Productivity Measurement and Management Accounting

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1. Introduction

Productivity improvement has become a key objective for U.S. industry.[1] Productivity measurement, however, has gone largely unnoticed by accounting professionals, particularly those teaching and doing research in accounting departments and business schools. Accounting textbooks virtually ignore issues of productivity measurement, and accounting journals contain few articles on the subject. Most articles on productivity measurement are written by economists—usually interested in productivity measurement at the national economy level—or by industrial engineers and production professionals.[2]

The implicit, and occasionally explicit, rationalization for the accounting profession's lack of interest in productivity measurement apparently arises from the belief that variances computed by the firm's standard cost system, particularly usage variances, are sufficient to measure the efficiency of the enterprise. Presumably, a desire for increased productivity could be signaled by across-the-board tightening of standards by the desired percentage. If a firm were inefficient or failed to meet its productivity improvement target, then the accounting system would report many unfavorable usage variances.

We do not believe that even well-designed and well-operated standard cost systems provide adequate information for productivity measurement and improvement programs. Primarily this is an empirical statement. We observe numerous companies, with extensive standard cost accounting sys-

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1. *Fortune* magazine, in a survey of the 500 largest corporations (April 1986), found that 78 percent of responding chief executive officers cited productivity improvement and cost control as the most important elements of their corporate strategy for the 1980s.

2. See, for example, Davis (1955), Craig and Harris (1973), Gold (1979, 1980), Babson (1981), Hayes (1982), and Kendrick (1986).

tems, establishing productivity measurement systems independent of the accounting system and even establishing separate departments to develop productivity statistics.[3] These companies apparently find a need to develop productivity measures to supplement the information being reported by their internal accounting systems.

The relationship between productivity measurements and the usage variances produced by standard cost systems has not been explored, nor is the relationship obvious. Further, because accounting researchers have not investigated productivity measurement in any depth, much of the considerable experience accounting scholars have gained during this century on the operation and analysis of standard cost systems has not been applied to productivity measurement techniques. In this paper, we attempt to meet both goals. We articulate a role for productivity measurement that is not easily met by a collection of usage variances. We illustrate the relationship between productivity measurement and the output from a standard cost system. And we identify some shortcomings of a widely quoted productivity measurement system. These shortcomings can be overcome by incorporating information from the standard cost system into the productivity measurement system. Thus, this paper will bridge the current gap between the usage variances produced by accountants and the productivity measures produced by economists, industrial engineers, and operations managers. In the process, we develop improved performance measures by synthesizing the best aspect from each school of thought.

2. Productivity Measurement

Productivity is measured as a ratio of outputs to inputs:

$$\text{Productivity} = \frac{\text{Quantity of outputs produced}}{\text{Quantity of inputs consumed}}$$

By itself, a productivity measure has no meaning. It only gains meaning when compared to productivity measures for prior periods, or to measures from comparable facilities producing similar outputs.

Productivity measures attempt to highlight improvements in the physical use of resources, that is, to motivate and evaluate attempts to produce more outputs with fewer inputs while maintaining quality.[4] By focusing on physical measures, outcomes are not influenced by changes in relative costs and prices. In the short run, profits can increase if output prices are raised faster

3. Hayes and Clark (1986), Armitage and Atkinson (1989).

4. We do not explicitly consider issues of quality in this paper.

than input costs are rising. In the long run, however, competitive market forces will prevent a firm from passing firm-specific, or even country-specific, cost increases on to customers. Sustainable competitive advantage arises only by having higher productivity than competitors or by offering specialized products and services that competitors cannot match.

Productivity measures will permit managers to separate profit changes due to productivity factors and sales activity from those due to changes in output prices relative to input costs. Further, by linking productivity measures year to year, we obtain a dynamic, multiperiod evaluation of the organization's performance. The annual change in productivity and the organization's long-term productivity trend provide a convenient summary of operating performance.

In principle, managers wishing to show annual improvement in operations could compare usage variances from year to year. But this would not be meaningful if standards change from one year to the next, or if significant annual fluctuations in output occur. Usage variances are typically not computed as ratios and hence are not normalized for actual levels of output. Basically, variance analysis provides only a static, one-period retrospective analysis of performance. Although we will show, in a subsequent section of this paper, how to make variance analysis more dynamic, in practice we have not observed organizations adopting a multiperiod perspective without using a summary measure of productivity. That is, when operating managers describe their improved performance, they tend to say, "Our productivity has been increasing by about 6 percent annually." We do not hear them saying, "Our usage variances improved from $7 million unfavorable to $1.5 million favorable." Note that the latter statement, while telling us that operating performance has improved, does not help us understand the significance of the cost improvement—whether it is a 3 percent or a 15 percent improvement.

Productivity measurement systems analyze performance based on actual outputs and inputs in different time periods. The productivity measurement system can be viewed as a variance analysis of the actual costs incurred in successive periods. In contrast, traditional management accounting systems analyze performance within a given period by comparing actual quantities and prices to predetermined standards for quantities and prices.

When using an aggregate measure such as productivity, executives do not have to specify in detail how an annual productivity improvement should be achieved. Discretion is left to operating managers as to whether, for this year, the productivity gain will come from improved material utilization; more efficient, less nonproductive labor use; new capital investment; process improvement efforts; or overhead reductions.

Variance analysis is also a poor substitute for productivity measurement if standards are unrealistic or obsolete. In this unfortunately not uncommon situation, variances become difficult to interpret within a period, much less period to period. Even with a reasonably well-functioning standard cost system, the method of assigning overhead to products[5] can lead to mysterious variances. These variances arise from using cost centers and burden rates that are too aggregate and that do not reflect the actual consumption of overhead resources by products passing through the cost centers.

Thus, relying on usage variances alone for motivating and evaluating productivity improvements can be ineffective if the standard cost system does not accurately reflect the current operating environment. In contrast, productivity measurement compares the ratio of actual outputs to actual inputs in each period and hence does not depend on having a well-functioning standard cost system. But productivity measurement is not without its own significant problems. Issues of aggregating multiple outputs and multiple inputs and how to measure and control for the use of capacity or fixed resources are among the set of issues we address in the remainder of this paper.

3. Productivity Variance Analysis from a Standard Cost System

The accountant's standard cost analysis implicitly assumes a separable and linear technology. The separable technology assumption requires that the quantities of each input (each material, labor, and overhead category) depend only on the quantity of output produced and not on the quantity used of any other input. That is, no trade-off exists among different classes of material, labor, capital, or other overhead resources. A standard for consumption of a certain material is defined without reference to the amount of labor or any other materials consumed to produce the output.

Linear (or constant marginal productivity) production technology assumes that each of the variable inputs is consumed proportionally to increases in production volume. Therefore, to determine the standard amount of material consumption for a given volume of output, we multiply the standard unit consumption of materials by the quantity of output produced. Since most productivity measurement systems also implicitly assume a linear and separable production function, we maintain these assumptions throughout our analysis in this paper too.[6]

We illustrate the procedure for computing productivity and price re-

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5. See Mayers Tap (C), HBS Case # 9-184-024-026.

6. Nonlinear, nonseparable production functions are discussed in Banker and Datar (1986).

TABLE 1

Data to Compute Accounting Variances

Technology Specification	*Product 1*	*Product 2*
Labor hours per product unit	0.20	0.30
Materials units per product unit	1.00	1.20
Variable overhead driver units per product unit	0.50	0.80
Discretionary fixed overhead driver units	196 units	
Committed fixed overhead	1 unit	

Outputs

	Standard Price	*Standard Quantity*	*Actual Price*	*Actual Quantity*	*Value*
Product 1	$10	50,000	$10.50	60,000	$630,000
Product 2	15	25,000	15.00	20,000	300,000
		75,000		80,000	930,000

Inputs

	Standard Price	*Actual Price*	*Actual Quantity Consumed*	*Value*
Labor	$ 10	$ 10.00	17,000	$170,000
Materials	5	5.20	82,000	426,400
Variable overhead	2	2.10	49,760	104,496
Discretionary fixed overhead	285	288.00	197	56,736
Committed fixed overhead	44,000	46,000.00	1	46,000
				$803,632
Total Actual Profit				$126,368

covery variances by working through a numerical example. The example, although simple, has enough features to capture all the aspects that would be relevant even in realistic, more complex settings.[7]

Table 1 describes the summary statistics for a company producing two products with inputs of a single raw material, a single grade of labor, and various types of overhead.[8] In addition to distinguishing between variable and fixed overhead, we also find it useful to distinguish between two types

7. The algebraic representation of the formulas used to analyze the numerical example is available, from the authors, in a technical appendix.

8. For simplicity in exposition, we assume throughout that production equals sales. In practice, modifications will have to be implemented to control for the sale of products produced in earlier periods and the production of items not yet sold.

of fixed overhead: committed and discretionary.[9] Committed overhead includes the costs of resources, such as the factory building (depreciation, insurance, taxes) and the plant manager, that cannot be reduced without shutting down the production facility entirely.[10] Committed overhead costs tend to be associated with indivisible resources that consist of only one unit (e.g., one building, one plant manager, one machine). Therefore, we would not normally think of obtaining productivity gains from committed overhead resources. Fluctuations in committed overhead costs arise from price changes for these resources and not from using more or fewer of them.

Discretionary overhead, in contrast, consists of most plant overhead expenses that are incurred at the discretion of management and can be influenced by managerial decisions. Therefore, a primary focus of productivity programs may be to accomplish the same amount of work with fewer discretionary overhead resources. Discretionary overhead resources may be fixed with respect to short-term fluctuations in the volume of production, but they will vary with other transactions or managerial decisions. For example, the costs of the set-up department and the production control department will vary with the number of set-ups and the degree of diversity in the product line (Cooper and Kaplan [1987]). Therefore, the quantity of discretionary overhead can be lowered by reducing complexity or product diversity in the factory, or by process-improving innovations, such as reducing set-up times and implementing just-in-time production systems. Such complexity reductions and process improvements will lower the demand for personnel in departments responsible for set-ups, inventory control, scheduling, and quality assurance, thereby permitting productivity gains with respect to discretionary overhead resources.

In general, any overhead department or cost center with more than one employee or one machine should be considered either a variable or a discretionary overhead account. For simplicity in our numeric example, we assume that all discretionary fixed[11] overhead is driven by one type of transaction, such as number of set-ups.

The variance analysis uses the decomposition approach introduced by Shank and Churchill (1977; hereafter, SC). This approach provides a con-

9. We introduce this distinction to show that distinguishing between committed and discretionary can be handled in any productivity measurement system.

10. As previously noted, we do not get into the details of measuring capital consumption costs; we assume financial depreciation is an adequate surrogate for the costs of using finite-lived assets and deal in more depth with this issue in a subsequent paper.

11. We are using *fixed* in its traditional accounting sense as overhead that does not vary with short-run fluctuations in output. The overhead is variable, however, over longer time periods with respect to other activity measures, such as transactions or product diversity.

venient method for analyzing the difference between actual and budgeted profits by decomposing the profit variance into components related to changes in sales activity and to changes in prices, costs, and efficiency. We extend the SC analysis by combining individual price and cost variances into an overall price recovery variance, and by introducing a productivity variance to represent the aggregation of usage variances. The actual computations for our proposed three-variance system are shown in Table 2.

First we compute a sales activity variance, shown in panel A of Table 2, to represent the change in profits caused by variation in the actual mix and volume of products produced and sold. The difference between actual and budgeted output quantities is evaluated at the standard margin for each output product. In this example, an unfavorable sales activity variance of −$2,000 occurs because the increased sales of the low-margin Product A (10,000 extra units at $2/unit) is offset by the lower sales of the high-margin Product B (5,000 fewer units at $4.40/unit).[12]

In some productivity measurement systems such as van Loggerenberg and Cucchiaro (1981–82), the sales activity variance is called a capacity usage variance and is considered a component of the overall productivity measure. We believe such treatment is inappropriate for two reasons. First, it is semantically misleading to refer to the higher profits earned by more favorable volume or mix of sales as due to capacity utilization. Capacity usage conjures up the spreading of "fixed" capacity costs over a larger volume of products. Although this could be true, it is not necessarily true. Even without any fixed costs or finite capacity, the firm could earn higher profits by selling more items or by shifting its mix from low- to high-margin products. The sales activity variance in panel A of Table 2 arises from the changes in contributions from selling different (from budgeted) quantities of output while holding fixed costs, selling prices, and unit-variable costs constant, not from absorbing more or fewer fixed expenses into product costs.

Second, we object to treating the sales activity (or the capacity usage) variance as a component of the overall productivity measure. We believe productivity improvement arises from better processes for using materials, labor, energy, support departments, and capital to produce a given quantity of output. We think it misleading to attribute productivity gains merely to increased activity levels.

Usage variances are computed in panel B of Table 2. The difference between standard and actual consumption of input resources at the actual

12. The sales activity variance could be decomposed further into mix, industry volume, and market share variances as described in Shank and Churchill.

TABLE 2

A. Sales Activity Variance

Standard margin for Product 1:

$$\$10 - 0.20 \times 10 - 1.00 \times 5 - 0.50 \times 2.00 = \$2/\text{unit}$$

Standard margin for Product 2:

$$\$15 - 0.30 \times 10 - 1.20 \times 5 - 0.80 \times 2.00 = \$4.40/\text{unit}$$

	(1) Standard margin	(2) Actual output	(3) Budgeted output	(4) = (2) (3) Difference in output	(5) = (1) × (4) Sales activity variance = Change in contribution margin	(6) = (1) × (3) Budgeted Contribution Margin
Product 1	$2.00	60,000	50,000	10,000	$20,000	$100,000
Product 2	4.40	20,000	25,000	(5,000)	(22,000)	110,000
Sales activity variance					$(2,000)	
						$210,000

B. Usage and Productivity Variances

	(1) Std. Consum. for Actual Output of Prod. 1	(2) Std. Consum. for Actual Output of Prod. 2	(3) = (1) + (2) Total Std. Consumption of Inputs	(4) Actual Cons.	(5) = (3) − (4) Difference in Inputs Consumed	(6) Std. Price of Inputs	(7) = (5) × (6) Usage Variance	(8) = (3) × (6) Std. Price of Actual Consumption
Labor	12,000	6,000	18,000	17,000	1,000	$ 10	$10,000	$180,000
Materials	60,000	24,000	84,000	82,000	2,000	5	10,000	420,000
Variable overhead	30,000	16,000	46,000	49,760	(3,760)	2	(7,520)	92,000
Discretionary fixed overhead			196	197	(1)	285	(285)	55,860
Productivity variance							$12,195	
								$747,860

TABLE 2 (*cont.*)

C. Price and Price Recovery Variance

Outputs	*(1)* *Actual Output Price*	*(2)* *Budgeted Output Price*	*(3) = (1) − (2)* *Difference in Prices*	*(4)* *Actual Output*	*(5) = (3) × (4)* *Sales Price Variance*	*(6) = (2) × (4)* *Actual Outputs at Budgeted*
Product 1	$10.50	$10.00	0.50	60,000	$30,000	$600,000
Product 2	15.00	15.00	0.00	20,000	0	300,000
Sales price variance					$30,000	$900,000

Inputs	*(1)* *Actual Input Price*	*(2)* *Budgeted Input Price*	*(3) = (1) − (2)* *Difference in Prices*	*(4)* *Actual Input Cons.*	*(5) = (3) × (4)* *Input Price Variance*	*(6) = (2) × (4)* *Actual Inputs at Budgeted Prices*
Labor	$ 10.00	$ 10	$ 0	17,000	$ 0	$(170,000)
Material	5.20	5	(0.20)	82,000	(16,400)	(410,000)
Variable overhead	2.10	2	(0.10)	49,760	(4,976)	(99,520)
Discretionary fixed overhead	288.00	285	(3.00)	197	(591)	(56,145)
Committed fixed overhead	46,000.00	$44,000	$(2,000.00)	1	(2,000)	(44,000)
					$(23,967)	$(779,665)
Price recovery variance					$ 6,033	$120,335

production volume for the year is evaluated using the standard price for each input resource. The productivity variance, defined as the sum of the individual usage variances, is favorable $12,195, with the favorable usage variances for labor and materials outweighing the unfavorable usage variances for variable and discretionary overhead. The productivity variance represents the increase in profits from better usage of individual inputs (including variable and discretionary overhead resources) to produce a given quantity of outputs. The actual volume and mix of outputs, prices of output products, and prices (or costs) of input resources are accounted for in other variances so that the productivity variance is influenced neither by production activity nor by relative price effects.

Note that the productivity variance is not simply an aggregation of the typically computed usage variances for direct or variable costs. The productivity variance includes a component for efficient use of discretionary fixed costs. Since discretionary fixed costs constitute a significant percentage of total costs in today's complex manufacturing environments, productivity improvements must arise not only from controlling variable costs, but also from controlling the quantity of discretionary fixed overhead resources. Most accounting systems do not decompose fixed overhead costs into quantity (usage) and price components as they do when disaggregating material and labor variances. We can achieve this separation into quantity and price effects for overhead because we identify the transactions or cost drivers that cause the quantity of discretionary fixed overhead resources to vary.

In the third and final calculation, price variances are computed separately for outputs and inputs and then added together to obtain a price recovery variance (see panel C of Table 2). The favorable $30,000 sales price variance for Product A exceeds the unfavorable price variances for material ($16,400), variable overhead ($4,976), discretionary overhead ($591), and committed overhead ($2,000) to produce a favorable price recovery variance of $6,033. This favorable variance indicates that, at actual outputs and inputs, the increased prices of output products generated revenues in excess of the higher costs from increased prices for input resources.

The difference between actual profits of $126,368 in Year 2 and the expected or budgeted profits for Year 2 of $110,140 can now be explained as:

$$\underset{\text{variance}}{\text{Profit}} = \underset{\text{variance}}{\text{Sales activity}} + \underset{\text{variance}}{\text{Productivity}} + \underset{\text{variance}}{\text{Price recovery}}$$

or

$$16{,}228 = -2{,}000 + 12{,}195 + 6{,}033.$$

The above computations follow directly from the SC decomposition analysis. We have extended the SC analysis by aggregating price and cost variances into an overall price recovery variance and by aggregating individual usage variances into an overall productivity variance. In addition, we have incorporated a component into the productivity variance to represent the quantity of discretionary fixed overhead costs consumed relative to the number of production transactions during the period.

4. Computing Productivity Ratios from Accounting Variances

The accounting variances computed in the previous section help separate a total profit variance into components caused by increases in the volume of sales, changes in relative prices between outputs and inputs, and productivity effects. But the variance components are themselves absolute numbers and do not translate readily into percentage improvements. Particularly when measuring productivity changes, managers generally find it easier to evaluate productivity improvements by percentages, such as by specifying a target for overall productivity improvement of, say, 7 percent annually. The percentage comparison facilitates comparison both to the scale of operations and to previous years. A favorable productivity variance of $200,000 is more impressive when total operating costs are $2 million than when they are $200 million. And a company that sets a goal of improving productivity by 7 percent each year will not find it immediately informative to learn that its productivity variance this year was a favorable $200,000.

In this section, we demonstrate how to represent the arithmetic productivity, price recovery, and sales activity variances of the preceding section as percentage or ratio measures. These ratio measures also permit us to compute elasticity numbers that indicate the sensitivity of overall profits to percentage changes in each of the three operating factors.

In order to obtain percentage measures for the three aggregate variance measures, we must choose an appropriate denominator to normalize each measure.[13] Standard costs or margins represent plausible bases for computing the percentage changes in productivity, price recovery, and sales activity.

13. The economic theory to identify the appropriate ratio measure is discussed in Banker (1988).

Accounting Variance	*Denominator*	*Magnitude (from last column in Table 4)*
Sales activity	Standard contribution margin at budgeted output	\$210,000
Productivity	Total standard costs at actual output	747,860
Price recovery	Standard gross margin at actual quantities of outputs and inputs	120,335

Table 3 presents the calculation of the ratios to explain the 14.73 percent increase in profits (actual profits = \$126,368; budgeted profits = \$110,140). First, the unfavorable −\$2,000 sales activity variance represents a −0.95 percent decrease in contribution margin from the *budgeted* contribution margin of \$210,000. The \$12,195 favorable productivity variance is a 1.63 percent reduction in actual costs relative to the standard costs of \$747,860, computed at the *actual* volume and mix of outputs (60,000 units of Product 1, 20,000 units of Product 2). Finally, the favorable \$6,033 price recovery variance represents a 5.01 percent improvement in gross margin measured with respect to the standard margin of \$120,335, computed with standard prices and costs at the *actual* quantities of outputs sold and inputs consumed.

In order to combine the three ratios, each normalized by a different activity base, into an overall measure of profit improvement, we compute weights (see column (2) of Table 3) as the ratio of each denominator measure (used to compute column (1) in the table) to the budgeted profits of \$110,140. Multiplying each weight in column (2) by the respective percentage change in column (1) yields the weighted percentage changes shown in column (3) of the table. Adding the three percentage changes in column (3) produces the overall percentage improvement in profits of 14.73 percent. We can now explain the 14.73 percent increase in profits by a productivity increase contributing 11.07 percent, a favorable price recovery experience of 5.47 percent, less a 1.82 percent drop in sales activity.[14]

In addition to this ability to decompose a percentage change in profits into sales activity, productivity, and price recovery components, we also obtain parameters of some economic significance. The weights we computed for column (2) of Table 3 can be interpreted as elasticities of profits with respect to changes in productivity, price recovery, and sales activity. For example, the productivity weight of 6.79 implies that every 1 percent in-

14. The aggregate ratios can be disaggregated into partial ratios that evaluate performance with respect to the volume of each product sold, the productivity of each input, and the changes in the prices of each input and output. The algebraic formulas for computing the partial components are available from the authors in a technical appendix.

TABLE 3

Decomposition of Profit Change into Sales Activity, Productivity, and Price Recovery Changes

Actual profit = $126,368

Budgeted profit = $110,140

Total profit variance = $ 16,228

$$\text{Percentage change in profits relative to budgeted profit} = \frac{16{,}228}{110{,}140} \times 100 = 14.73\%$$

Percentage change in sales activity	=	Sales activity ratio	=	(2,000)/210,000 = (0.95%)
Percentage change in productivity	=	Productivity ratio	=	12,195/747,860 = 1.63%
Percentage change in price recovery	=	Price recovery ratio	=	6,033/120,335 = 5.01%

	(1) *Percentage*	*(2)* *Elasticity Weights*	*(3) = (1) × (2)* *Impact on Profit*
Sales activity change	(0.95%)	$\frac{210{,}000}{110{,}140} = 1.91$	(1.82%)
Productivity change	1.63%	$\frac{747{,}860}{110{,}140} = 6.79$	11.07%
Price recovery change	5.01%	$\frac{120{,}335}{110{,}140} = 1.09$	5.48%
Profit change			14.73%

crease in productivity produces a 6.79 percent increase in total profits (holding prices and output quantities constant). The price recovery weight of 1.09 implies that a 1 percent improvement in gross margin due to changing output and input prices will produce a 1.09 percent increase in profits; and the sales activity weight of 1.91 indicates that each 1 percent increase in aggregate output will produce a 1.91 percent increase in profits (holding productivity, prices, and costs constant). Thus, the weights serve to decompose a traditional accounting variance into a ratio plus an elasticity factor that determines the sensitivity of profits to percentage changes in operating and activity factors.

5. Evaluation of the APC Measurement System

Now that the relationship between the variances from a standard cost accounting system and productivity ratio measures has been developed, we can analyze a commonly cited productivity measurement system proposed

TABLE 4

Data to Illustrate a Problem with APC Productivity Measure

Technology Specification	*Year 1 Product 1*	*Year 2 Product 2*
Labor hours per product unit	0.20	0.30
Materials units per product unit	1.00	1.20
Variable overhead driver units per product unit	0.50	0.80

	Year 1			*Year 2*		
	Value	*Quantity*	*Price*	*Value*	*Quantity*	*Price*
Sales						
Product 1	$500,000	50,000	$10.00	$400,000	40,000	$10.00
Product 2	375,000	25,000	15.00	570,000	38,000	15.00
	$875,000	75,000	$11.67	$970,000	78,000	$12.44
Costs						
Labor	$175,000	17,500	$10.00	$194,000	19,400	$10.00
Materials	400,000	80,000	5.00	428,000	85,600	5.00
Variable overhead	90,000	45,000	2.00	100,800	50,500	2.00
Fixed overhead	101,000	101,000	1.00	101,000	101,000	1.00
	$766,000			$823,800		
Profit	$109,000			$146,200		

by the American Productivity Center (APC), which is based only on the actual quantities and prices of outputs and inputs over a period of time. We briefly describe the APC system using the data in Table 4.

The first step in productivity measurement under the APC system is the computation of the quantity change ratios (QCR) for outputs and inputs. QCR for Product 1 is equal to actual quantity for Year 2 (40,000) divided by actual quantity for Year 1 (50,000) equal to 0.8. QCR for Product 2 is 38,000/25,000 = 1.52. QCR for labor is equal to actual quantity for Year 2 (19,400) divided by actual quantity for Year 1 (17,500) equaling 1.1086. Similarly, QCR for materials = 1.07, QCR for variable overhead = 1.12, and QCR for fixed overhead = 1.00.

An aggregate output quantity change ratio (AOQCR) is computed as a weighted average of the individual output quantity change ratios, where the weights are the Year 1 share of output value for each product. AOQCR is equal to (500/875) * 0.80 + (375/875) * 1.52 = 1.1086. The aggregate input quantity change ratio (AIQCR) is computed in an exactly analogous manner, with the weights being the relative cost shares for each input resource (labor, material, and overhead) in Year 1, and is equal to (175/766) * 1.1086 + (400/766) * 1.07 + (90/766) * 1.12 + (101/766) * 1.00

= 1.0755. The aggregate productivity ratio (APR) is computed by dividing the AOQCR by the AIQCR equal to 1.1086/1.0755 = 1.0308.

The APC system defines the aggregate profitability performance ratio (APPR) as the change in output value (970,000/875,000) divided by the change in input value (823,800/766,000) equal to 1.1086/1.0755 = 1.0308, indicating that the change in output value was 3.08 percent higher than the change in input values.[15] The aggregate price recovery performance ratio equals the APPR (1.0308) divided by the APR (1.0308) equal to 1.00. The APC analysis suggests that the relative improvement in profitability (output values increasing faster than input values) from Year 1 to Year 2 is entirely attributed to productivity gains and more efficient use of inputs.

The APC system uses the actual quantities and prices of both outputs and inputs to compute productivity and price recovery ratios. The technological standards—for labor, material, and overhead—that specify the expected relationship between inputs and outputs in a standard cost system are not exploited under the APC productivity measurement system or, indeed, in any other productivity measurement system.

Lacking such a technological specification, productivity measurement systems rely on values (price times quantity) to aggregate across multiple outputs and multiple inputs when computing productivity ratios. In particular, the APC system uses base-period output value weights to aggregate outputs and inputs. But there is no reason why, from one period to the next, the quantities of inputs consumed will vary in proportion to the value of outputs as assumed by the APC weighting system. As a consequence, it is possible for the APC system to signal changes in productivity that are caused solely by shifts in the output mix and not by any change in the productivity of the production process.

This problem is easy to demonstrate using the simple example in Table 4. The basic set-up for the example in the table is similar to the numeric examples used earlier, but we have eliminated all price and cost variances, simplified the overhead structure, and changed physical quantities sold under actual (for Year 2) so as to focus only on the distorting effect from using output values as weights. Also, based on the technology specification given at the top of the table, no usage variances occur in producing the actual output. That is, the consumption of labor, materials, and overhead exactly equals standard quantities for the given mix of output in both Years 1 and 2. Therefore, there should be no difference in productivity between the two

15. The APC system does not reconcile the 3.08 percent APPR with the actual 34 percent profitability gain.

periods since the output in both periods is produced using the standard quantities of inputs.

But the APC productivity computations yield a 3.08 percent productivity improvement from period 1 to period 2. This apparent productivity gain arises because the percentage increase in sales value (as measured by the AOQCR of 10.86 percent) does not require the same percentage increase in input costs (as measured by the 7.55 percent value for the aggregate cost quantity change ratio [ACQCR]). Thus, productivity computations under the APC system are strongly influenced by output and input prices; the APC productivity measure cannot be based solely on changes in physical inputs and physical outputs.

The information, however, on the physical intensity with which individual input resources are consumed to produce each of the outputs is readily available in the technological specification of standard cost systems. By examining the physical relationship between standard quantities of inputs consumed to actual outputs produced, the standard cost accounting system provides a stronger foundation for evaluating productivity changes across periods.

To summarize, because the APC measure assumes a constant product mix between periods, it can signal productivity improvements when there have been no productivity improvements in the use of labor, material, or overheads. False productivity improvements can be signaled merely by changes in the mix of output. Unrecognized fluctuations in the prices of outputs and inputs will further distort the productivity measure.

The dependence of the APC productivity measure on the mix and prices of outputs is not a weakness that can be fixed, given the limited data assumed by traditional productivity measurement systems. We were able to demonstrate the problem by relying on the technological specification of standard quantities of inputs required for each unit of output produced, information that exists in any well-functioning standard cost system. Traditional productivity measurement systems lack such data on budgets and standards since they attempt only to compare actual performance from period to period. Without any data on standard quantities and prices, the weights typically used to aggregate across multiple outputs and inputs are the weights from output and input values. In the productivity computations we derived in Section 4, we used weights derived from standard quantities of inputs, at actual output, to aggregate across multiple inputs and thereby avoided having our productivity ratio distorted by fluctuations in the mix and prices of outputs.

One advantage, however, of productivity measurement systems over traditional accounting variance systems is the attention they focus on period-to-period changes in productivity (even though they do not explain period-to-period profitability changes). In contrast, the variance analysis of standard cost systems focuses on comparisons within a given year. Rarely are the variances in one accounting period normalized and aggregated so that they can be compared conveniently to the variances reported in prior or subsequent periods. In the next section we show how to extend the productivity analysis system, developed in Sections 3 and 4, to explain profit changes from one period to the next in terms of percentage changes in sales activity, productivity, and price recovery.

6. Multiperiod Productivity Measurement System

The goal of explaining changes in actual profits from one period to the next sounds straightforward but actually differs from both the goal of traditional productivity measurement systems and that of standard cost accounting systems. The APC measurement system only explains changes in profits not caused by changes in output levels. Recall from Section 5 that the APC system signaled a 3.08 percent profitability change between two periods when actual profits increased 34 percent. Standard cost variance analysis, as a one-period retrospective analysis of performance, can explain differences between actual and budgeted profits in a period (as accomplished by SC) but does not explain period-to-period changes in profitability. It is straightforward, by combining the best features from both approaches, to evaluate profit performance over time.

Our proposed system for reconciling actual performance in successive periods can be easily expressed by the diagram in Figure 1. The productivity, price recovery, and sales activity variances shown in the figure are analogous to those computed in Sections 3 and 4. The major innovation occurs in computing a usage standards variance to incorporate expected changes in the manufacturing process between Years 1 and 2. This variance will control for any changes introduced in the standards for input quantities per unit of output. As before, we illustrate the analysis via a numerical example.

Table 5 contains the standards for two years of operation and the revenue, cost, quantity, and price information for two years. The two productivity variances (for Years 1 and 2) and the price recovery variance between Years 1 and 2 are computed exactly as illustrated in Section 3 (see Table 4, panels B and C) with the actual price in Year 1 being used instead of the budgeted price in Year 2. Just for illustration, we show the computation of the productivity during Year 1 variance in Panel A of Table 6. Notice that favorable productivity performance in Year 1 (actual consumption is below standard) is shown with a negative sign to signify that good productivity performance

Figure 1

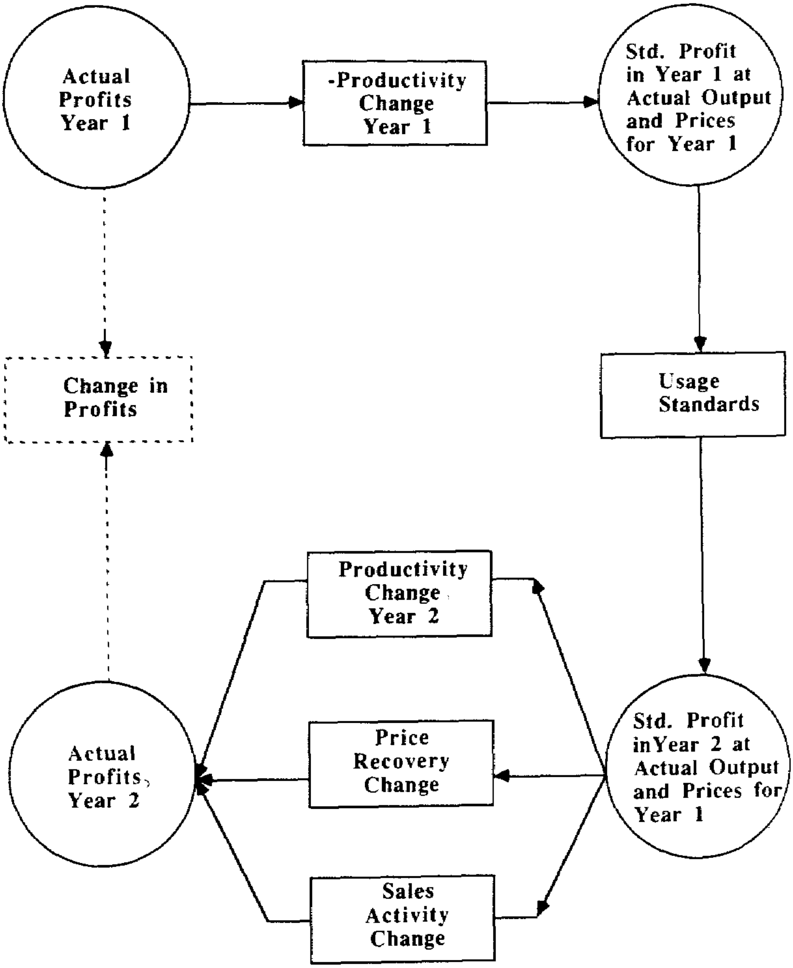

FIGURE 1

TABLE 5

Data to Compute Two-Period Variances Example

	Year 1		*Year 2*	
Technology Specification	*Product 1*	*Product 2*	*Product 1*	*Product 2*
Labor hours per product unit	0.21	0.33	0.20	0.30
Materials units per product unit	1.00	1.24	1.00	1.20
Variable overhead driver units per product unit	0.52	0.83	0.50	0.80
Discretionary fixed overhead driver units per year	200 units		196 units	
Committed fixed overhead each year	1 unit		1 unit	

Actuals

	Year 1			*Year 2*		
	Value	*Quantity*	*Price*	*Value*	*Quantity*	*Price*
Sales						
Product 1	$500,000	50,000	$ 10.00	$630,000	60,000	$ 10.50
Product 2	375,000	25,000	15.00	300,000	20,000	15.00
	$875,000	75,000	$ 11.67	$930,000	80,000	$ 11.63
Costs						
Labor	$179,300	17,930	$ 10.00	$170,000	17,000	$ 10.00
Materials	390,000	78,000	5.00	426,400	82,000	5.20
Variable overhead	88,000	44,000	2.00	104,496	49,760	2.10
Discretionary fixed overhead	56,715	199	285.00	56,736	197	288.00
Committed fixed overhead	44,000	1	44,000.00	46,000	1	46,000.00
	$758,015			$803,632		
Profit	$116,985			$126,368		

in Year 2 is lower when compared to actual performance in Year 1 than when compared to budgeted or standard performance in Year 1.

Panel B of Table 6 shows the calculation of the sales activity variance, which differs slightly from that shown in Section 3 (in panel A of Table 2). In the multiperiod calculation, margins are computed using the actual prices and the standard usage quantities from Year 1. In the previous section, the contribution margin for computing the sales activity variance was a function of standard prices and standard usage quantities in Year 2. Otherwise the calculations are identical.

The main innovation is the calculation of a usage standards variance (see panel C of Table 6) to reflect changes in the input consumption standards between Year 1 and Year 2. The tighter standards in Year 2 reflect productivity improvements made during Year 1 that need to be incorporated when computing actual productivity gains from Year 1 to Year 2. The calculation proceeds by evaluating, at the actual output levels of Year 2, the difference in the standard consumption of inputs between Year 1 and

TABLE 6

Two-Period Variance Computations
A. Sales Activity Variance

Actual margin for Product 1 based on Year 1 prices $= \$10.00 - 0.21 \times 10 - 1.00 \times 5 - 0.52 \times 2.00 = 1.86$

Actual margin for Product 2 based on Year 1 prices $= \$15.00 - 0.33 \times 10 - 1.24 \times 5 - 0.83 \times 2.00 = 3.84$

	(1)	(2)	(3)	(4)	(5)=(1)×(4)	(6)=(1)×(3)
	Std. Margins in Year 1	*Actual Output in Year 2*	*Actual Output in Year 1*	*Differences (2)−(3)*	*Sales Activity Variance*	*Budgeted Contribution in Year for Actual Output in Year 1*
Product 1	$1.86	60,000	50,000	10,000	$18,600	$ 93,000
Product 2	3.84	20,000	25,000	(5,000)	(19,200)	96,000
Sales activity variance					$(600)	$189,000

B. Productivity Variance—Year 1

	(1)	(2)	(3)=(1)+(2)	(4)	(5)=(4)−(3)	(6)	(7)=(5)×(6)	(8)=(3)×(6)
	Std. Cons. for Act. Output of Product 1	*Std. Cons. for Act. Output of Product 2*	*Total Std. Cons. of Inputs*	*Actual Consumption*	*Difference between Actual and Standard Consumption*	*Price of Inputs*	*Usage Standards Variance*	*Std. Cons. of Inputs at Year 1 Prices*
Labor	10,500	8,250	18,750	17,930	(820)	$ 10	$(8,200)	$187,500
Materials	50,000	31,000	81,000	78,000	(3,000)	5	(15,000)	405,000
Variable overhead	26,000	20,750	46,750	44,000	(2,750)	2	(5,500)	93,500
Discretionary fixed overhead			200	199	(1)	285	(285)	57,000
Productivity variance							$28,985	
								$743,000

TABLE 6 (*cont.*)

C. Usage Standards Variance

	(1) Std. Cons. Based on Year 2 Std.	(2) Std. Cons. for Year 2 Based on Year 1 Std.	(3) = (2) − (1) Standard Change in Inputs	(4) Actual Input Prices in Year 1	(5) = (3) × (4) Usage Standards Variance	(6) = (2) × (4) Consumption of Inputs in Year 2, at Year 1 Prices and Input Standards
Labor	18,000	19,200	1,200	$ 10	$12,000	$192,000
Materials	84,000	84,800	800	5	4,000	424,000
Variable overhead	46,000	47,800	1,800	2	3,600	95,600
Discretionary fixed overhead	196	200	4	285	1,140	57,000
Usage standards variance					$20,740	
						$768,600

D. Overall Variances

	Profitability	Productivity—Year 2	Price Recovery	Sales Activity	Productivity—Year 1	Usage Standards
Outputs						
Product 1	48,600		30,000	18,600		
Product 2	(19,200)		0	(19,200)		
	29,400	0	30,000	(600)		
Inputs						
Labor	13,800	10,000	0		(8,200)	12,000
Materials	(17,400)	10,000	(16,400)		(15,000)	4,000
Variable overhead	(14,396)	(7,520)	(4,976)		(5,500)	3,600
Discretionary fixed overhead	(21)	(285)	(591)		(285)	1,140
Committed fixed overhead	(2,000)	0	(2,000)		0	0
	(20,017)	12,195	(23,967)	0	(28,985)	20,740
Total	9,383	12,195	6,033	(600)	(28,985)	20,740

Year 2. For example, Year 2 output is 60,000 units of Product A and 20,000 units of Product B. Using Year 1 material quantity standards, the standard material consumption for this output would be 60,000 * 1 + 20,000 * 1.24 = 84,800 units of material. Based on the tighter Year 2 standards, the standard material consumption is 60,000 * 1 + 20,000 * 1.20 = 84,000 units.

The difference in each input quantity is priced out using the actual input prices in Year 1.[16] The difference of 800 units of material (84,800 − 84,000) is multiplied by the $5 actual material price in Year 1 to produce the $4,000 materials usage standards variance. The individual variances are summed to produce the total usage standards variance of $20,740. Note that no usage standards variance is computed for committed fixed overhead since the quantity of such overheads is assumed not to be reducible (at least within the time frame of the productivity analysis). Also, the usage standards variance we have defined includes a component for a standards change in discretionary fixed costs. This recognizes the importance of achieving productivity gains in discretionary overhead by reducing the number of transactions and the unit costs of these transactions required to produce a given amount of output. Traditional accounting variance analysis and productivity measurements have ignored the opportunities for productivity gains in the use of discretionary overhead.

The overall change of $9,383 in actual profits from Year 1 to Year 2 can now be decomposed (see panel D of Table 6) into an aggregate productivity variance (equal to the sum of the productivity variances in Year 1 and Year 2, and the usage standards variance between Years 1 and 2) plus price recovery and sales activity variances.

As in Section 4, we can combine the accounting variances computed in Table 6 into ratio measures suitable for measuring and evaluating performance between the two years (see Table 7).

Each of the five accounting variances computed in Table 6 is normalized by an appropriate denominator:

Accounting Variance	*Denominator*
Sales activity	Budgeted contribution margin at standard usage quantities and actual prices for Year 1
Price recovery	Gross margin, computed with Year 1 prices, and Year 2 quantities of outputs and inputs

16. Actual input prices in Year 1 basically serve as standards for evaluating Year 2 performance.

TABLE 7

Percentage Changes in Profits, Sales Activity, Price Recovery, and Productivity

Actual profit in Year 2	= \$126,368
Actual profit in Year 1	= \$116,985
Total profit variance from Year 1 to Year 2	= 9,383
Percentage change in profit relative to actual profit in Year 1	$= \frac{9,383}{116,985} \times 100 = 8.02\%$
Percentage Changes in:	
Sales activity (Table 6, panel A)	$= \frac{(600)}{189,000} \times 100 = (0.32\%)$
Price recovery (Table 4, panel C)	$= \frac{6,033}{120,335} \times 100 = 5.01\%$
Productivity—Year 2 (Table 4, panel B)	$= \frac{12,195}{747,860} \times 100 = 1.63\%$
Productivity—Year 1 (Table 6, panel B)	$= \frac{(28,985)}{743,000} \times 100 = (3.90\%)$
Usage standards (Table 6, panel C)	$= \frac{20,740}{768,600} \times 100 = 2.70\%$

Productivity	Total standard costs at actual outputs with standard input consumption
Usage standards	Total standard costs at actual outputs in Year 2 with Year 1 standard consumption of inputs

The computations for the denominator for each accounting variance are shown in the last column of Table 6, panels A–C, and in Table 2, panels B and C.

In order to combine the various ratios, each normalized by a different activity base, into an overall measure of profit, we compute the weights shown in column (2) of Table 8. The weights are the ratio of each denominator measure to the actual profits in Year 1 of \$116,985. Multiplying each weight in column (2) by the respective percentage change in column (1) yields the weighted percentage changes shown in column (3) of the table.

The actual change in profits between Years 1 and 2 can now be explained in terms of the performance ratios in column (3) of Table 8. The actual change in profits (see Table 5) between Year 1 and Year 2 equals \$126,368 − \$116,985 = \$9,383, or 8.02 percent of Year 1's profits. That portion of this profit increase due to productivity improvements can be computed as the sum of

TABLE 8

Decomposition of Profit Change into Sales Activity, Price Recovery, and Productivity Changes

	(1) Percentage Changes	(2) Elasticity Weights	(3)=(1)×(2) Total Impact on Profits	
Sales activity performance	(0.32%)	$\frac{189{,}000}{116{,}985} = 1.61$		(0.51%)
Price recovery performance	5.01%	$\frac{120{,}335}{116{,}985} = 1.03$		5.16%
Productivity—Year 2 performance	1.63%	$\frac{747{,}860}{116{,}985} = 6.39$	10.42%	
Productivity—Year 1 performance	(3.90%)	$\frac{743{,}000}{116{,}985} = 6.35$	(24.78%)	
Usage standards	2.70%	$\frac{768{,}600}{116{,}985} = 6.57$	17.73%	
Productivity performance between Year 1 and Year 2 actuals				3.37%
Total change in actual profits from Year 1 to Year 2				8.02%

Productivity, Year 2	10.42%
Productivity, Year 1	−24.78
Usage standards variance	17.73
Total productivity	3.37%

The 10.42 percent improvement in productivity during Year 2 represents the actual performance in Year 2 relative to the standards for that year. The 17.73 percent improvement in usage standards represents the tighter standards in Year 2 relative to Year 1. Therefore, relative to the standards in existence during Year 1, the productivity performance during Year 2 is 28.15 percent higher. But the −24.78 percent figure for productivity during Year 1 indicates that Year 1's actual performance was already much better than its standards for that year so that the actual improvement in productivity between Years 1 and 2 nets out to 3.37 percent.

The extent of profit change due to price recovery improvements is 5.16 percent. This indicates that product prices changed favorably, particularly for Product 1, without corresponding increases in the prices of resource inputs. The increased prices for variable overheads and materials were more than offset by an increase in the price of Product 1 to yield a 5.16 percent increase in the budgeted profit. Sales activity has a negative 0.5 percent impact on profits. Although total volume increased, profits declined because of an unfavorable shift in the mix toward the lower contribution margin of Product 1.

As before, our analysis yields an elasticity measure (column (2) of Table 8) as the impact of each component on overall profits. For example, the 6.39 weight for productivity during Year 2 indicates that a 1 percent increase in Year 2 productivity will produce a 6.39 percent increase in Year 2's actual profits, holding all other factors constant.

Using the procedure described in the previous section, it can be verified that, in this case, the APC measure shows no productivity improvement between Years 1 and 2, whereas we show an improvement in excess of 3 percent. The failure of the APC measure to signal a productivity improvement between the two years, when one apparently occurred, provides another example of the distorting effect from using output value weights to aggregate across multiple outputs and inputs.

7. Summary and Conclusions

Our synthesis of productivity measurement and standard cost systems has yielded several useful insights. First, the intraperiod standard cost variance analysis, comparing actual to budgeted costs within each period, can be combined with an interperiod productivity measurement system, comparing actual costs between successive periods, to provide a more systematic and comprehensive explanation of changes in profitability each period and over time. Overall changes in profitability can be decomposed into three components: changes in sales activity (including both volume and mix effects), changes in productivity, and changes in price recovery. By explicitly recognizing the profit change component caused by changes in the mix and volume of outputs, we do not permit the confounding effects of increases or decreases in sales to distort the measurement of either productivity or price recovery changes, a distortion that exists in traditional productivity measurement systems.

The aggregation of usage variances into an overall productivity variance provides a convenient and interpretable aggregation of what would otherwise be a myriad of individual, detailed local variances. Also, the productivity variance extends the traditional standard cost focus on direct labor and materials to also include productivity performance with respect to variable and discretionary overhead resources. Standard cost systems can report overhead efficiency variances, but these are not decomposed into price and quantity components. Measuring productivity performance with respect to overhead resources should be especially valuable as overhead resources consume a larger proportion of total manufacturing costs. The separation of so-called fixed overhead into its component parts, discretionary and committed, permits better measurement and control over the consumption of the organization's capacity resources. In particular, attempting to identify and measure the cost drivers for discretionary overhead—transactions and events such as set-ups, purchase orders, parts counts, number of vendors, engineering and production change orders, and shipments—should permit better understanding of and control over discretionary overhead.

Standard cost systems can control well for sales activity effects, but typically do not link performance in one period with that in subsequent periods. Especially when standards change from period to period, it would be difficult to develop period-to-period productivity improvement measures from a traditional standard cost system. In Section 6, we showed how to develop a comprehensive productivity measurement in which (1) the productivity measure is not distorted by sales volume and mix effects, (2) the effects of standards changes from period to period are incorporated in the productivity measure, and (3) all measures can be linked from period to period so that cumulative changes in productivity, price recovery, and sales activity can be obtained conveniently.

The analysis in this paper falls far short of exhausting all the possible paths for measuring and analyzing productivity performance. Measuring the per-period resource consumption of assets with multiperiod lives is only one of the issues still to be developed in subsequent research. We hope that the integrative framework developed in this paper will stimulate new research in the productivity measurement area, especially by accounting professionals who have mostly ignored this topic in their research, teaching, and practice.

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