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Note

# The advantage of using external financing (leverage) to design/build/operate a new chemical plant

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ABSTRACT

This research note includes a significant theoretical extension and minor errata for an earlier publication [Mellichamp, DA. New discounted cash flow method: estimating plant profitability at the conceptual design level while compensating for business risk/uncertainty. CACE 2013; 48:251–63.]. A closed-form theoretical expression is developed that provides a direct estimate of the financial advantage to be obtained by using outside financing rather than internal (enterprise) funds to build a chemical plant. Emphasis is at the conceptual design level, where the reduction in financial profitability ($ROI_{BT}$) required to justify further work on a project is developed in terms of the financial parameters (enterprise rate, construction rate, bond rate, etc.). An unexpected outcome is that the reduction in required profitability is independent of any specified risk cushion ($NPV_{\%}$) or long-term profitability ($NPV$); it is solely a function of background financial market rates and project internal timing assumptions vis-a-vis the enterprise' historic rate of return.



## 1. Introduction

Among several new concepts introduced in an earlier *CACE* publication (Mellichamp, 2013) was the idea that a project should be analyzed from the very start of conceptual design incorporating external financing to pay the design and construction costs via a varying balance loan and then plan to refinance this loan immediately after the plant is finished and operating via a bond issue. It was shown that, even having to make bond payments during each year of operations, a significantly lower minimum value of profitability required to justify the project (i.e., $NPV_{\%}^{required}$, $ROI_{BT}^{required}$, or $IRR_{\min}$) will be specified than if the plant is paid for during construction using internal enterprise funds.

The unstated condition needed to obtain the advantage of this method, which should be included in the build/no build evaluation from the outset, is that the *Enterprise Rate* (*ER*, the average year-over-year rate of return on the company's collective investments) exceeds external *Finance Rates*, *CR* and *FR*. One might anticipate that this criterion will always be met; surely a process company can achieve higher average year-over-year returns on its investments (*ER*) than a commercial bank loaning money (rate, *CR*) or market rate bond financing (*FR*, assumed to be the current ten-year bond rate). Otherwise the company should cash out all assets, quit the process world, and go into the financing business.

Since publication, several readers have communicated a misunderstanding as to both the important implication of this condition, and also just what the origin of the advantage is. How can it be cheaper to finance a project using a construction loan and a bond issue, paying extra annual interest costs, than simply to pay off the project costs using internal funds as construction proceeds. What about the extra financing costs?

The outcome, essentially an example of the advantage of "using other people's money" (OPM), is known in the financial community as "leveraging," and is a well-known mechanism for improving profits. In the case of conceptual process design, use of leveraging reduces the profitability hurdle faced by a candidate design and can avoid what otherwise might be its early and unnecessary elimination from the evaluation process.

## 2. Theory/calculation

In the reference, the unlabeled table immediately following Fig. 1 (pg. 258) was developed specifically to show the investment disadvantage incurred by paying-off design/construction costs early rather than at the very end of the project. The published table purported to evaluate results at an *ER* value of 8%, and did so for the unfinanced results. Unfortunately, a value for *ER* of 10% was used for the financed results. The results correctly showed a relatively

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large advantage for use of external financing, but one that grows with increased level of $NPV_{\%}$, the profitability factor associated with "risk" that was developed in the original work.

When calculated correctly Table 1 reads as follows:

Interestingly, the corrected results still reveal a *significant penalty for not using external bond financing*, at least with the parameters chosen for illustration. A 12.2% higher value of $ROI_{BT}$ than actually required to show suitable profitability amounts to the imposition of an excessively high hurdle. But the correct results given here indicate that the penalty is constant, not a function of the $NPV_{\%}$ value (risk factor) as indicated in the original paper.

These essentially constant results raise a question: can a closed-form expression for the profitability penalty $\Delta ROI_{BT}^{required}$ be found that will help understand better which financial parameters do affect the magnitude of the prospective advantage, and how. If such a simple criterion were available, one could decide *a priori* and easily if inclusion of external bond financing in the profitability model will be financially worthwhile. In the original work, the intuitive (but unstated) criterion was $ER > FR$.

An analytical expression for the decrease in $ROI_{BT}$ provided when a project is externally financed can be found by evaluating the incremental cost difference between the two alternative pay-back methods, focusing initially on *Net Present Value* at the time of plant start-up, $NPV_0$. Then, using known analytical relations developed in the original paper linking $NPV_0$ and $ROI_{BT}$, equivalent values in terms of the simpler measure, $ROI_{BT}$, can be obtained:

$$\begin{aligned}\Delta NPV_0^C &= \text{Pay-Back Constr. Costs at End of Year}\quad(0)\\ &\quad-\text{Pay-Back Costs at End of Year}\quad(y)\\ &= TCI(1+ER)^0 - TCI(1+ER)^{-y} = TCI[1-(1+ER)^{-y}]\end{aligned}\tag{1}$$

where $y$ represents the length in years of the operations period.

The net cost for $y$ years of bond payments during the operations period, after adjusting for savings that accrue from not having to pay taxes on bond payments (a tax-deductable extra operating cost) is:

$$\begin{aligned}\Delta NPV_0^B &= TCI\quad FR(1-TR)[(1+ER)^{-1}+(1+ER)^{-2}+\cdots+(1+ER)^{-y}]\\ &= TCI\quad FR\quad TR_C\frac{1-(1+ER)^{-y}}{ER}\end{aligned}\tag{2}$$

A full comparison of the late payment scenario relative to the early payment scenario, requires that bond payment costs be included [Eq. (2)] to reduce the Difference in *Net Present Values* in Year (0) as given in Eq. (1), yielding:

$$\begin{aligned}\Delta NPV_0 &= NPV_0^{PO} - NPV_0^B = TCI\,[1-(1+ER)^{-y}] - TCI\quad FR\quad TR_C\frac{1-(1+ER)^{-y}}{ER}\\ &= TCI\left\{[1-(1+ER)^{-y}] - FR\quad TR_C\frac{1-(1+ER)^{-y}}{ER}\right\} = TCI[1-(1+ER)^{-y}]\left\{1-\frac{FR\quad TR_C}{ER}\right\}\\ &= TCI\left[\frac{1-(1+ER)^{-y}}{ER}\right](ER-TR_CFR) = TCI\quad\sigma\quad(ER-TR_CFR)\end{aligned}\tag{3}$$

since $\sigma = (1-(1+ER)^{-y})/ER$ (as defined in prior work) is the familiar "compound annuity factor," more correctly referred to as the "discrete uniform-series compound amount factor." It is always positive. The term in parentheses is positive whenever $ER > TR_C\ FR$. Thus one notes that the condition for an advantage to be obtained via external financing is even easier to satisfy than earlier suspected; hardly a case will be encountered in which external financing is not helpful! In order to know by how much, it is useful to modify Eq. (3) to obtain the normalized and annualized profitability $\Delta NPV_{\%}$, and from it the corresponding $\Delta ROI_{BT}$.

First note that

$$\Delta NPV_{\%} = \frac{(1+ER)^{-x}}{TCI(x+y)}\Delta NPV(0) = \frac{(1+ER)^{-x}}{(x+y)}\sigma(ER-TR_CFR)\tag{4}$$

where $x$ = length (years) of the construction period and $x+y$ = length of the entire project. This definition is arbitrarily based on $NPV(-x)$. Then the corresponding change in $ROI_{BT}$ is

$$\Delta ROI_{BT} = e\Delta NPV\%\tag{5}$$

where the constant $e$ was developed in the original work as part of Eq (A.14):

$$e = \frac{(x+y)\sigma_a}{(1+\alpha_{WC}+\alpha_{SU})TR_C(1+ER)^{-x}\sigma_b}\tag{6}$$

Therefore,

$$\Delta ROI_{BT} = \frac{(x+y)\sigma_a(1+ER)^{-x}}{(1+\alpha_{WC}+\alpha_{SU})TR_C(x+y)(1+ER)^{-x}\sigma_b}\sigma(ER-TR_CFR)\tag{7}$$

Recall that $\Delta ROI_{BT}$ is the % decrease in the value of $ROI_{BT}$ that can be earned and still meet the *required* Return on Investment (still achieve the design value, originally specified by the risk factor $NPV_{\%}^{required}$) as a result of external funding of the project. After simplification, a relation for $\Delta ROI_{BT}$ expressed solely in terms of the financial parameters is obtained:

$$\Delta ROI_{BT} = \frac{\sigma_a\sigma}{(1+\alpha_{WC}+\alpha_{SU})(TR_C\sigma_b)}(ER-TR_CFR)\tag{8}$$

Eq. (8) may be rearranged to better understand the relations. First, for reasons that will become obvious, it is convenient to write the multiplier in (8) as

$$\frac{\sigma_a\sigma}{(1+\alpha_{WC}+\alpha_{SU})(TR_C\sigma_b)} = \frac{1}{\left(\frac{\sigma_a}{(1+\alpha_{WC}+\alpha_{SU})}\right)^{-1}\left(\frac{TR_C\sigma_b}{\sigma}\right)}\tag{9}$$

The first term in the rearranged denominator of Eq. (9), $\left(\frac{\sigma_a}{(1+\alpha_{WC}+\alpha_{SU})}\right)^{-1}$, is

$$TCI^{dim/norm} = \frac{\sigma_a}{1+\alpha_{WC}+\alpha_{SU}} = \frac{\sum_{j=-3}^{0}a_j(1+CR)^j+\alpha_{WC}+\alpha_{SU}}{1+\alpha_{WC}+\alpha_{SU}}\tag{10}$$

which equals the "total capitalized investment over the design/construction period in dimensionless, normalized form, discounted at Construction Rate $CR$." This "investment timing factor" clearly equals 1 when $CR = 0$ or if all $a_j = 0$ (other than $a_o$).

Similarly, the second term in the denominator of Eq. (9) is

$$P_{BT}^{dim/norm} = \frac{\sigma_b}{\sigma} = \frac{1}{\sigma}\sum_{j=1}^{y}b_j(1+ER)^{-j}\tag{11}$$

which represents the "dimensionless, normalized before-tax profit, discounted at rate ER and totaled over the operating lifetime of the project." If all $b_j = 1$, the term $= P_{BT}^{dim/norm}$ reduces to the value 1, as follows: