of the data. The volume variability estimates resulting from this improved cross-sectional analysis are summarized in Table 1.

Table 1 does not include volume variability estimates for the registry and remote encoding activities because the amount of data available for analysis for these two activities is very limited. I do not believe that it is adequate at this time to support an econometric analysis of the volume variability of mail processing labor costs. Hence, for these two activities I recommend that the Commission reaffirm its earlier finding that mail processing labor costs are 100 percent volume variable.

Table 1

Volume Variability Estimates Derived from Modified Version of Bradley's Cross-Sectional Model

Activity	Results Based Upon the Full Sample*	Standard Errors
MODS Direct		
BCS Sorting	132%	0.0251
OCR Sorting	121%	0.0379
LSM Sorting	121%	0.0151
FSM Sorting	116%	0.0185
Manual Letter Sorting	125%	0.0293
Manual Flat Sorting	131%	0.0333
Manual Parcel Sorting	110%	0.0755
Manual Priority Mail Sorting	110%	0.0462
SPBS - Priority Mail Sorting	129%	0.1254
SPBS - Non Priority Mail Sorting	98%	0.0901
Cancellation and Mail Prep	109%	0.0490
MODS Allied		
Opening - Pref Mail	134%	0.0674
Opening - Bulk Business Mail	128%	0.1584
Pouching	131%	0.1709
Platform	146%	0.0646
BMC Direct		
Sack Sorting Machine	119%	0.1100
Primary Parcel Sorting Machine	159%	0.1904
Secondary Parcel Sorting Machine	89%	0.2705
Irregular Parcel Post	84%	0.1756
Sack Opening Unit	82%	0.0734
Non Machinable Outsides	78%	0.1982
BMC Allied		
Platform	45%	0.3565
Floor Labor	120%	0.5152

* Source: WP I.

DEFECTS IN BRADLEY'S APPROACH

A. Bradley Fails to Use Appropriate Measures of Cost and of Volume

Any empirical study of the volume variability of costs must relate a suitable measure of cost to a suitable measure of volume. This is a fundamental threshold requirement. In Bradley's study, however, there is neither a true measure of cost, nor a true measure of volume.

1. Hours Are Not a Suitable Proxy For Cost

At the most basic level, "cost" is a quantity that is defined in monetary units. However, no such measure appears anywhere in Bradley's datasets or results. Instead, he focuses on labor hours "clocked" into the various activities he examines. Of course, labor hours and labor costs are related. That relationship is expressed by average compensation cost per labor hour. By definition, total labor costs are equal to the product of average compensation per labor hour times total labor hours.

But average compensation per hour is influenced by a variety of different factors. At a given facility and a given point in time, there will be a schedule that specifies hourly wage rates for different crafts, different levels of seniority, different types of employees (i.e., permanent, casual, temporary, etc.), and for different types of time (i.e., straight time, overtime, holiday time, etc.). This schedule of wages may be higher or lower, depending upon labor market conditions, inflation, collective bargaining agreements, and other factors. All else equal, the higher these wage rates, the higher the average compensation per hour will be.

Average compensation per hour will also be influenced, however, by the *mix* of labor hours at a facility. A shift in the mix of hours toward more costly types of time (such as overtime), higher paid crafts, more senior employees, or more highly paid categories of employees will raise average compensation per hour even if the wage schedule remains unchanged. The greater the range of wage rates that are paid, the more powerfully average compensation per hour will be influenced by changes in the mix of types of hours worked.

Bradley ignores the effects that changes in the mix of types of hours have on average compensation per hour and therefore on total labor costs. He asserts that:

> For mail processing labor cost, the variations in mail processing hours *are* the variations in cost.[1]

This statement is not correct. For example, it is obvious that if wage rates increase, costs will also increase even in the absence of a change in labor hours. In addition, the cost associated with a given number of labor hours will also increase if the *mix* of hours shifts in the direction of more highly paid types of time. Overtime is perhaps the best illustration of the fallacy in Bradley's assertion that hours are the same as cost; using hours as a proxy for costs will not capture the

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1. Direct Testimony of Michael D. Bradley on Behalf of the United States Postal Service, USPS-T-14, p. 12 (emphasis added).

total impact of increased volume on costs when the increase in volume leads to a need for higher paid overtime hours.

If either of these two factors -- the schedule of wage rates or the mix of types of hours -- changes systematically with volume, this change will influence the overall variability of mail processing costs. Because Bradley's analysis ignores changes in average compensation per hour, it is not capable of determining whether or the extent to which such volume-related effects exist or of factoring them into his estimates of volume variability.

While one might argue that the schedule of wage rates is determined largely by general labor market conditions rather than by mail volume, the same cannot be said for the mix of types of time. There are a number of reasons for believing that the mix of hours at a facility might vary systematically with volume. High-volume periods could be characterized by the more extensive use of lower-cost temporary or casual workers. Conversely, high-volume periods could require the involvement of higher-cost senior or supervisory personnel in order to meet mail processing schedules and maintain service standards. It is also possible that maintenance of service standards during high-volume periods could involve greater use of overtime and greater amounts of overtime pay.

We have no idea what the net effect is of these different factors. The only way to determine whether average compensation per hour varies systematically with volume and, if so, by how much, is to examine the relationship between actual labor costs and volume. Bradley has not done this.

Bradley argues that his use of hours rather than cost to measure cost variation with volume is a virtue rather than a limitation of his study. He characterizes hours as "a 'real' variable that inflation does not influence." Hence, he argues, "hours are directly comparable through time, and I do not have to adjust them for inflation." [2]

These statements are not entirely correct. While it is true that by focusing on hours Bradley has eliminated changes in costs that are associated with shifts in the overall wage schedule rather than with volume, it is *not* true that the resulting measure of hours is comparable across sites or across time, a precondition for the use of labor hours as a proxy for costs. The hours of supervisory personnel and skilled craftsmen are not the same as the hours of unskilled casual workers. Nor is it even true that the straight time and overtime hours of the same individual are comparable, since there are real resource cost differences between the two types of time. Even after removing the effects of shifts in the overall schedule of wages, these other differences remain. Bradley has not dealt with them.

The need to account for changes in overall wage levels cannot serve as a justification for failure to account for variations in the mix of hours. While it is true that focusing on compensation costs would have necessitated adjustments for the effects of inflation and changes in wage levels, such adjustments are not difficult to make.

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2. USPS-T-14, p. 13.

2. *"Total Piece Handlings" Is Not a Suitable Proxy For Volume*

It is also obvious that an econometric study of the variability of mail processing costs with changes in volume should involve an analysis of changes in the volume of mail delivered. On this count, too, Bradley's analysis comes up short. With the sole exception of registered mail, Bradley's datasets and results are devoid of any measure of the volume of mail actually delivered. Instead, Bradley bases his conclusions on an analysis of piece handlings. This measure is conceptually distinct from volume and, therefore, using it as a proxy for volume can easily lead to erroneous conclusions regarding the volume variability of costs.

On its route toward final delivery, a particular item of mail will generate an additional piece handling every time it passes though a processing step. Thus, the more complex an item's routing, the more piece handlings it will require. An item that passes through a single SCF will undergo less processing than one that must travel through two SCFs, or one that goes from one SCF through a BMC to another SCF, or one that must travel from an SCF through two BMCs to another SCF. An item that requires both a primary and a secondary sort will experience more piece handlings than one that requires only a single sort. A presorted dropshipped item will require less processing than one that is deposited in a corner mailbox with other unsorted items.

Even if Bradley is correct in his assertion that "[t]he primary driver of costs in any activity is the number of pieces sorted in that activity,"[3] he cannot draw

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3. USPS-T-14, p. 13.

conclusions about the volume variability of costs from an analysis of piece handlings without first considering the volume variability of piece handlings. If the number of times a piece of mail is handled tends to decline with volume, Bradley's analysis will overstate the volume variability of costs; if the number of times a piece of mail is handled tends to increase with volume, Bradley's analysis will understate the volume variability of costs.[4]

A variety of different factors could alter the relationship between piece handlings and volumes. That relationship could be affected, for example, by: (1) changes in the use of presort options by business mailers; (2) changes in the proportion of intra-BMC or intra-SCF movements; or (3) modifications in mail handling procedures that result in the addition or deletion of processing steps.

Changes in the relationship between piece handlings and volume could mask significant diseconomies of scale. There are a variety of ways in which this might happen. For example, increases in volume could lead to increases in error sorting rates and could thereby result in mail having to be resorted after being delivered to the wrong processing center. When such missorted mail arrives at the incorrect destination, it would then have to reenter the processing stream and pass a second time through the sequence of sorting and processing steps. Even though the increase in error rates clearly leads to an increase in cost, Bradley's analysis

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4. In cross examination on his testimony regarding purchased transportation costs, Bradley conceded that failure of a proxy measure of volume to directly track a true measure of volume can bias estimates of volume variability: "I did not study the relationship between cubic-foot miles and volume. And certainly I think to the extent that that second analysis had a lower variability then my capacity variabilities would be too high." Tr. 7/3823-24.

would incorrectly interpret this as an increase in productivity, since it would allow the original sort to handle pieces in less time.

It is possible for the number of times an item is handled to increase systematically with volume, even over the long term. At higher volumes it may become economical to incorporate greater specialization and therefore also more individual processing steps into the overall processing sequence.

Bradley has provided no information on the relationship between piece handlings and volume. Without such information the Commission cannot determine what his piece handling variability estimates imply for the volume variability of mail processing costs.

B. Flaws In Bradley's Implementation

Apart from the fundamental deficiencies in conceptual approach discussed above, there are a number of significant problems in the implementation of this approach that call into serious question the reliability of its results. These deficiencies have to do with the data sources relied upon, the "scrubbing" process to which the data have been subjected, the treatment of technological change, and the focus on the *short-run* response of hours to changes in piece handlings. Correcting these problems generally results in higher estimates of variability. The sensitivity of the results to changes in sample selection, model specification, and method of estimation raises questions about whether these results are reliable enough and stable enough to provide a sound foundation for ratemaking.

1. There Are Serious Shortcomings in the Piece Handling Data Used in Bradley's Econometric Analysis

The data quality requirements for a sound econometric study exceed those for simpler forms of analysis. Measurement errors that might cancel out in the latter context can give rise to biased results when the same data are used to develop regression equations. For this reason, it is essential to scrutinize data sources carefully before using them in sophisticated econometric studies. Scrutiny of Bradley's data source for Total Piece Handlings indicates potentially serious problems.

The MODS piece handlings data that Bradley relies upon for major portions of his analysis have been the target of considerable criticism. A recent review of measurement systems conducted by the U.S. Postal Inspection Service found large variances between the piece handling figures contained in the MODS system and actual piece counts.[5] These variances were attributed to a variety of different causes, including inadequate conversion factors,[6] improper data input, and out-of-tolerance scales. The magnitudes of these variances could be substantial. In one instance, the count projected by the MODS system for 57 trays

5. National Coordination Audit: Mail Volume Measurement and Reporting Systems, United States Postal Inspection Service, December 1996, LR-H-220.

6. In many situations, the MODS system records number of trays, sacks, or pounds of mail and then uses conversion factors to convert these estimates to piece counts. See LR-H-220, p. 8.

was 29,637 pieces, while the actual piece count was 17,842 pieces -- an error of 66 percent.[7]

In one of his interrogatory responses, Bradley claimed that "several of the report's findings are irrelevant for my analysis because much of the data set used in my analysis is not based upon FHPs [First Handling Pieces], but rather on end-of-run data and machine counts."[8] However, First Handling Pieces is a part of the piece handling variable used by Bradley; the MODS Manual[9] states clearly in Section 212.2 that Total Piece Handlings is the sum of First Handling Pieces and Subsequent Handling Pieces. Even if the MODS counts of downstream handlings are totally free of the measurement problems that infect estimates of First Handling Pieces, all of the problems surrounding the measurement of First Handling Pieces are still passed forward into Bradley's analysis. The questions that have been raised regarding the accuracy of the MODS piece handling data naturally lead one to question whether the same problems infect the PIRS piece handling data upon which Bradley based his analysis of BMC mail processing costs.

In fact, examination of Bradley's datasets reveals many problems. There are, for example, hundreds of instances in which a site reports piece handlings for a specific activity for only a single period out of the nine years covered by Bradley's dataset. See Table 2, below. It is difficult to imagine actual operational practices that would so frequently bring an activity to life for only a

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7. LR-H-220, p. 8.

8. Tr. 11/5369.

9. LR-H-147.

single accounting period. Data entry errors, such as recording piece handlings under the wrong activity or with the wrong facility identifier, would seem to provide a more plausible explanation.

Table 2

Number of Instances in Which Piece Handlings Are Reported at a MODS Facility for a Direct Activity for Only a Single Accounting Period

Activity	Single Period Observations
MODS Direct	
BCS Sorting	59
OCR Sorting	40
LSM Sorting	62
FSM Sorting	43
Manual Letter Sorting	71
Manual Flat Sorting	68
Manual Parcel Sorting	67
Manual Priority Mail Sorting	41
SPBS - Priority Mail Sorting	12
SPBS - Non Priority Mail Sorting	23
Cancellation and Mail Prep	63
Total	549

Source: WP II.

There are also numerous reporting gaps in Bradley's datasets. See Table 3, below. Often an activity will "disappear" at a site for a single accounting period or for a number of accounting periods, only to reappear at a later date. It is possible, of course, for an activity to be temporarily shut down. However, the large number of instances in which this occurs suggests that it may also be common for the data simply not to make their way into the MODS system.

Table 3

Number of Instances in Which Gaps in Piece Handlings Reported at a Facility Appear for MODS Direct Activities

	Length of Gap			
Activity	**Single Period Gaps**	**2-6 Period Gaps**	**6+ Period Gaps**	**Total Gaps**
MODS Direct				
BCS Sorting	15	13	20	48
OCR Sorting	54	48	42	144
LSM Sorting	21	11	4	36
FSM	18	15	24	57
Manual Letter Sorting	38	3	11	52
Manual Flat Sorting	23	10	13	46
Manual Parcel Sorting	163	126	52	341
Manual Priority Mail Sorting	88	75	76	239
SPBS - Priority Mail Sorting	121	169	147	437
SPBS - Non Priority Mail Sorting	65	111	165	341
Cancellation and Mail Prep	35	22	23	80
Total:	641	603	577	1,821

Source: WP II.

Econometric studies are especially sensitive to data errors. It is a well-established econometric principle that measurement error in an independent variable causes downward bias in coefficient estimates. This result is stated clearly in a recent text:

> As long as σ^2_u [the variance of the measurement error in the independent variable] is positive, *b* [its estimated

> coefficient] is inconsistent, with a persistent bias toward zero. . . . The effect of biasing the coefficient toward zero is called attenuation.[10]

Bradley acknowledges the possibility that his data on piece handlings may be subject to measurement error:

> When using operating data, there is always a concern that the data might contain measurement error. If the measurement error is in the dependent variable, hours, it will simply be part of the specified error term in the econometric regressions. If the measurement error is in the right-hand-side variables, however, traditional least-squares methods will not accurately account for it. This is called the "errors-in-variables" problem.[11]

Although Bradley correctly cites the existence of the errors-in-variables problem, he fails to describe the full nature of the attenuation effect. In the specific context of Bradley's analysis, the attenuation effect means that if there is measurement error in the piece handlings variable, Bradley's analysis will *understate* the true volume variability of mail processing labor costs.

The pattern of results reported by Bradley suggests that his results may have been powerfully influenced by errors in the measurement of piece handlings. There are a number of instances in which Bradley reports volume variability estimates for both the manual and the automated sorting of the same type of mail. In the automated sorting activities, the data on piece handlings come

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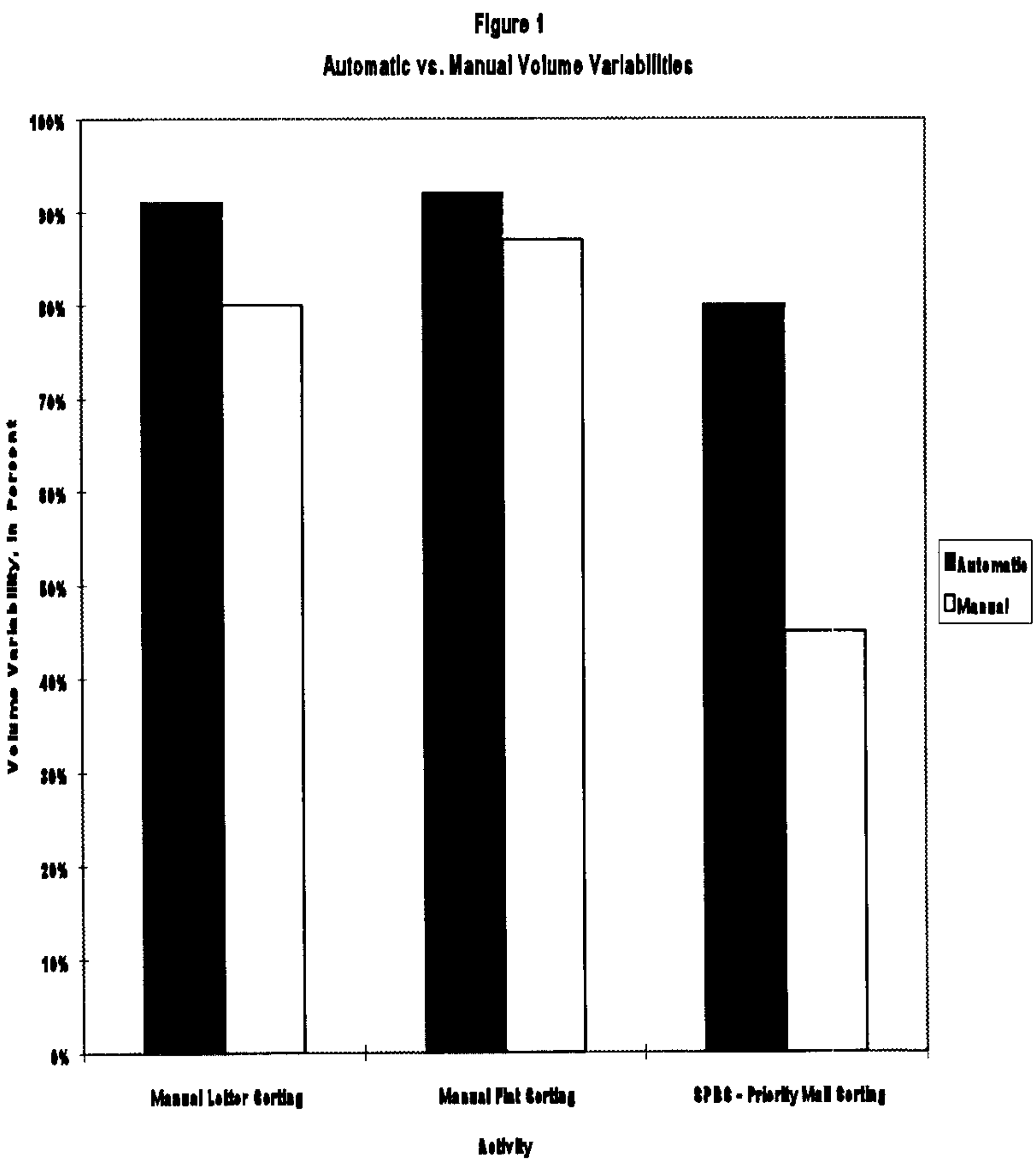
10. Greene, William H., *Econometric Analysis*, Third Edition, Prentice Hall, 1997, p. 437.

11. USPS-T-14, p. 80.

from counters on the machinery. In contrast, for manual activities, piece counts are derived indirectly by applying conversion factors to measures of weight, cubic volume, or some other proxy. One would expect, therefore, to find greater measurement error and stronger attenuation effects in the manual activities. Bradley's results confirm this expectation. Figure 1 shows Bradley's volume variability estimates for the mechanized and manual sorting of letters, flats, and Priority Mail. In every case the volume variability estimates are lower for the manual activities, sometimes by a substantial margin.

Figure 1

Automatic vs. Manual Volume Variabilities



In his direct testimony Bradley presents the results of an analysis that, he claims, quantifies the effects of measurement error in his piece handlings variable. He does not derive his final estimates of volume variability from this analysis, but he does use it to support an argument that "measurement error in manual letter and flat piece handling volumes is not a critical problem for the estimation of cost elasticities for those activities."[12] However, there are problems in this analysis that call into question its ability to support these claims. Bradley claims to have found *upward* bias in his estimate of the volume variability of the manual letter sorting activity rather than the downward bias that Greene states is the result of measurement error. As shown in Appendix A to my testimony, the formulas that Bradley himself presents in his direct testimony show clearly that upward bias is a mathematically impossible result. Bradley's finding of upward bias is therefore a sign of serious and fundamental flaws in his analysis.

It is clear that the effect of measurement error in the piece handlings variable is to cause Bradley to understate the true volume variability of mail processing labor costs. Despite Bradley's attempt to quantify it, the magnitude of this bias remains unknown. The analysis that Bradley puts forward to support his claim that measurement error is not a critical problem is clearly unreliable. Both this analysis and the claim based upon it should be ignored.

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12. USPS-T-14, pp. 83-84.

2. *Bradley's Data "Scrubbing" Procedures Have Substantively Altered His Results*

Bradley's volume variability estimates are derived from a dataset that is the end product of an extensive editing process in which enormous amounts of data are eliminated from his analysis based solely on subjective criteria. The volume variability estimates derived from this reduced dataset are substantially different from those derived from the initial dataset, calling into question the reliability of Bradley's estimates of volume variability.

In his direct testimony Bradley describes the elaborate, multi-step process through which he discarded what he regarded as questionable data. These steps included:

(a) Elimination of observations corresponding to periods in which the site is just starting the activity, and in which volumes are thus still ramping up;[13]

(b) Elimination of all sites having less than 39 consecutive usable observations in the activity under examination;[14]

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13. This description is based upon statements contained in Bradley's direct testimony, USPS-T-14, p. 30, lines 22-25. Since the filing of that testimony, his rationale for this particular step in the "scrubbing" process has changed somewhat. Examination of the computer programs used to do the "scrubbing" had indicated that this step in the process had eliminated not just observations corresponding to the first periods in which an activity was present at a facility, but also long runs of observations in the middle of the reporting periods for some established sites. When asked about this under cross-examination, Bradley indicated that his "general intent was to eliminate from the data any period in which the level of activity fell below this minimum, normal operating activity." Tr. 11/5571.

14. For the allied activities he required 26 consecutive observations. Tr. 11/5475.

(c) If a site has more than one run of 39 or more consecutive usable observations in the activity under examination, elimination of all runs for that site but the most recent;[15]

(d) Elimination of observations corresponding to high or low productivities in the activity under examination;

(e) If the elimination of high or low productivity observations results in a site having less than 39 consecutive observations that have survived all previous steps in the process, elimination of the site from the analysis; and

(f) If the elimination of high or low productivity observations results in a site having more than one run of 39 consecutive observations that have survived all previous steps in the process, elimination of all runs for that site but the most recent.

This process eliminates an enormous amount of otherwise usable data. Details for the 23 activities Bradley "scrubs" are presented in Table 4, below. In 21 of the 23 activities, he discards over ten percent of the data. In seven cases he discards over 20 percent of the data. In two cases he discards over 30 percent of the data, and in one case -- SPBS Priority -- he throws away a staggering 49 percent of the potentially usable data. Across all of his models he discards over 50,000 observations.

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15. For the allied activities he required 26 consecutive observations. Tr. 11/5475.

Table 4

Data Eliminated Due to Data "Scrubbing"

Activity	Usable Observations [4]	Observations Discarded [5]	Observations Remaining [6]	Percent Discarded [7]
MODS Direct [1]				
BCS Sorting	26,426	3,402	23,024	12.87%
OCR Sorting	21,345	2,614	18,731	12.25%
LSM Sorting	23,251	3,278	19,973	14.10%
FSM Sorting	21,544	3,382	18,162	15.70%
Manual Letter Sorting	28,648	3,558	25,090	12.42%
Manual Flat Sorting	28,504	4,215	24,289	14.79%
Manual Parcel Sorting	24,814	7,235	17,579	29.16%
Manual Priority Mail Sorting	21,914	5,977	15,937	27.27%
SPBS - Priority Mail Sorting	3,903	1,906	1,997	48.83%
SPBS - Non Priority Mail Sorting	6,775	2,053	4,722	30.30%
Cancellation and Mail Prep	26,280	6,470	19,810	24.62%
MODS Allied [2]				
Opening - Pref Mail	19,834	2,978	16,856	15.01%
Opening - Bulk Business Mail	17,560	3,123	14,437	17.78%
Pouching	17,122	2,263	14,859	13.22%
Platform	19,684	2,032	17,652	10.32%
BMC Direct [3]				
Sack Sorting Machine	1,916	159	1,757	8.30%
Primary Parcel Sorting Machine	2,094	196	1,898	9.36%
Secondary Parcel Sorting Machine	2,069	211	1,858	10.20%
Irregular Parcel Post	2,032	367	1,665	18.06%
Sack Opening Unit	2,094	511	1,583	24.40%
Non Machinable Outsides	2,094	267	1,827	12.75%
BMC Allied [3]				
Platform	2,094	318	1,776	15.19%
Floor Labor	2,094	435	1,659	20.77%

Sources:

[1] LR-H-148-7, Table H148-1
[2] TR. 11/5447
[3] Tr. 11/5448
[6] = [4] - [5]
[7] = [5]/[4]

The extreme lengths to which Bradley takes his "scrubbing" process raise a number of significant questions. How can one be sure that the data that are "scrubbed" away contain errors and not important information about how costs vary with volume? How justifiable are the subjective criteria Bradley used in deciding which observations to discard and which to retain? How have the character of Bradley's results been affected by his decisions to discard large portions of the data? And, of course, if the datasets Bradley is using are so dirty as to require such extreme clean-up measures, how reliable can the conclusions be that are derived from them?

How can one be sure that the data that are "scrubbed" away contain errors and not important information about how costs vary with volume? One cannot. Bradley cites no external evidence that could be used to provide independent verification of the accuracy or inaccuracy of any of his data. His "scrubs" eliminate observations that look "unusual" relative to other observations in the dataset. The fact that they may look unusual to a particular observer can be attributed to either of two causes. It is possible that what was in fact going on at the site was quite normal, but that the data were recorded incorrectly. In such cases, the elimination of observations might be appropriate. However, it is also possible that the data were in fact recorded correctly but look unusual even though they are normal for that site. In the latter case the elimination of observations is harder to justify. The rates that will be set as a result of these proceedings will apply to all facilities, so they should reflect the variability of costs at all facilities, both "usual" and "unusual."

It is very possible that such "unusual" observations contain the most information about the true relationship between cost and volume. A site that has experienced an enormous increase in volume may well be unusual, but it may also provide the clearest possible picture of how processing costs vary with volume. It is for this very reason that Dennis Cook, an authority on the analysis of outliers, has warned against discarding an observation simply because it exerts a disproportionate influence over the estimated regression results:

> . . . influential cases are not necessarily undesirable. Often, in fact, they can provide more important information than most other cases.[16]

Bradley's decision to eliminate observations involving low levels of piece handlings also raises questions about the representativeness of his results. Examination of the data reveals sites that exhibit low levels of piece handlings over extended periods of time. See, for example, Figure 2, below. The relationship between piece handlings and hours at such sites is part of the normal overall relationship between piece handlings and hours. If these observations have been systematically eliminated from Bradley's analysis, we have no reason to believe that his results are applicable to their circumstances. To give such sites and observations appropriate weight, one needs to include their data in the analysis.

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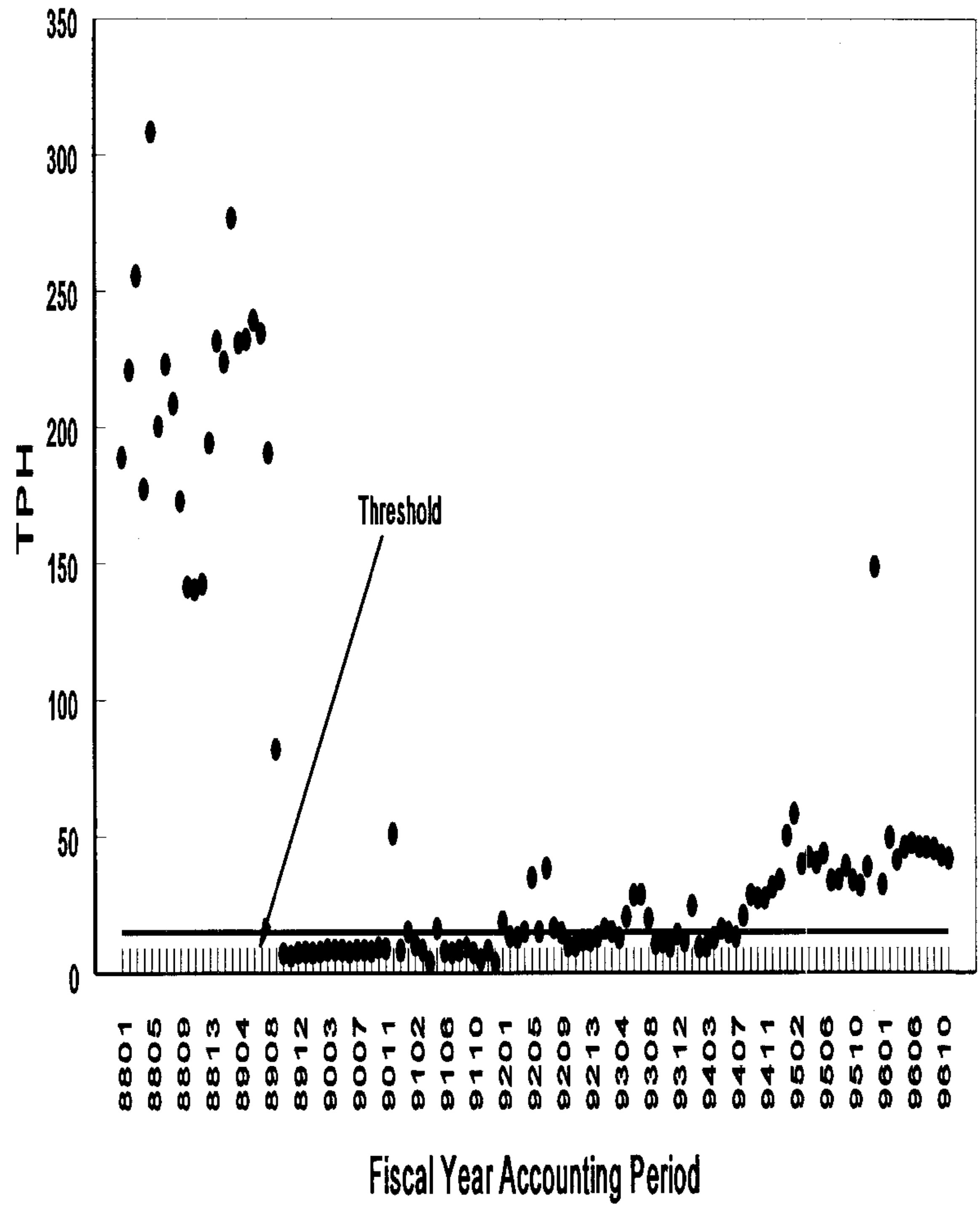
16. R. Dennis Cook and Sanford Weisberg, Residuals and Influence in Regression, Chapman and Hall (1982), p. 104.

Figure 2
Manual Parcel Sorting Site #242 Threshold Criteria



Bradley's decision to include only sites that have 39 periods of continuous data appears to be especially arbitrary. There is nothing about Bradley's models or analysis that mandates such a requirement. Bradley's models include piece handlings for both the current accounting period and the preceding accounting period. Hence, in order for a data point to be included in the estimation of his fixed effects model, it is necessary only that complete data be available for two consecutive accounting periods. In order for a data point to be included in the estimation of his fixed effects model with serial correlation, it is necessary only that complete data be available for three consecutive accounting periods. None of his programs or calculations inherently requires data for 39 consecutive accounting periods.

The requirement that a site have complete data for 39 consecutive accounting periods accounts for the largest portion of the observations that are discarded as a result of Bradley's "scrubbing" procedures. Bradley fails to present a rigorous defense of his decision to discard observations with such abandon. Discussing his continuity requirement in his direct testimony, Bradley simply states:

> The time dimension is an important part of the nature of panel data and if possible, it is preferable to have continuous data. Continuous data facilitate the estimation of accurate seasonal effects, secular non-volume trends, and serial correlation corrections.[17]

Nothing in this statement refers to his specific decision to require three years of consecutive data, and the assertions which it does contain are not entirely

17. USPS-T-14, p. 31.

correct. Estimation of accurate seasonal effects requires simply that the dataset contain adequate numbers of usable observations in each of the different seasonal periods, a requirement that is easily met. It is not necessary that they occur consecutively. Similarly, estimation of accurate secular non-volume trends requires only that the dataset provide adequate coverage of all of the dates within the overall sample period. Again, it is not necessary that they occur consecutively.

Estimation of accurate serial correlation corrections does require consecutive observations in order to make it possible to relate prediction errors in one period to prediction errors in the prior period. However, only two consecutive observations are needed to contribute to the estimation of the Baltagi-Li serial correlation coefficient. To contribute to the estimation of the final fixed effects model with serial correlation correction, three consecutive observations are required. Neither estimation requires 39 consecutive observations.

Bradley's decision to discard huge volumes of data has had a substantial effect on his results. To illustrate this point, I reran his econometric analyses on the full dataset using all of the observations for which complete data were available. The results of this exercise are shown in Table 5 below, which also compares the estimated volume variabilities to those reported by Bradley. The results differ sharply from those presented by Bradley in his direct testimony. Using the full dataset produces volume variabilities that are often higher than those reported by Bradley. For example, using the full dataset raises the estimated volume variability for the MODS OCR sorting activity from 79 percent to 83 percent. The estimated variability for MODS LSM sorting increases from 91 percent to

98 percent. For MODS bar code sorting, variability increases from 95 percent to 108 percent, indicating the presence of diseconomies of scale in this activity. Dramatic changes occur for most activities.

Table 5

Effects of Discarding Usable Observations on Bradley's Estimates of the Volume Variability of Mail Processing Labor Costs

Activity	**Bradley's "Scrubbed" Data [1]**	**All Usable Observations [2]**
Estimated Volume Variability of Mail Processing Labor Costs		
MODS Direct		
BCS Sorting	95%	106%
OCR Sorting	79%	83%
LSM Sorting	91%	97%
FSM Sorting	92%	102%
Manual Letter Sorting	80%	84%
Manual Flat Sorting	87%	90%
Manual Parcel Sorting	40%	32%
Manual Priority Mail Sorting	45%	42%
SPBS - Priority Mail Sorting	80%	73%
SPBS - Non Priority Mail Sorting	47%	36%
Cancellation and Mail Prep	65%	53%
MODS Allied		
Opening - Pref Mail	72%	79%
Opening - Bulk Business Mail	74%	108%
Pouching	83%	81%
Platform	73%	76%
BMC Direct		
Sack Sorting Machine	99%	94%
Primary Parcel Sorting Machine	86%	85%
Secondary Parcel Sorting Machine	97%	77%
Irregular Parcel Post	75%	62%
Sack Opening Unit	72%	92%
Non Machinable Outsides	67%	61%
BMC Allied		
Platform	53%	31%
Floor Labor	60%	81%

Source:

[1] USPS-T-14, p. 9
[2] WP IV

One should always be suspicious of decisions to discard data when those decisions alter the conclusions of the analysis in substantively important ways. One of the key elements of the scientific method is its emphasis on the reproducibility of results. If Bradley has done his work correctly, it should be possible for someone to independently replicate his analysis and arrive at the same conclusions. Independent replication is more than simply rerunning Bradley's computer programs to produce the same set of computer outputs. It means being able to follow each of the steps of the analysis and verify that each of the specific actions taken is an appropriate response to the problems encountered. Bradley has chosen to require 39 consecutive observations in order to include a site in his analysis of MODS direct activities. Yet, Bradley himself has indicated that 26 consecutive observations may be sufficient.[18] Results that depend strongly on such specific judgment calls regarding which data points to include and which to discard do not pass this test. From an economic and policy perspective, decisions to discard data whose implications are this significant require greater and more objective empirical and conceptual justification than Bradley has provided.

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18. Tr. 11/5450.

3. Bradley's Results Imply Implausible Patterns of Technological Change

Bradley has included in his cost equations a number of time trend variables intended to account for the effects on productivity of changes in mail sorting technology. The manner in which Bradley has introduced time trends into his models is rather complex. First, he introduces not one time trend variable, but two. Both of these trend variables are mean-centered, along with his other variables. Both are entered into the equations in both linear and squared forms. Interaction terms between the time trends and the other independent variables in the model are also included. The specification that Bradley uses for the MODS direct activities includes eight estimated coefficients for terms involving the time trend variables.[19]

In his direct testimony Bradley explains their presence as follows:

> Thus, in my equations, the time trend's coefficient measures the rate of growth (or decline) in hours *not* attributable to increases (or decreases) in piece-handlings. A trend approach is particularly well suited for looking at mail processing labor costs because changes in technology generate smooth changes in mail processing productivity.[20]

This statement accurately describes the rationale for the use of time trend variables to capture the effects of technological change. Such change is driven by the gradual accumulation of knowledge and improvement in technique and by their diffusion into practical application. The use of time trends for the

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19. This specification is presented as equation (2) on page 36 of USPS-T-14.

20. USPS-T-14.

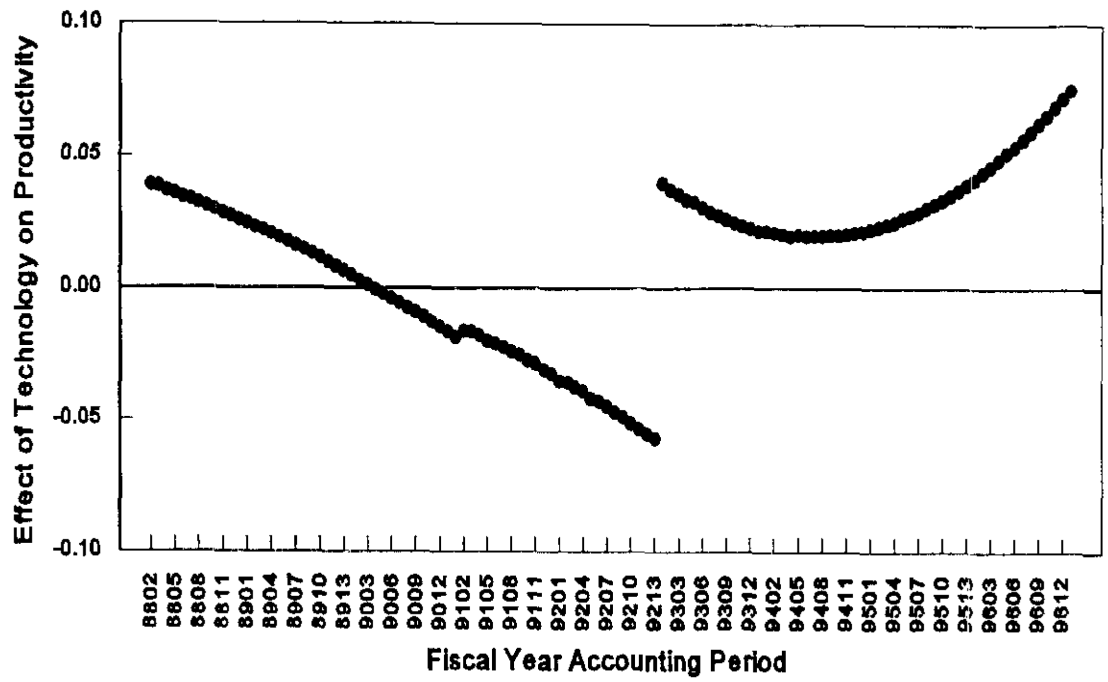
econometric measurement of the effects of technological change is motivated by the expectation (shared by Bradley) that the effects of such change would be manifested in a steady and gradual improvement in productivity.

In Bradley's analysis we have even more reason to expect the effects of technological change to be manifested in smooth and steady changes in productivity. Bradley's activity-based analysis examines each sorting technology in isolation. Because he examines manual sorting and automated sorting separately, we will never observe in his results the discontinuous jumps in productivity that can result from changes such as the move from manual to automated sorting. Instead, we should see the effects of gradual refinements of the equipment and improvement in workers' familiarity with its operation. We thus have strong reasons to expect the effects of technological change in Bradley's analysis to result in a steady and gradual improvement in productivity.

However, the pattern of technological change implied by Bradley's time trend results can best be described as one of lively variation rather than smooth and steady change. His models contain so many terms involving time trends that their effects are hard to summarize.

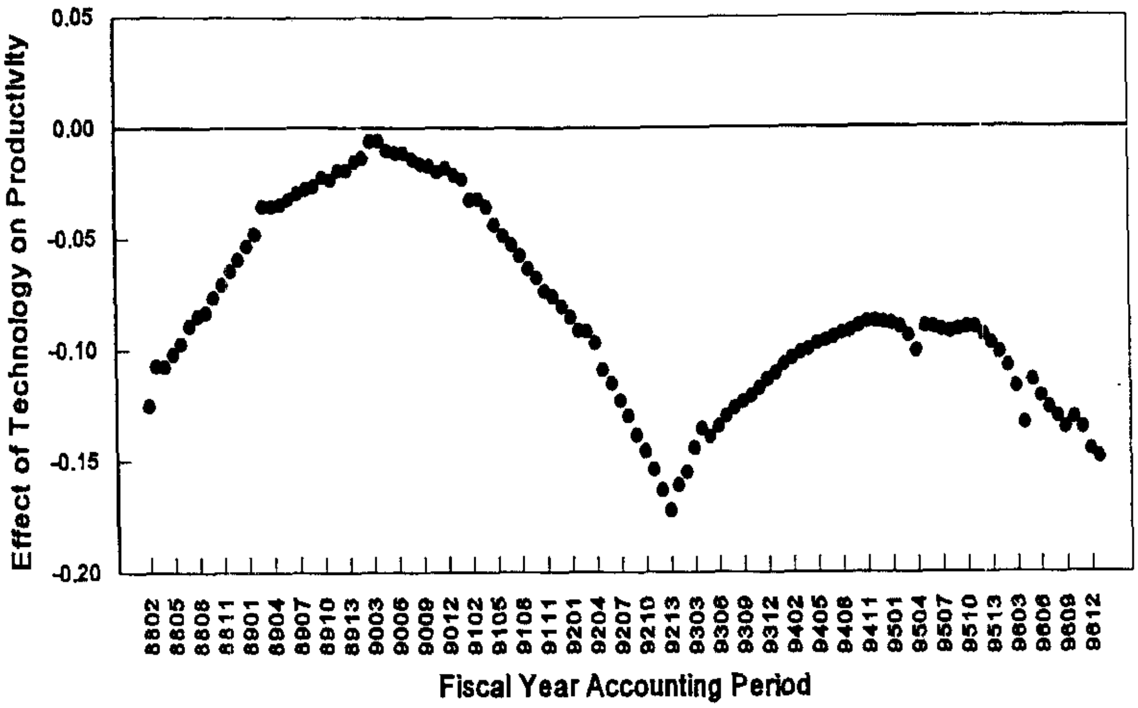
Figures 3 and 4 show results for the manual letter sorting and manual parcel sorting activities. In each case, the horizontal axis shows the time period covered by Bradley's analysis. The vertical axis shows the products of the time trend variables and their estimated coefficients.

Figure 3
Effects of Time Trend Variables in Bradley's Manual Letter Sorting Model



Source: WP VI.

Figure 4
Effects of Time Trend Variables in Bradley's Manual Parcel Sorting Model



Source: WP VI.

The patterns revealed in these two manual activities are complex, and strikingly different. In manual letter sorting we see an initial period of sharply declining productivity. Then, suddenly, in the beginning of 1993 there is a large and discontinuous jump in productivity. From that point on productivity continues to rise for a time, but eventually it levels off and then begins to decline. Again, in manual parcel sorting we see a period of rising productivity, followed by a period of falling productivity, followed by a period of rising productivity, followed by a period of falling productivity.

The results presented in Figures 3 and 4 are indicative of the general patterns that appear in Bradley's time trend results. In Bradley's world, technological progress is neither gradual nor smooth. Nor does it always move in a positive direction. At the same points in time one finds some activities rapidly gaining in efficiency, while others show losses. One also finds discontinuous jumps and declines and rapid alterations between increases and decreases in productivity.

The magnitudes of these shifts are not trivial. The vertical axes in Figures 3 and 4 are measured in terms of percentages of average labor hours in the activity. In the case of manual parcel sorting, the gap between the lowest efficiency point and the highest efficiency point amounts to approximately 17 percent of labor hours. In the case of manual letter sorting it amounts to approximately 13 percent.

The pattern of Bradley's time trend results causes me to question his interpretation of their meaning. Although he has alluded to a "major restructuring" that took place in FY 1993, he has not explained the nature or significance of this change. Moreover, he has provided little substantive explanation of what changes could account for such erratic patterns within the periods prior to and following the restructuring. I am hard pressed to envision a pattern of technological change that would produce such variations in productivity, and hence I do not believe that his time trend coefficients are really picking up the effects of technological progress.

C. Bradley's Analysis Sheds Little Light on the Long-Run Volume Variability of Costs

The fixed effects models that Bradley relies upon for his variability estimates do not appear to be capable of providing reliable estimates of the long-run variability of mail processing labor costs. Those models relate mail processing labor hours in a four-week accounting period to the number of piece handlings in that same period and in the previous period. Because these models look back only a single accounting period, they are not capable of detecting or accounting for changes that take place over longer periods of time. Their short-run view of labor cost variability calls into question their relevance to this proceeding.

The extent to which mail processing labor costs vary with volume will depend upon the time horizon over which volumes and costs change. It is possible that productivity might increase in response to a temporary surge in volume. Workers might increase the pace of work, take fewer or shorter breaks, or adopt other strategies for dealing with the added workload. In his responses to interrogatories, Bradley concedes this point.[21] Such increases in productivity may not be sustainable, however, and if the increase in volume persists it may eventually be necessary to hire additional workers to handle the increased workload. Thus, after an initial surge it is likely that productivity would decline to something closer to its original level. Over an even longer period of time, increases in volume could facilitate greater reliance on specialization or automation and thereby lead to higher productivities. Thus, the estimate that one gets for the volume variability of mail processing labor costs may differ, depending upon how long a time is allowed for costs to respond to changes in volume.

In past proceedings, the Commission has relied upon evidence of the long-run volume variability of costs in its findings regarding the attribution of costs. "Long-run," in this context, has been interpreted as changes that occur over periods longer than a year.[22] The eight week adjustment period provided for in Bradley's fixed effects models falls well short of this threshold.

BRADLEY'S CROSS-SECTIONAL MODEL PROVIDES SUPERIOR RESULTS

In his workpapers, Bradley presents regression results for what he calls the "between" model for each of the mail processing activities he examines. These "between" models are essentially cross-sectional versions of the specification he

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21. Tr. 11/5512.

22. National Association of Greeting Card Publishers v. United States Postal Service, 462 U.S. 810, 815-16 (1983).

uses in his fixed effects analysis. The volume variability estimates produced by these cross-sectional models are presented in Table 6.

Table 6

Volume Variability Estimates from Bradley's "Between" Model

Activity	Volume Variability
MODS Direct	
BCS Sorting	113%
OCR Sorting	111%
LSM Sorting	105%
FSM Sorting	103%
Manual Letter Sorting	106%
Manual Flat Sorting	110%
Manual Parcel Sorting	99%
Manual Priority Mail Sorting	107%
SPBS - Priority Mail Sorting	120%
SPBS - Non Priority Mail Sorting	93%
Cancellation and Mail Prep	108%
MODS Allied	
Opening - Pref Mail	109%
Opening - Bulk Business Mail	110%
Pouching	99%
Platform	133%

Source: USPS-T-14 WP I and II

The results of Bradley's cross-sectional analysis appear to provide a superior basis for estimating the volume variability of mail processing labor costs. They are more likely to show long-run effects, and they are less sensitive to data quality problems and to judgments about how to "scrub" the data.

Adoption of a cross-sectional approach de-emphasizes the effects of short-term increases and decreases in volume, focusing the analysis instead on the long-run effects of changes in mail volumes. A cross-sectional approach emphasizes the contrast between facilities that differ systematically in the volume of mail they process and that have had the chance to adjust fully to those systematic differences. Indeed, one would expect decisions regarding staffing levels, degree of automation, layout of the processing flows, and other significant factors affecting the volume variability of processing costs to be closely related to the volumes typically processed at a facility.

Under cross-examination on his testimony regarding purchased transportation costs, Bradley readily conceded the ability of cross-sectional analysis to yield simpler and more direct estimates of the volume variability of costs:

> And one of the advantages of a cross-sectional analysis is it allows me to estimate how quickly cost rises or falls with increases or decreases in volume without the necessity of tracing the size of total accrued cost through time.[23]

Later he conceded that cross-sectional analysis is not just an appropriate way to address these issues, but also perhaps the more common approach:

> However, another approach which is widely used, perhaps even more so for the type of analysis I'm doing, is to, for a cross-section of facilities or in this case contracts, collect the information on costs and cubic-foot miles and use the variation between the small contracts, that is small cubic-

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23. Tr. 7/3809.

> foot miles, and the large cubic-foot miles, to measure how it is costs vary with cubic-foot miles.[24]

He concluded with a strong affirmation of the relevance of cross-sectional analysis: ". . . I believe it's an entirely valid methodology to collect a cross-sectional cross-section of data and to analyze . . . how it is costs increase with cubic-foot miles."[25]

Bradley's between model offers advantages over and above those cited in his purchased transportation testimony. Cross-section results are less subject to attenuation due to errors-in-variables bias than his fixed effects model results. He constructs the observations that enter into his cross-sectional analysis by averaging across time periods the values for the dependent and independent variables associated with each facility. The averages created in this way become the inputs to his cross-sectional regression model. In this averaging process, instances of over-estimation and under-estimation of piece handlings will tend to cancel out, with the result that net measurement error in the independent variables will become proportionately less significant.

The volume variabilities implied by the cross-sectional models are often higher than those reported by Bradley and are generally very close to 100 percent (or greater than 100 percent, implying diseconomies of sale). The differences between the cross-sectional results and the fixed effects results can be attributed to the fact that the cross-sectional results are closer to the long-run volume variabilities and are less subject to attenuation effects caused by measurement

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24. Tr. 7/3813-14.

25. Tr. 7/3814.

error in the piece-handlings variables. For these reasons, the cross-sectional results provide a more appropriate basis for the attribution of mail processing labor costs.

BRADLEY HAS NOT DEMONSTRATED THAT VOLUME VARIABILITY IS LESS THAN 100 PERCENT

Bradley's analysis is not sufficiently reliable to justify rejection of the Commission's established determination that mail processing labor costs are 100 percent volume variable. Taken at their plain face value, these analyses do not address the right question, nor do they use the right variables.

Even if one were to set aside concerns about the appropriateness of Bradley's measures of cost and volume, ample reasons for skepticism remain. Many aspects of his data, his sample selection criteria, his model, and his results seem questionable. His econometric results do not appear to be stable. Changes in approach, or even changes in data "scrubbing" criteria, lead to substantially different results. Moreover, there is good reason to believe that his econometric estimates understate the true variabilities.

A RELIABLE ECONOMETRIC ESTIMATE OF VOLUME VARIABILITY?

The points discussed above indicate the presence of serious problems with Bradley's econometric results. The Commission should not use those results to draw any conclusions regarding the volume variability of mail processing labor costs. Nonetheless, it is necessary at times to make policy decisions even in the absence of definitive empirical information. This fact logically raises an important question: If the Commission is seeking the best econometric estimate of volume variability that is achievable given the available data and resources, to which set of results should they turn? This section of my testimony attempts to answer that question.

A. Bradley's Cross-Sectional Model Provides An Appropriate Starting Point

As I have stated, the most accurate and reliable estimates of the volume variability of mail processing labor costs to be found in Bradley's results are those provided by the cross-sectional analysis embodied in his "between" models. My reasons for this belief are set forth above, but are worth repeating here. Most important, the cross-sectional approach is inherently better able to provide estimates of long-run volume variability. Also, the averaging across time that is part of the cross-sectional model development process mitigates some of the deleterious effects of the measurement error problems in the MODS and PIRS piece handlings data.

B. Some Modifications of Bradley's Cross-Sectional Model Are Appropriate

If the Commission were to rely upon an econometric analysis of mail processing labor cost variability, two modifications to Bradley's "between" model results would be in order. I recommend dropping the time trend variables and interaction terms from the model. In Bradley's fixed effects analysis, these variables give rise to some curious coefficient estimates that raise questions about whether they are in fact capturing the effects of technological change. In the cross-sectional context, they have little meaning. Also, it is clearly necessary to extend Bradley's "between" approach to all of his activities.

C. Data "Scrubbing"

If the Commission decides to rely upon an econometric approach to the estimation of volume variability, it will have to decide how much "scrubbing" of the data is appropriate. In the absence of any external validity checks, it is hard to find a clear and objective basis for deciding which data to use and which data to discard. For this reason, as described above, the best approach is to dispense with all of the "scrubbing" and run the analyses on the full set of data.

Bradley's "threshold" scrub seems designed systematically to eliminate certain types of facilities or time periods from his analysis. Since these facilities and time periods do exist and their effect on costs must be dealt with in the rate setting process, I see no justification for eliminating them from the analysis. In fact, eliminating them almost guarantees that the results will not be representative of the cost-volume relationship that actually exists over all postal facilities. I therefore recommend dropping the threshold "scrub." For similar reasons, I would recommend against adoption of Bradley's "productivity" scrub. It systematically eliminates observations and reduces the representativeness of Bradley's analysis sample. Finally, I would also recommend dropping the continuity "scrubs." They have no clear justification in the context of the fixed effects model and even less in the context of the cross-sectional analysis. They also result in the elimination of large numbers of observations from the analysis.

Econometric estimates of the volume variability of mail processing labor costs that are based upon these recommendations are presented on page 7 above, in Table 1.

D. Implementation of These Changes Still Leaves a Model That Fails to Consider Either Actual Costs or Actual Volumes

Implementation of all of the recommendations presented above will still result in a model that (1) fails to include either a true measure of cost or a true measure of volume and (2) relies heavily on a data source of uncertain and unproven accuracy. As a result, I recommend that the Commission stand by its *long-established determination that mail processing labor costs are 100 percent* variable.

CONCLUSION

Bradley's econometric analysis contradicts the common sense conclusion that labor is inherently a highly variable cost factor. Bradley urges the Commission to reject its traditional treatment of mail processing labor costs as 100 percent variable in favor of an alternative approach that would move significant portions of mail processing labor costs into the institutional cost category. A call for such a sweeping departure from precedent bears a substantial burden to support the assertion that such a departure is in fact warranted. Bradley has not met this burden.

At the most basic level, Bradley has failed to address the questions that are really relevant to this proceeding. His analysis fails to include a true measure either of cost or of volume. He cannot, therefore, claim to have measured accurately the volume variability of costs. His model also adopts an excessively short-term view of volume variability; it is constructed to allow for a complete adjustment of costs to a change in volume in two accounting periods and can reflect only the changes that take place over that brief period. The relevance of such short-run effects to the process of setting rates that will remain in effect for years is highly questionable.

Moreover, there are a number of problems with the implementation of Bradley's econometric analyses. He has relied heavily on data of uncertain accuracy. He has discarded from his analysis huge volumes of data on the basis of highly subjective judgments. These exclusions have substantially altered the character of his empirical results. His empirical results do not appear to be robust; equally defensible changes in approach lead to quite different estimates of the volume variability of mail processing labor costs.

For all of these reasons, Bradley's results should be rejected. He has not offered a compelling reason for the Commission to reject its traditional approach to mail processing labor costs. In fact, a more appropriate cross-sectional analysis suggests that the traditional, common sense conclusion that mail processing labor costs are 100 percent volume variable is correct.

APPENDIX A

The essence of Bradley's errors-in-variables analysis involves the comparison of two alternative estimators of volume variability that are subject to differing degrees of attenuation. The comparison of the two estimates, Bradley claims, allows him both to quantify the degree of measurement error in piece handlings and to determine the true value of volume variability. The formulas showing the magnitudes of the attenuation effects for the two alternative estimators are shown in equations (19) and (21) on pages 81 and 82 of Bradley's direct testimony (USPS-T-14). Combining these two expressions, Bradley derives the formula shown in equation (22) on page 82 of USPS-T-14 for the true value of volume variability. Equation (22) is derived from equations (19) and (21) by replacing the probability limits shown there with the two estimated coefficient values, combining the two resulting expressions, and solving for the true value of volume variability. Equation (22), therefore, is derived from and depends upon the accuracy of equations (19) and (21).

Both equation (19) and equation (21) demonstrate the attenuation effects cited by Greene. Equation (19) takes the following form:

$$plim\hat{\beta}_f = \beta\left[1 - \frac{(T-1)\sigma_{\psi}2}{TVar(x_{it*} - \bar{X}_i^*)}\right]$$

where $\hat{\beta}_d$ is the estimate of volume variability generated by the fixed effects estimator, β is the true volume variability, T is the number of time periods in the dataset, σ^2_ψ is the variance of the measurement error in the piece-handlings variable, x^*_{it} is the recorded number of piece handlings for site i in period t, and $\bar{x}^*_i$ is the average across all time periods of the recorded piece handlings for site i.

This equation shows that the estimate of volume variability provided by the fixed effects estimator will be equal to the true volume variability multiplied by a term that is equal to one minus the ratio of two variances. Since variances must be positive, the ratio of the two variances will also be positive. Hence, the estimated volume variability will be equal to the true volume variability multiplied by a number less than one. In other words, the estimated variability will be less than the true variability.

Analysis of equation (21) yields a similar result. That equation takes the following form:

$$Plim\beta_d = \beta\left[1 - \frac{2\sigma_\psi 2}{Var\ x_{it*} - x^*_{i,t}\ -1)}\right]$$

where β is the estimate of volume variability generated by the first difference estimator. For the same reasons as those set forth above, the estimate of volume variability provided by the first difference estimator will be equal to the true volume variability multiplied by a number less than one. Again, the estimated variability will therefore be less than the true variability.

These mathematical facts call into question the reliability of the estimates of the true volume variabilities presented by Bradley in Table 17 on page 84 of his direct testimony. For the manual letter sorting activity he presents values of .6048 for the true volume variability,[26] .6316 for the volume variability estimate produced by the fixed effects estimator, and .7232 for the volume variability estimate produced by the first difference estimator. Note that the value that Bradley presents for the true volume variability is *higher* than either of the two attenuated estimates. If equations (19) and (21) are correct, the only way to arrive at such a conclusion would be for the variance of the measurement error to be negative, a mathematically impossible result.

The reasons for these anomalous results are not completely clear. Strictly speaking, Bradley's equation (22) holds only as his sample size grows toward infinity. It is possible that these results reflect the small sample properties of equation (22), although, as Bradley often points out, he has quite a large sample available. The source for equations (19) and (21) cited by Bradley in his direct testimony bases the derivation of these assumptions upon a number of specific assumptions about the structure of the data[27] -- assumptions that may not hold for

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26. This quantity is identified in the table as the "Errors-in-Variables β." Under cross-examination (Tr. 11/5575, 5576) Bradley stated that this quantity was calculated from equation (22), and so it is identical to what I have called here the true value of the volume variability coefficient.

27. Cheng Hsiao, Analysis of Panel Data, Cambridge University Press, 1986, (continued...)

the data used by Bradley. Regardless of the explanation, however, it is clear that Bradley's errors-in-variables analysis produces nonsensical results in the case of the manual letter sorting activity. We cannot place any credence in an estimate of the "true" volume variability that depends upon the existence of a measurement error process with a negative variance.

This result is not limited to the manual letter sorting activity. Table A-1 shows the results that are obtained when Bradley's errors-in-variables methodology is applied to all of the MODS direct activities. The mathematically impossible result of a negative measurement error variance appears in connection with a number of activities.

27.(...continued)
pp. 63-65.

Table A-1

Results Obtained When Bradley's Errors-in-Variables Methodology Is Applied to All MODS Direct Activities

Activity	"Errors-in-Variables"	Implied "Piece Handlings" Measurement Error Variance
MODS Direct		
BCS Sorting	1.0040	0.0026
OCR Sorting	0.9708	0.0035
LSM Sorting	0.8263	-0.0011
FSM Sorting	1.1359	0.0028
Manual Letter Sorting	0.5881	-0.0047
Manual Flat Sorting	0.6967	-0.0002
Manual Parcel Sorting	0.5938	0.0195
Manual Priority Mail Sorting	0.5539	-0.0010
SPBS - Priority Mail Sorting	0.9619	0.0121
SPBS - Non Priority Mail Sorting	0.7751	0.0072
Cancellation and Mail Prep	0.5470	0.0000

Source: WP III.