Mutual Complementarity in the DuPont System and the Value of Marginal Improvements

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Abstract: In the well-known DuPont system of financial analysis, return on equity is decomposed into margins, turnover, and leverage. This paper shows that these three conceptual measures are mutually complementary and that their effects are superadditive: an increase in one’s magnitude increases the marginal effect on ROE of increases in the other two. Consequently, managerial attention aimed at improving ROE will have maximal effect if directed towards the lowest of these three complementary drivers, shoring up the firm’s weaknesses rather than extending its strengths. Both calculus-based derivations and numerical illustrations show the ROE advantages of balancing these three profitability drivers to exploit the superadditivity of marginal improvements. A small improvement in one lagging component can offset disproportionately large decreases in two leading components without loss of ROE. Finally, we examine empirical implications of the theory’s predictions about the effects on future profitability of certain common managerial initiatives aimed at increasing one or more DuPont components and some challenges in formulating tests of complementarity based on accounting data.

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The DuPont system of financial analysis is a mainstay of managerial accounting and the financial analyses of business operating performance (e.g., Kline and Hessler, 1955; Horrigan, 1968; President and Fellows of Harvard College, 1988; Amit and Livnat, 1991; Brealey and Myers, 1996) and, as such, is familiar to nearly every MBA student and graduate. As a tool for the targeting of strategic initiatives designed to improve ROE, however, the DuPont system is still in its infancy. In this analysis, we assume that improved ROE is an explicit managerial goal and show how analysis of complementarities among the DuPont system’s components can help achieve that goal.

The DuPont system of analysis combines financial performance information from the income statement with from the balance sheet. The basic DuPont system equation decomposes return on equity (ROE) into three portions (margins, turnover, and leverage) as shown in Equation 1:

\[
ROE = \frac{\text{Profits}}{\text{Sales}} \times \frac{\text{Sales}}{\text{Assets}} \times \frac{\text{Assets}}{\text{Equity}}
\]  

\(1\)

*Profit* and *sales* are income-statement elements, whereas *assets* and *equity* are balance-sheet elements. Note that the three DuPont components (margins, asset turnover, and leverage) are linked by two common variables: *sales* is the denominator of margins and the numerator of asset turnover; likewise, *assets* is the denominator of asset turnover and the numerator of leverage. The accounting identities used to define “margins,” “asset turnover” and “leverage” in the DuPont system thus allow a detailed explanation of the factors that drive improved (or reduced) return on equity, particularly across reporting periods.
One interesting property of the DuPont system (and a common caveat about using it as a system of managerial “levers” to affect future performance, as opposed to a tool to analyze the results of historical decisions) is that there is no way to achieve exactly one effect by changing sales or asset levels: the denominator of one fraction appears as the numerator in the next component, which leads to linked change in the two subcomponents dyads of margins and asset turnover (linked by sales) or asset turnover and leverage (linked by assets), respectively. An increase in sales, for example, decreases margins but at the same time increases asset turnover; an increase in assets decreases asset turnover but increases leverage. While this tradeoff analysis is undoubtedly useful, it does not completely exhaust how the DuPont system can be used to support financial decision analysis.

The DuPont system is frequently used in practice (and in management education, e.g., President and Fellows of Harvard College, 1988) to illustrate how ROE can be improved by increasing margins, asset turnover, or leverage separately. For example, increasing gross profit on the same base of sales (which increases margins without affecting turnover or leverage), decreasing equity needed to support the firm’s assets or an increase in debt capital that does not increase the cost of capital or operations risk (which increases leverage without affecting turnover or margins), are all clear managerial successes.

Beyond these immediate and obvious ways of improving ROE, however, there are additional ways to simultaneously change two or more components to increase ROE. These simultaneous improvements are superadditive (Topkis, 1978, 1998; Milgrom and Roberts, 1990); the effect on ROE of more than one simultaneous change has a greater effect than would be expected by simply adding the two effects together, signifying that margins, turnover, and leverage are complementary to one another. Higher margins raise the incremental improvement
in ROE caused by an increase in leverage or turnover; increased turnover raises the incremental improvement in ROE engendered by an increase in margins or leverage; and higher leverage raises the power of increased margins or improved turnover to increase ROE.

**Claim:** Improvements in margins, asset turnover, and leverage are mutual complements in the DuPont system.

**Proof:** Consider the effects of simultaneous increases in profit (as the numerator of margins), sales (as the numerator of turnover), and assets (as the numerator of leverage) as follows:

\[
\text{ROE}_t = \frac{\text{Profit}}{\text{Sales}} (1 + \pi_t)^* \frac{\text{Sales}}{\text{Assets}} (1 + \sigma_t)^* \frac{\text{Assets}}{\text{Equity}} (1 + \alpha_t)
\]  

(2)

where \( \pi_t \geq -1, \sigma_t \geq -1, \) and \( \alpha_t \geq -1. \)

Expressing the supplemented ROE as a function of the original ROE from (1),

\[
\text{ROE}_t = \text{ROE}^* (1 + \pi_t)(1 + \sigma_t)(1 + \alpha_t)
\]  

(3)

Differentiating the ratio of ROE\(_t\) to ROE with respect to \( \pi_t \), the improvement in gross margin, yields

\[
\frac{\partial (\text{ROE}_t)}{\partial \pi_t} = (1 + \alpha_t)(1 + \sigma_t)
\]  

(4)

Note that improvement in gross margin \( \pi_t \) generates constant returns to scale when considered by itself as a one-dimensional improvement (that is, when \( \alpha_t = \sigma_t = 0). \)

Increasing gross margin by an additive factor (e.g., \( \pi_t = 5\% \)) increases ROE in exactly that proportion, to 105\% of its original

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1 Although the following analysis would hold even more strongly assuming decreasing returns to scale, we do need to explicitly assume that the opportunities for increasing returns to scale have already been exhausted.
value. It is important to note that ROE (which is, itself, customarily expressed as a percentage) increases not additively but multiplicatively; a 20% original ROE which experiences a 5% improvement rises to 21% \[20\% \times 1.05\], not 25% \[20\% + 5\%\].

A single, unilateral improvement in margins (or, by symmetry, any other factor) is not the only possible type of improvement, however. In the presence of increases in turnover and/or leverage, an increase in margins exhibits additional returns. \(\frac{\partial(\text{ROE})}{\partial I_\sigma}\), which is the amount of improvement in the ROE ratio for a given change in gross margin, is clearly increasing in both \(\alpha\) and \(\sigma_i\):\(^2\)

\[
\frac{\partial^2(\text{ROE})}{\partial I_i \partial \alpha_j} = (1 + \sigma_i) > 0 \quad \text{and} \quad \frac{\partial^2(\text{ROE})}{\partial I_i \partial \sigma_j} = (1 + \alpha_j) > 0
\]

which is a sufficient condition for complementarity between \(\pi_i\) and either \(\alpha\) or \(\sigma_i\) \(\text{(Topkis, 1998)}\); an increase in either turnover or leverage increases the marginal effect of an increase of margins on ROE. A similar analysis holds (by symmetry) for \(\alpha\) and \(\sigma_i\).

**Corollary:** Because improvements in margins, asset turnover, and leverage are mutual complements in the DuPont system, an increase in any one of these factors will have a greater effect on ROE when one or both of the other two factors are also higher.

**Proof:** The argument that the corollary is true for an increase in \(\pi_i\) follows directly from the fact that \(\frac{\partial(\text{ROE})}{\partial I_i}\) is increasing in both \(\alpha\) and \(\sigma_i\). The two similar arguments covering an independent increase in \(\alpha\) or \(\sigma_i\), while holding the other two parameters constant, follow by symmetry.

\(^2\) Readers familiar with economic production functions (cf. Chambers, 1988) will recognize this multiplicative formulation as a simple form of a translog production function – in effect, a three-factor Cobb-Douglas system where output is equated to ROE and the three factor inputs are margins, turnover, and leverage. Since the implicit exponent on these three inputs is 1 (e.g., unity), it is unsurprising from a production-function perspective that the entire system exhibits constant returns to scale in each input but cross-factor returns to scale and scope.
Implications of Complementarities and Increasing Marginal Value of Improvements

Complementarity analyses have a 30+-year history in organizational economics and management, from the original Alchian and Demsetz (1972) paper to recent contributions to the Strategic Management Journal (Lippman and Rumelt, 2003a, 2003b). Alchian and Demsetz (1972) invoked the original property of mutual complementarity in a team theory context, in which the marginal productivity of every team members’ effort is higher when other team members are also exerting high effort. This complementarity effect, when each individual is putting in low levels of individual effort, can be sufficiently strong to reverse the traditional assumption of decreasing marginal returns from an individual’s contribution; when each teammate is working hard and efforts are strongly mutually complementary, each individual sees the benefit of working hard themselves and relatively high effort can be achieved without monitoring. The general theory of complementary activities in complex value-creation processes was developed in Milgrom and Roberts (1990, 1992), who showed that high levels of an entire portfolio of activities were necessary to achieve maximum value from any of the complementary activities. Nolan and Croson (1995) and Croson (1995) hypothesized that investments in information technology were complementary to organizational change initiatives, partially because such strong incentives could be supported at the individual level. These complementarity hypotheses were demonstrated empirically in Brynjolfsson and Hitt (2000) and Bresnahan et al. (2002), who showed strong increases in the marginal value of IT investment when organizational changes were undertaken concurrently. Even more recently, papers emphasizing the proper allocation of gains from complementarities (Lippman and Rumelt, 2003a, 2003b)

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3 First-best effort requires not only complementarity but also additional information, as some system of attributing individual effort and allocating rewards, or punishment for shirking, appropriately is required to support incentives. See, for example, Jacobides and Croson (2001).
2003a; 2003b) and treatments of the impact of complementarities on business strategies such as quality improvement (Besanko et al., 2003).

In the DuPont system, each improvement in margins, turnover, or leverage has constant marginal returns on its own behalf, but increasing marginal returns when its effect on the system is taken into account, as shown in Table 1. “Margin Advantage”, “Turnover Advantage”, and “Leverage Advantage” correspond to $\pi$, $\alpha$, and $\sigma$, respectively. “Cumulative Effect” is the simple difference between ROE$_t$ from (2) and ROE from (1) – in effect, the additive increase in ROE generated by the joint effect of margin, turnover, and leverage advantages. “Effect of Complementarity” is the difference between Cumulative Effect and the sum of the individual advantages in margin, turnover, and leverage – effectively providing a measure of the synergy from complementary investments after the direct improvements have been accounted for individually.

<table>
<thead>
<tr>
<th>Row #</th>
<th>Margin Advantage</th>
<th>Turnover Advantage</th>
<th>Leverage Advantage</th>
<th>Cumulative Effect</th>
<th>Effect of Complementarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>1%</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
<td>0%</td>
</tr>
<tr>
<td>1B</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
<td>10%</td>
<td>0%</td>
</tr>
<tr>
<td>1C</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
<td>100%</td>
<td>0%</td>
</tr>
</tbody>
</table>

When only one factor is changed (as in rows 1A, 1B, and 1C), the total effect is exactly the same as the single-factor effect. There can be no complementarity because, by definition, complementarity is the interaction between two or more improvements.\(^4\)

\(^4\) It is certainly true that, all else equal, firms with higher turnover or leverage will get more of a gain in ROE from an incremental improvement in margins, such as shown in rows 1A, 1B, and 1C, than would firms with smaller turnover or leverage. This inherent complementarity, however, has also been factored into the original ROE, to which we are comparing the post-change ROE$_t$ using ratio analysis. Such improvements cancel in the ratio.
Table 2: Effect of Two Simultaneous Improvements

<table>
<thead>
<tr>
<th>Row #</th>
<th>Margin Advantage</th>
<th>Turnover Advantage</th>
<th>Leverage Advantage</th>
<th>Cumulative Effect</th>
<th>Effect of Complementarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2A</td>
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<td>1%</td>
<td>0%</td>
<td>2.01%</td>
<td>0.01%</td>
</tr>
<tr>
<td>2B</td>
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<td>0%</td>
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<td>0.1%</td>
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<tr>
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<td>1%</td>
<td>0%</td>
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<td>1%</td>
</tr>
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<td>10%</td>
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<td>1%</td>
</tr>
<tr>
<td>2E</td>
<td>100%</td>
<td>10%</td>
<td>0%</td>
<td>120%</td>
<td>10%</td>
</tr>
<tr>
<td>2F</td>
<td>100%</td>
<td>100%</td>
<td>0%</td>
<td>300%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 3: Effect of Three Simultaneous Improvements

<table>
<thead>
<tr>
<th>Row #</th>
<th>Margin Advantage</th>
<th>Turnover Advantage</th>
<th>Leverage Advantage</th>
<th>Cumulative Effect</th>
<th>Effect of Complementarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>3A</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
<td>3.03%</td>
<td>0.03%</td>
</tr>
<tr>
<td>3B</td>
<td>10%</td>
<td>1%</td>
<td>1%</td>
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<td>0.21%</td>
</tr>
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<td>1%</td>
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<td>1.21%</td>
</tr>
<tr>
<td>3D</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>33.10%</td>
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</tr>
<tr>
<td>3E</td>
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<td>1%</td>
<td>1%</td>
<td>104.02%</td>
<td>2.02%</td>
</tr>
<tr>
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</tr>
<tr>
<td>3G</td>
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<td>100%</td>
<td>1%</td>
<td>304%</td>
<td>103%</td>
</tr>
<tr>
<td>3H</td>
<td>100%</td>
<td>100%</td>
<td>10%</td>
<td>340%</td>
<td>130%</td>
</tr>
<tr>
<td>3I</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>700%</td>
<td>400%</td>
</tr>
</tbody>
</table>

For small changes in two factors (such as in rows 2A-2B or 3A-3C), the effect of complementarity is so small as to be dismissible as rounding error; the complementarity effect can remain small even when one change is relatively large (as in rows 2C or 3E). For two or more matched larger changes, however, the effect of complementarity makes up a substantial proportion of the cumulative effect, exceeding 1/3 in the case of two matched 100% improvements (as in rows 2F and 3G) and ½ in the ambitious case of three matched 100% improvements (as in row 3H and 3I). In the next section, we examine the impact of this balancedness on such improvements.
The Importance of Balance in Marginal Improvements

Consider a situation wherein two elements of ROE (e.g., margins and leverage) are to be simultaneously improved, while leaving the third (e.g., asset turnover) constant. This corresponds to setting $\pi > 0$ and $\alpha > 0$ while setting $\sigma = 0$. Assume that $\pi + \alpha = v$, a fixed improvement which is to be spread across margins and turnover. What split of $v$ between $\pi$ and $\alpha$ will maximize ROE?

**Claim:** When dividing a fixed amount of improvement across two factors, the division which maximizes ROE is an equal division. Thus, the optimal division of $v$ into $\pi + \alpha$ is $(\pi^*, \alpha^*) = \left(\frac{v}{2}, \frac{v}{2}\right)$.

**Proof:** The optimization to be performed is

$$\text{Max } ROE_I = (1 + \pi_I)(1 + 0)(1 + \alpha_I) = (1 + \pi_I)(1 + v - \pi_I)$$  \hspace{1cm} (6)

Differentiating with respect to $\pi_I$,

$$\frac{\partial (ROE_I)}{\partial \pi_I} = (1 + v - \pi_I) - (1 + \pi_I)$$  \hspace{1cm} (7)

The first-order condition for optimality is

$$(1 + v - \pi_I^*) - (1 + \pi_I^*) = 0$$  \hspace{1cm} (8)

Solving for the optimal $\pi_I^*$ in (8) yields $\pi_I^* = \frac{v}{2}$ as claimed; allocating the remaining value $v - \pi_I$ to $\alpha_I$ yields $\alpha_I^* = \frac{v}{2}$ as well.

Note that balance across the three factors is critically important in maximizing ROE: (100%, 25%, 25%) is a better allocation of a 150% improvement than (100%, 5%, 45%), and by extension (50%, 50%, 50%) will outperform both. The ROE improvements for these three allocations are 312.5%, 304.5%, and 337.5%, respectively, which all show the power of
complementarity in compounding of the 150% baseline improvement. The baseline improvement is responsible for the first 150% improvement in ROE, but the balancing is responsible for up to 187.5% additional improvement – well over half of the total improvement created. Well-balanced but modest-sized improvements can thus result in more ROE gains than poorly balanced but objectively larger performance improvements.

Why does balancing generate such enormous incremental returns? Re-allocating a small amount of total improvement from the best-performing category to the worst-performing category is always beneficial for ROE: the marginal value of improving the lowest quantity, which is more “deficient,” is higher than the marginal reduction in value from reducing a higher quantity. Correspondingly, a given target of proportional ROE improvement becomes increasingly difficult to meet using the same managerial lever over time, as its own contribution towards improvement of ROE is dampened by the other two deficient factors. More research is indicated in developing the relationship between the exertion of effort and the creation of improvements, both direct improvement through increases in individual elements and indirect improvements gained through complementarity. For example, if managers have a fixed amount of attention (or any other scarce, rival, and nontradeable resource, as in Levinthal and Wu, 2005) to devote to improvements in margins, turnover, or leverage, the optimal allocation of this scarce resource will equate the marginal returns of its various uses.

Table 4 shows the relative effects of balanced improvements (where a given \( v \) is divided equally across all three components) vs. unbalanced improvements (where the entire \( v \) improvement is allocated to one area.) Note the extremely large effects of complementarity as \( v \) increases; the superadditivity increases in the magnitude of the underlying primary changes.
Table 4: Comparing Balanced vs. Unbalanced Improvements

<table>
<thead>
<tr>
<th>Margin Advantage</th>
<th>Turnover Advantage</th>
<th>Leverage Advantage</th>
<th>Cumulative Effect</th>
<th>Effect of Complementarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>3%</td>
<td>0%</td>
<td>0%</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>1%</td>
<td>1%</td>
<td>1%</td>
<td>3.03%</td>
<td>0.03%</td>
</tr>
<tr>
<td>30%</td>
<td>0%</td>
<td>0%</td>
<td>30%</td>
<td>0%</td>
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<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>33.33%</td>
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<td>237.02%</td>
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</tr>
<tr>
<td>300%</td>
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<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>700%</td>
<td>400%</td>
</tr>
</tbody>
</table>

Numerical Example

As a concrete numerical example, consider a firm with the following characteristics (all numbers in thousands):

Profit: $1,000
Sales: $2,000
Assets: $10,000
Equity: $5,000

The corresponding Margin, Asset Turnover, Leverage and ROE are as follows:

Margin = 1,000/2,000 = 50%
Asset Turnover = 2,000/10,000 = 20%
Leverage = 10,000/5,000 = 200% (2:1)
Return on Equity = 0.50*0.20*2.00 = 20%

ROE can clearly be improved in a linear fashion by increasing any of these three ratios.

However, for a fixed increase, improvements in Asset Turnover, the lowest of the three components, will have the greatest effect.
For example, let us evaluate the ROE effect of a single 5% increase, applied to each ratio in turn:

Improving Margins: \[ \text{ROE} = (0.50 + 0.05) \times 0.20 \times 2.00 = 22\% \]

Improving Asset Turnover: \[ \text{ROE} = 0.50 \times (0.20 + 0.05) \times 2.00 = 25\% \]

Improving Leverage: \[ \text{ROE} = 0.50 \times 0.20 \times (2.00 + 0.05) = 20.5\% \]

Note that improving Asset Turnover creates an extra 3% improvement in ROE which is not realized when improving Profit Margin (and an additional 4.5% over that gained by increasing Leverage). This extra improvement in ROE – which, on a proportional basis, is 25% higher than the old ROE – is directly due to the complementarity effect: bringing the laggard Asset Turnover level of 0.20 closer to the higher levels (0.50 and 2.00) of the other two components improves ROE in a more-than-proportional manner.

Thus, given a choice among alternative investments capable of improving each of the three components of ROE, the firm will clearly achieve the greatest increase in ROE by focusing on those investments that target the lowest ratio. Because the three components are complementary, redistributing performance 1%-for-1% from a higher-performing area to a lower-performing component will improve the overall ROE result. To a certain extent, the firm can thus be better off on an ROE basis even if it incidentally erodes one or both of the other ratios in order to achieve this balance. In fact, the improvements in balance are powerful enough that it is possible to maintain (or improve) ROE even while realizing partial declines in the level of the higher ratios. For example, in the prior illustration the effect of improvement on Asset Turnover exceeds similar improvements in Profit Margin or Leverage even if such an increase were to actually decrease one or more of the other measures so long as those decreases are not too large.
Increasing asset turnover by 5%, while holding ROE constant by reducing margins, yields a required margin level of \((0.20)/(0.25 * 2.00) = 40\%\). Thus, margins can suffer a 10% absolute decline (a 20% proportion) while maintaining overall ROE if the laggard turnover increases by only 5%. A similar calculation for increasing asset turnover while holding ROE constant and allocating the loss to leverage yields a required leverage level of \((0.20)/(0.50 * 0.20) = 50\%\). Increasing turnover by 5% reduces the amount of leverage required to maintain a constant 20% ROE from 2:1 to 1.6:1 (presumably through reduced debt), improving the firm’s equity-to-total capital ratio from 33.3% to 38.5%.

An interesting experiment results when we ask what happens when we simultaneously decrease both leverage and margins to keep ROE constant, while increasing turnover; one way to answer this question would be to calculate the proportional decrease in each of the leading two performance measures which could be tolerated to achieve a 5% increase in the most laggard measure; this level turns out to be approximately 8.3%. Thus, in our numerical example, a single 5% increase, placed correctly in the deficient area, can counteract the ROE reduction from either a decrease of 10-25% in a single factor or two matched 8.3% decreases in leading areas. Given the generous ratio of the allowable simultaneous decreases to the required single increase (8.3% vs. 5%), such self-cannibalizing strategies seem quite promising. A deeper examination of this result (and of its variation as the absolute levels change) would be particularly illuminating, as the mathematics of complementarity explicitly contraindicate strategies advocating managerial focus on a firm’s strengths as a driver of superior future financial performance, such as propounded in influential works in the popular management press (e.g., Treacy and Wiersma, 1993; 1995) frequently cited (and, apparently, even more frequently purchased) by management consultants.
**Implications for Corporate Strategy and Performance**

Margins, turnover, and leverage are dynamic, not static; each is the result of managerial decisions and the interaction of managerial levers of control with the firm’s existing performance. A firm which expects an exogenous reduction in its drivers of profitability (e.g., a firm with outstanding gross margin which faces new competition; a firm which outstanding asset turnover which suffers a supply chain breakdown, forcing it to hold more inventory; or a firm with a high debt-to-total capital ratio which is forced to retire some of its loans) ought to be focusing on shoring up the DuPont measures which are new weaknesses, not continuing to invest in its previous strengths. Attempting to compensate for reduced ROE by increasing performance in other areas will not work (or will require extremely large improvements to return to the previous performance level) unless these other areas (a) were previously the laggards and (b) remain laggards even after the attacked measure of performance has been reduced. Shoring up weaknesses in the face of performance reduction will sometimes lead to counterintuitive allocation of managerial effort. For example, a firm with high margins and turnover but low financial leverage which faces competition from a small new entrant will likely see mildly reduced margins and turnover due to the increased rivalry with the new entrant. It certainly seems counterintuitive for managers to increase financial leverage at this point – but it is actually the correct strategy (albeit implemented later than optimally); leverage will still be the laggard provided that margins and turnover do not dip so much that they overtake leverage for the dubious honor of being the lowest-performing measure.

There is an interesting parallel between this effect of strategically shoring up weaknesses and the phenomenon of compound interest on investments. The compound annual growth rate of capital (CAGR) is the geometric mean, not the arithmetic mean, of the individual years’
performances. The geometric mean is the $n^{th}$ root (a concave function) of the product of the individual years’ returns (a multiplicative function, and therefore one exhibiting mutual complementary, as shown above). A basic implication of this concavity, well-known in both the mathematical investment-finance literature [e.g., Luenberger, 1997] and in popular personal-finance treatments of risk and return [e.g., Poundstone, 2005], is that a given amount of gain becomes superadditive when divided: the net gain from one year of 0% returns and one year of 30% returns ($1.00 \times 1.30 - 1 = 30\%$) is less than the total effect of two sequential years of 15% returns ($1.15 \times 1.15 - 1 = 32.25\%$). Choosing to allocate a given-size improvement to the laggard component effectively “smoothes out” the drivers of performance and compounds overall ROE, even within a single time period, as the effect is “compounded” over margins, turnover, and leverage; over multiple time periods, keeping a smoothly maximized ROE (as opposed to a highly variable one) over time yields substantially higher compound returns.

Finally, examining the effects of strategic initiatives in businesses where two of the three DuPont levers are at high levels and one is at an extremely low level ought to illustrate the power of considering the three DuPont measures as a complementary system, and thereby targeting weaknesses for managerial attention and turnaround. Since a small improvement in the deficient performance measure yields surprisingly high increase in ROE because of the complementarity effect, a business should experience an extremely large ROE improvement by shoring up its single weakness.

For example, Amazon.com has extremely low margins, very high turnover, and excellent leverage. Initiatives that increase gross margins even 1% will have a huge incremental impact on ROE because of complementarity. Amazon’s success at improving its margins has thus had an immense impact on their profitability. During early years when Amazon had net negative gross
margins, its high turnover and increasing use of debt capital ($1.84 billion, as of December 31, 2004) compounded its negative ROE (-270% in 1999), resulting in an accumulated negative net equity of $3 billion at the end of fiscal year 2003. Now that it has positive gross margins, Amazon erased approximately 80% of its accumulated deficit during fiscal year 2004, and ROE once again had an intuitive meaning once shareholders’ equity became positive again after 2005 results were reported.

Hilton Hotels has excellent margins and significant leverage, but faces a turnover challenge: not all of its available rooms are rented. Improved inventory management by increasing room occupancy (or REVPAR, revenue per available room) even 1% will have a huge effect on ROE. Similarly, slightly more accurate better predictions of when to liquidate rooms on inventory-salvage services such as Priceline would be immensely valuable. A similar argument could be made for knowledge-intensive industries like consulting, or audit accounting wherein the assets to be leveraged are knowledge assets, embodied in individuals who are not always mobile or fully utilized).

ACE Ltd., an offshore reinsurance company, completes our minicase trio. They have excellent margins and enormous turnover (as their assets are minimal compared to their sales.) ACE’s challenge is in leverage: the very nature of the insurance industry requires that capital be conspicuously available to pay claims, and thus that a large amount of equity must be invested in the business at all times. If ACE could reduce the severity of its worst-case outcomes even slightly, they could increase their leverage (their deficient attribute) and thereby more than double ROE. More efficient forecasting of natural disasters, creative contracting with third parties to transfer risks (e.g., Croson and Kunreuther, 2000) to smooth out the financial impacts of these extreme events could greatly increase the CAGR of their invested capital.
Challenges in Empirical Testing of DuPont Complementarity Hypotheses

The DuPont system’s characteristic combination of financial measures taken from the balance sheet and income statement means that empirical testing of the core theory of ROE’s superadditivity in margins, turnover, and leverage is quite challenging; a reduced-form regression is guaranteed to produce high levels of fit regardless of whether complementarity is built into the structural model. Consider the following regression, the log version of (1):

\[
\ln(ROE) = \beta_0 + \beta_1 \ln \frac{\text{Profits}}{\text{Sales}} + \beta_2 \ln \frac{\text{Sales}}{\text{Assets}} + \beta_3 \ln \frac{\text{Assets}}{\text{Equity}} + \epsilon \tag{9}
\]

Because (1) is an accounting identity, estimating (9), the log-log version of equation (1), will yield astonishingly high (if not perfect) measures of fit, along with convergence in the estimated values of the parameter vector to

\[
\begin{bmatrix}
\beta_0 \\
\beta_1 \\
\beta_2 \\
\beta_3
\end{bmatrix} =
\begin{bmatrix}
0 \\
1 \\
1 \\
1
\end{bmatrix}
\]

This might be taken as evidence that complementarity exists (because all three elasticities are positive, cf. footnote 2 supra.) Unfortunately, this fit means nothing in terms of advice to managers; since the inputs are calculated static measures of a firm’s performance, taken as snapshots at a particular point in time, they are not a direct measure of the dynamic changes in performance resulting from the allocation of management’s scarce attention. To test the hypothesis that managerial attention should be diversely allocated when the DuPont components are balanced but concentrated on the laggard when unbalanced, a more sophisticated design incorporating management’s intentions (and, ideally, their effort allocation) seems to be required, with a correspondingly richer dataset.
A simpler, indirect test of complementarity could show that firms that make simultaneous improvements in two or more components (e.g., $\frac{\partial \pi}{\partial t} = d_1$ and $\frac{\partial \alpha}{\partial t} = d_2$) will experience greater ROE increases than firms making improvements in only one component, with correspondingly higher magnitude (e.g., $\frac{\partial \sigma}{\partial t} = d_1 + d_2$) Care must be taken to ensure that the complementarity effects can be separated; if $\sigma$ were the lagging DuPont component initially, however, the main effect of an increase in ROE through rebalancing (by increasing the laggard component) would confound the measurement of the complementarity effects of the two simultaneous changes and potentially lead to a false rejection of complementarity.

Conclusions and Opportunities for Future Research

The DuPont system of financial analysis is a mainstay of managerial accounting and, as such, is familiar to every MBA student and graduate. As a tool for the targeting of strategic initiatives designed to improve ROE, however, the DuPont system is still in its infancy. The three components of DuPont analysis (margins, turnover, and leverage) are mutually complementary; an increase in any one of them increases the effect of an increase in any other. Given this mutual complementarity, marginal improvements yield the greatest increase in ROE when they are concentrated in the weakest “laggard” performance measure. We hope that this analysis of the complementarity among the DuPont system’s components, and the resulting changes in the value of marginal improvements on ROE, will encourage managers who excel in two DuPont areas but lag in the third to focus their attention on their lagging performance measure, rather than amplifying their existing advantages. Such emphasis on the laggards will result in greatly improved return on equity, which in turn will result in significantly higher compounded annual growth rates of shareholders’ capital and thus long-term shareholder value.
Mutual Complementarity in the DuPont System and the Value of Marginal Improvements

References:


