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A New Approach to Variance Analysis

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A NEW APPROACH TO VARIANCE ANALYSIS

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by

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ABSTRACT

Every standard cost variance can be associated with a conceptually identical index. Restating variances in terms of equivalent indices facilitates comparisons across products enabling critical areas to be pinpointed. Additional advantages are the insights that index analysis yields into management's response to price changes and the improvement that results from these insights in performance evaluation.

A NEW APPROACH TO VARIANCE ANALYSIS

Accountants typically use variances to express, and to analyze, changes in costs; economists, on the other hand, use indices for the same purpose. This paper demonstrates that the underlying methodology is identical and that for every variance there is a corresponding index and vice-versa. These indices may be calculated directly very easily and offer three benefits to management.

**They make comparisons of changes of costs and especially of changes in unit costs possible across products and across inputs within the company and with other companies in the economy.

**They give insight into the nature of the variances themselves since they reveal very clearly the weighting systems that are in use in the calculation of variances.

**They are a useful addition to the analysis of management's behavior and they are of value, therefore, in evaluating performance.

To which should be added that one can bring the experience of economists in analyzing indices together with the experience of accountants in analyzing variances.

The first part of this paper provides a numerical example of a production system in which mix variances are calculated. The second shows how mix indices may be calculated directly and how one might convert these indices to variances and back, and then discusses an immediate advantage of having these indices at one's disposal. The third section discusses the weighting systems being used in calculating indices in the context of variance analysis. The fourth section demonstrates how one might calculate some alternative indices and discusses the insights these give one. A brief conclusion follows.

I. MIX VARIANCES

INTRODUCTION

Consider, by way of example, a manufacturer distilling perfume from three raw materials. Exhibit I shows the unit prices paid for these materials this year and the prices that were budgeted to be paid for these materials at the start of the year. Also found in that exhibit is the quantity of each raw material used to produce 75,000 ounces of distillate and the percentage each input formed of the total, i.e., the nature of the mix. Above the actual figures appear the comparative budget figures.

The exhibit reveals that the price of the first material fell by $0.50 or by 8.3 percent while the prices of the other two materials rose by 20 percent and 10 percent, respectively. Management's response was to increase the use of the first material relative to the others. The actual blend increased the overall yield from 75 percent to 80 percent reducing the use of materials from a total of 100,000 ounces to 93,750 ounces.

The exhibit shows that the actual costs were $703 above the budgeted costs of $420,000 -- a rise of 0.17 percent. A completely conventional variance analysis where the $703 is split into a favorable price variance of $1,172, an unfavorable mix variance of $28,125, and a favorable yield variance of $26,250, follows.

These variances may be given a fairly simple -- although, as will be seen, a slightly misleading -- interpretation. Prices fell on average saving the company $1,172. The relative prices shifted in such a way that management was obliged to shift to a less favorable mix costing the company $28,125; however, this new blend, while less favorable in terms of its mix, yielded more distillate proportionately and so saved the company $26,250.

II. MIX INDICES

INDEX ANALYSIS

The analysis of variance just completed is repeated in percentage or index terms in Exhibit II where all the necessary formulae are displayed too. (The body of this article limits itself to results as far as possible. The details of all calculations may be found in the exhibits.) The formulae in Exhibit II demonstrate that to arrive at an index one essentially divides one cost by the other rather than subtracting one cost from the other. This process is further simplified by the use of weights so that one uses weighted average unit costs in the analysis.

For example, to calculate the price index one divides the actual average unit cost of $4.4875 by $4.50 which is the average unit cost that would have been incurred if the actual mix had been used but prices had remained steady. The corresponding price variance subtracts the two unit costs yielding a difference of ($0.125) and multiplies this by the actual number of ounces used or 93,750. The result is the ($1,172) found in Exhibit I.

The mix index is found similarly. The weights now in use in the numerator and denominator are the standard prices. The denominator is the standard average unit cost of $4.20 and the numerator is the $4.50 described in the previous paragraph. If instead of dividing these two average costs they are subtracted one from the other and the result multiplied by the actual total usage the mix variance of $28,125 found in Exhibit I results.

The interpretation of the indices in Exhibit II is as straightforward as their calculation although, as with the variances, the interpretation is phrased, at this point, in slightly misleading terms. Prices are shown to have fallen on average 0.28 percent, i.e., 100 less 99.72 percent. Management responded by rearranging the mix of inputs. The new mix, without taking changes in the yield into account, caused costs to rise 7.14 percent; however, this was offset by a decline of 6.25 percent in costs owing to improved yield. The product of these three indices i.e., 0.9972 x 1.0714 x 0.9375 results in an overall rise in costs of 0.17 percent or an index of 1.0017.

CONVERSIONS

Converting price variances to price indices and back again is not difficult as Exhibit III demonstrates. Take the price variance by way of example. The amount of 93,750 is the total raw material input actually used to produce 75,000 ounces of distillate. The $4.4875 is this year's average unit cost. The 0.9972 is the associated price index that was calculated in Exhibit II. The product is the price variance as it appeared in Exhibit I.

This conversion may be reversed. The mix index, for instance, is the sum of this year's actual usage of 93,750 ounces multiplied by the standard average unit cost of $4.20 and the mix variance of $28,125 from Exhibit I divided by the actual usage multiplied by the standard average unit cost. The resulting index of 1.0714 may be verified in Exhibit II.

SOME ADVANTAGES

There are several immediate advantages to either calculating indices directly or converting variances to indices by the methods just outlined. The first is that indices, while no more difficult than variances to calculate, lend themselves to comparative statements. For example, one can compare the cost reduction of 6.25 percent due to the increased yield with similar percentages in other perfumeries.

A similar argument is often made about accounting net income figures versus return on investment. And quite frankly, indices simply formalize common practice anyway since most people speak in terms of percentages rather than dollar numbers.

The second advantage of estimating indices is that they give one insights into the nature of variances. These insights result from the fact that with every variance may be associated a conceptually identical index. Indices emphasize the weights used in their calculation but these weights are implicit in the variances too. A study of index weights can provide insights into variances therefore. This conceptual link between indices and variances is explored more fully in the following section.

A third advantage is that the combination of variance and index analysis enables management to draw on both the work of economists and of accountants. This is especially valuable in the area of price changes where price indices are used far more frequently than price variances. For example, an internal price index may be compared with the government's price indices for similar materials -- or an internal wage index with the economy wide change in average wages.

III. WEIGHTING INDICES

WEIGHTING PRICE INDICES

All price indices involve a basket of goods. Most typically this is a set of items that an average family might have purchased some years back. Each month or year, this basket is repriced. The cost of the basket when it was originally constructed is set at a level of 100. The current cost of that basket is calibrated accordingly. An alternative seldom used by economists is to construct a new basket of goods each year and then to work backwards. In other words, one would base the index on the set of items that an average family purchased this year. The current cost of this basket is established and compared with the cost of a similar basket in previous years.

The first method creates what is known as a Laspeyres Index, the second creates a Paasche Index. The disadvantage of the Laspeyres Index is that people's tastes change. Items that were in the basket ten years ago might not even be made today. Also, the proportion in which goods find their way into baskets shifts. Fewer middle-income families own homes today; more rent houses. Everyone buys less gasoline. The obvious way out is to update the basket each year, i.e., to use a Paasche Index, but that is a more costly procedure. So the Laspeyres tends to be favored by economists.

As noted in the previous paragraph, every price variance can be associated with a price index. An examination of the price indices in Exhibit II reveals quite clearly that the weights being used to arrive at an average unit cost both in the numerator and the denominator are those of the actual mix of raw materials. The basket, or blend, is today's. In other words, the price index that the accountant implicitly calculates is a Paasche index. Stated otherwise, when it was asserted that the index analysis revealed a decline of prices of 0.28 percent, the assertion was based on the actual blend of material management used.

The price index may now be interpreted more precisely. A Paasche index, as calculated here, is really a residual index. It shows the fall in average unit cost after management changed the blend. The following section demonstrates that average unit costs "actually" rose in this period. The Paasche index reflects a fall only because management was able to shift to materials that were less affected by rises in price.

In summary, it is useful to calculate the Paasche index because it reveals the effects of management's efforts to cope with changes in price. On the other hand, the Paasche price index gives one little or no information about the rise or fall in prices with which management had to cope in the first place. For that one needs the Laspeyres price index developed in Section IV of this paper.

WEIGHTING MIX INDICES

An analysis similar to the one just undertaken for the price index can be done for the mix index. The weights used in the mix index are prices rather than quantities. The particular index established in Exhibit II used standard prices and by analogy with price indices may be labelled a Laspeyres mix index.

A more precise interpretation of this index may now be given. If prices had not differed from those budgeted, and if the yield had not improved, then the change in mix from that budgeted to that actually used would have caused costs to rise by 7.14 percent. Of course, the only reason why this new mix was adopted was because it led to a higher yield offsetting the effect of the unfavorable cost effects of a change in the blend.

It is interesting to note briefly at this point how the traditional variance or index analysis leads one logically to work backwards from the actual costs of $420,703 to the budget of $420,000. If prices had not changed, the actual quantities used would have cost $420,703 divided by the price index of 0.9972 or $421,875. If the yield had not improved, the cost would have risen to $450,000 or $421,875 divided by the yield index of 0.9375. Finally, if the mix had not changed, the cost would have been the original budgeted cost of $420,000 or $450,000 divided by the mix index of 1.0714.

IV. ALTERNATIVE INDICES

LASPEYRES PRICE VARIANCES

Exhibit IV reveals how a price index might be calculated using the original blend. The unit costs, actual in the numerator and standard in the denominator, are multiplied by the actual material weights or equivalently, by the proportion each material forms in the actual total of 93,750 ounces that were used. All these figures are freely available from the normal analysis of variance so that this Laspeyres index can be calculated as easily as the Paasche index.

As noted on several occasions, with each index is an associated variance. Exhibit V shows how one might calculate the Laspeyres price variance. The only change from the Paasche variance is that the differences in unit costs are multiplied by the standard quantities rather than the actual quantities. As with the index, the necessary figures are freely available.

The price index calculated in this way shows a rise in average unit costs of 2.02 percent. This translates into a dollar variance of $8,500. This was the rise in costs that management faced if it did not respond. The Paasche index calculated earlier shows that management did respond by changing the mix and in so doing actually turned the rise in average unit costs of 2.02 percent into a decline of 0.28 percent.

The two forms of the price index between them provide an illuminating analysis of management's initial situation and their subsequent response. The Laspeyres index shows the size of the problem; the Paasche indicates the outcome from management's response to the problem; and the difference between the two, the effect of management's response.

Of course, for a full understanding of changes in costs one must examine the mix and yield variances as well as the price variance. In particular, it is also useful on occasion to look at the Paasche mix indices which are associated with the Laspeyres price indices.

PAASCHE MIX INDICES

To calculate the Paasche mix index, one weights the actual and standard mixes by the actual unit costs rather than the standard unit costs. The result, as shown in Exhibit IV, is a mix index of 1.0473 indicating that, at actual unit costs, the change in mix caused a rise in costs of 4.73 percent.

As before, the Paasche mix index can be converted to a Paasche mix variance. Alternatively, the variance may be calculated directly. Exhibit V demonstrates how this might be done. All figures are freely available from the standard variance analysis so that it is quite straightforward to arrive at the figure of $20,250.

It is interesting now to contrast this alternative analysis with the more traditional variance analysis. As noted earlier, the traditional analysis leads logically backwards. The Paasche index, by contrast, leads forwards from the budget of $420,000 to the actual costs of $420,703. If prices had risen but no further action had been taken prices would have risen 2.02 percent from $420,000 to $428,500. If the mix had been changed but no yield benefit had been felt the costs would have risen a further 4.73 percent from $428,500 to $448,750. The improved yield reduced this last by 6.25 percent to $420,703.

V. CONCLUSION

To draw all the aforegoing together, this article has suggested that index analysis is an overlooked tool with all sorts of potentially rich applications for analyzing the effects of cost changes. In particular, the variance analysis familiar to accountants is identical to the index analysis familiar to economists.

The benefits of converting variances to indices are three. First, it enables the accountant to draw on all the insights into the behavior of indices that economists have generated over the years. Second, it enables management to compare the effects of price changes within the firm with those outside the firm. Third, the different percentage changes, instead of variances, enable one to identify very simply where the largest price effects are occurring across the firm.

The proposal is simple. All the figures used in the proposed analysis are freely available from the conventional variance analysis. Given the potential benefits the relative cost of the few additional lines of programming it would take to implement the proposal would appear to be minimal.

EXHIBIT I

Conventional Variance Analysis

	Materials			
	A	B	C	Total
Standard Prices (SP_i)	\$6.00	\$3.50	\$2.50	
Standard Quantities (SQ_i) required for 75,000 ounces	40,000	30,000	30,000	100,000
Standard Mix Proportions (SM_i)	0.40	0.30	0.30	
Standard Cost of Materials	\$240,000	\$105,000	\$75,000	\$420,000
Actual Prices (AP_i)	\$5.50	\$4.20	\$2.75	
Actual Quantities Used (AQ_i)	46,875	23,475.5	23,437.5	93,750
Actual Mix Proportions (AM_i)	0.50	0.25	0.25	
Actual Cost of Materials	\$257,812	\$98,438	\$64,453	\$420,703

Price Variance $= \sum(AP_i - SP_i)\, AQ_i$
$= (\$5.50-6.00)(46,875) + (\$4.20-3.50)(23,437.5)$
$+(\$2.75-2.50)(23,437.5)$
$= \$(1,172)$ F

Mix Variance $= \sum(AQ_i - SQ_i)(SP_i-\overline{SP})$
$= (46,875-40,000)(\$6.00-4.20) + (23,437.5-30,000)$
$(\$3.50-4.20) + (23,437.5-30,000)(\$2.50-4.20)$
$= \$28,125$ U

Yield Variance $= (\overline{SP})(\sum AQ_i - \sum SQ_i)$
$= (\$4.20)(93,750-100,000)$
$= \$(26,250)$ F

Total Variance = (Price + Mix + Yield Variances)
= \$703 U

$\overline{SP} = \sum(SP_i)(SQ_i)/(\sum SQ_i)$

F = Favorable U = Unfavorable

EXHIBIT II

Index Analysis

Price Index: $\sum(AP_i)(AQ_i)/\sum(SP_i)(AQ_i)$

$= \sum(AP_i)(AM_i)/\sum(SP_i)(AM_i)$

$$= \frac{\$5.50 \times 0.5 + \$4.20 \times 0.25 + \$2.75 \times 0.25}{\$6.00 \times 0.5 + \$3.50 \times 0.25 + \$2.50 \times 0.25}$$

$$= \frac{\$4.4875}{4.50}$$

$= 0.9972$

Mix Index: $\sum(AM_i)(SP_i)/\sum(SM_i)(SP_i)$

$$= \frac{0.5 \times \$6.00 + 0.25 \times \$3.50 + 0.25 \times \$2.50}{0.4 \times \$6.00 + 0.30 \times \$3.50 + 0.30 \times \$2.50}$$

$$= \frac{\$4.50}{\$4.20}$$

$= 1.0714$

Yield Index: $\sum AQ_i/\sum SQ_i$

$= 93,750 / 100,000$

$= 0.9375$

Overall Costs $= \$420,703 / \$420,000$

$= 0.9972 \times 1.0714 \times 0.9375$

$= 1.0017$

EXHIBIT III

Indices to Variances

Price Variance $= \sum(AQ_i)(\overline{AP})[1 - (\text{Price Index})^{-1}]$

$= (93{,}750)(\$4.4875)[1 - 0.9972^{-1}]$

$= \$(1{,}172)$

Mix Variance $= \sum(AQ_i)(\overline{SP})[\text{Mix Index} - 1]$

$= (93{,}750)(\$4.20)[1.0714 - 1]$

$= \$28{,}125$

Yield Variance $= \sum(AQ_i)(\overline{SP})[1 - (\text{Yield Index})^{-1}]$

$= (93{,}750)(\$4.20)[1 - 0.9375^{-1}]$

$= \$(26{,}250)$

Price Index $= \sum(AQ_i)(\overline{AP})[\sum(AQ_i)(\overline{AP}) - \text{Price Variance}]^{-1}$

$= (93{,}750)(\$4.4875)[93{,}750 \times \$4.4875 + 1{,}172]^{-1}$

$= 0.9972$

Mix Index $= [\sum(AQ_i)(\overline{SP}) + \text{Mix Variance}]\ [\sum(AQ_i)(\overline{SP})]^{-1}$

$= [(93{,}750)(\$4.20) + \$28{,}125]\ [(93{,}750)(\$4.20)]^{-1}$

$= 1.0714$

Yield Index $= [\sum(AQ_i)(\overline{SP})]\ [\sum(AQ_i)(\overline{SP}) - \text{Yield Variance}]^{-1}$

$= (93{,}750)(\$4.20)\ [(93{,}750)(\$4.20) + \$26{,}250]^{-1}$

$= 0.9375$

EXHIBIT IV

Alternative Index Analysis

Price Index: $\sum(AP_i)(SM_i)/\sum(SP_i)(SM_i)$

$$= \frac{\$5.50 \times 0.4 + \$4.20 \times 0.3 + \$2.75 \times 0.3}{\$6.00 \times 0.4 + \$3.50 \times 0.3 + \$2.50 \times 0.3}$$

$$= \frac{\$4.285}{\$4.20}$$

$= 1.0202$

Mix Index: $\sum(AM_i)(AP_i)/\sum(SM_i)(AP_i)$

$$= \frac{0.50 \times \$5.50 + 0.25 \times \$4.20 + 0.25 \times \$2.75}{0.40 \times \$5.50 + 0.30 \times \$4.20 + 0.30 \times \$2.75}$$

$$= \frac{\$4.4875}{\$4.285}$$

$= 1.0473$

Yield Index: $\sum AQ_i/\sum SQ_i$

$= 93,750/100,000$

$= 0.9375$

Overall Costs: = \$420,703/\$420,000

$= 1.0202 \times 1.0473 \times 0.9375$

$= 1.0017$

Exhibit V

Alternative Variance Analysis

(i) Price Variance $= \sum(AP_i - Sp_i)SQ_i$

$= (\$5.50-6.00)(40{,}000) + (\$4.20-3.50)(30{,}000) + (\$2.75-2.50)(30{,}000)$

$= \$8{,}500$

(ii) Mix Variance $= \sum(AQ_i - (SQ_i)(AP_i - \overline{AP})$

$= (46{,}875-40{,}000)(\$5.50-4.4875) + (23{,}437.5-30{,}000)(\$4.20-4.4875) + (23{,}437.5-30{,}000)(\$2.75-4.4875)$

$= 20{,}250$

(iii) Yield Variance $= (\overline{AP})(\sum AQ_i - \sum SQ_i)$

$= (\$4.4875)(93{,}750-100{,}000)$

$= (\$28{,}047)$

$\overline{AP} = \sum(AP_i)(AQ_i)/(\sum AQ_i)$

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