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Break-even Analysis with Learning Effect Under Inflation

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Abstract

Break-even analysis is a simple and useful tool in decisions and planning activities though its use is somewhat limited to short-term analysis. The subject is discussed in the fields of engineering economics, production management, cost and managerial accounting, finance, marketing, and so on. Conventional break-even analysis suits the case of stable price and low interest rate. In this paper, we try to overcome the limit by considering following factors, namely, time value of money, depreciation, tax, and capital gains. Also, considering learning effect, we increase applicability to a new project which raises certain changes such as a replacement of production process, an employee turnover, etc. Thus, we suggest a model which has a dynamic break-even quantity per period for the project. Furthermore, we examine the effect of inflation in break-even analysis.

1. Introduction

When we undertake a sensitivity analysis of a project or look at alternative scenarios, we ask how serious it would be if sales or costs turn out to be worse than we forcast. Managers sometimes prefer to rephrase this question and ask how bad sales can be before the project begins to lose money. This exercise is break-even analysis, often called as cost-volume profit relationships. It is a very simple and important tool in decision of the corporate, but has a number of inherent weaknesses [7]. First, it assumes that the company

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faces linear total revenue and total operating cost functions in many cases. The second weakness of break-even analysis is the difficulty of classifying semivariable costs, which are fixed over certain ranges of volume, but vary between others. Finally, the use of break-even analysis is often limited to the short-term analysis.

Although, in this paper, all of these weaknesses are not overcome, the exquisiteness of the break-even analysis may be improved by considering following factors. First, time value of money is considered. This is a critical factor in the case when it has high interest rate, huge investment, or a purpose of long-period analysis. Reinhardt [15] showed early that this factor was important in the Lockheed's Tri-Star case. He suggested that the break-even quantity increased almost twice by including time value of money. Secondly, learning effect is considered. McIntyre [12] utilized the average-time model for learning, but he did not present a general solution for the break-even quantity due to the exponential form. We utilize a time-constant model for learning, which was first suggested by Towill [18], and obtain a general solution. Finally, we consider the effect of inflation in a long-term break-even analysis. Dhavale and Wilson [4] examined this effect in the break-even analysis and Shashua and Goldschmidt [16] extended Dhavale and Wilson's study by considering time value of money.

Our study is to complement and extend Shashua and Goldschmidt's study, and obtain the break-even productivity level at any time t in production phase by considering above-mentioned factors and others, such as tax, depreciation and capital gain.

In order to simplify the computations and to obtain an operative formula, the analysis in this paper is based on the following assumptions:

1) All cash flows occur continuously.
2) All interests are compounded continuously.
3) The life of a project is equal to the life of the equipment and tool for the project.

The following are the basic notations which are used in this paper.

$P(t)$ = selling price per unit at time t.
$V(t)$ = production cost per unit product at time t.
Q = break-even quantity for the project.
a = inflation rate per unit time for initial investment.
b = inflation rate per unit time for production cost.
c = inflation rate per unit time for sales price.
p = average inflation rate per unit time.
α = rate of the salvage value to the initial investment's value at the end of the project.
r = rate of interest under stable price state.
r^* = rate of interest under inflationary state.
tx = corporate's tax rate.
And the unit time is one year.

2. Learning Effect and Productivity

As an organization or work group gains familiarity with its task responsibility, the output per unit time is increased. Besides direct labor improvements, efficiency improvements in production may be due to other activities such as changes in production methods, equipment changes, design improvements, and improved management of operation. Thus, at the beginning of new production system, a company may produce less quantity than to produce after labors are well acquainted with the system.If the break-even analysis is applied to the system without the learning effect, a company ought to hold a level of production uniformly during a production period to break-even at the end of the period. If, however, the learning effect is confirmed, the break-even productivity may vary over the period. Thus, in order to improve the applicability of the break-even analysis, it is necessary to include the learning effect.

There are two models which represent an improvement in task performance, namely learning effect. One is a time constant model and the other is an average time model. We use the former. Specifically, 'years' might be the units on the X-axis and production output in 'units per year' on the Y-axis, and this model is formulated as

$$Y(t) = Y_c + Y_f\,(1 - e^{-t/\tau}) \quad \cdots\cdots (1)$$

where $Y(t)$ is a production function, which indicates productivity at time t; Y_c denotes the productivity at time $t=0$; Y_f is a degree of productivity improvement by learning; $(Y_c + Y_f)$ represents the productivity at time $t=\infty$ (the productivity at steady state); and τ is model time to be constant by task, and it differs from task to task (Kaloo and Towill [10]).

In order to apply the learning effect to the break-even analysis, a company ought to estimate three parameters, Y_c, Y_f and τ. However it seems to be more practical to estimate the ratio of Y_f to Y_c rather than separate estimation of Y_c and Y_f. The ratio can be simply calculated from a proportion of expected quantity at the beginning of the production period to the one at the steady state. If we let $\gamma = Y_f / Y_c$, then equation (1) can be written as

$$Y(t) = Y_c\,[1 + \gamma\,\{1 - \exp(-t/\tau)\}\,], \text{ for } 0 < t < N. \quad \cdots\cdots (2)$$

3. Break-even Analysis Under Stable State

We are interested in a following project which is often realized in a production system. We let 'present' be the time when a corporate finishes to invest to the facilities and tools related to the project and begin to produce the products ($t=0$). Thus, we divide entire project perios into two phases, initial investment phase and production phase, as shown in figure 1.

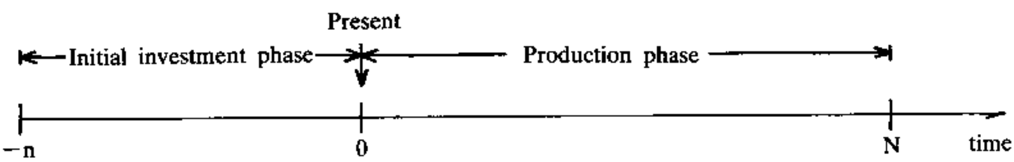

Figure 1. The Life of a Project

Initial investment phase relates to the period when the corporate invests to the facilities and tools for the project, production phase relates to the period when the corporate produces the products, and at the end of the project the corporate disposes the facilities and tools for the project. Here, $-n$ is the beginning point of this project and cash flows occur; N is the end of the project and cash flows; and 0 represents the end of initial investment phase and the beginning of production phase as well.

In order to evaluate a project, we use the net present value criterion which is widely used as proper evaluation method [2]. As cash flows are continuous and continuously compounding interest rate is applied over the life of a project, this criterion is

$$NPV(r) = -\int_{-n}^{0} I(t)\, e^{-rt}\, dt + \int_{0}^{N} [R(t) - C(t)] e^{-rt}\, dt$$

$$= -\int_{-n}^{0} I(t)\, e^{-rt}\, dt + \int_{0}^{N} R(t)\, e^{-rt}\, dt - \int_{0}^{N} C(t)\, e^{-rt}\, dt, \text{ for } -n < t < N, \quad (3)$$

where NPV(r) is the net present value of project, discounted at the project's effective annual cost of capital, r; I(t) is the stream of investment to the facilities and tools at time t; R(t) and C(t) denote the stream of revenues and disbursements at time t respectively.

In equation (3), the first term is the present value of the initial investment. The second term is the present value of revenues of the project, and the third term is that of disbursements of the project. Also, the first term relates to an initial investment phase and the second and third terms are linked to a production phase.

3.1 The Stream of Investments

The disbursements related to the initial investment phase cover the construction of appropriate production facilities and the manufacture or procurement of the machine tools, assembly jigs, etc., required during the production phase. As it doesn't alter our conclusions significantly, we assume that the disbursements in initial investment phase occur uniformly. Then the initial cost term can be expressed as

$$IC = \int_{-n}^{0} I(t)\, e^{-rt}\, dt = I\,(F/\bar{A}, r, n), \cdots\cdots \quad (4)$$

where $(F/A, r, n) = (e^{rn} - 1)/r$ and the capital letter, I, denotes the uniform rate of investments to production facilities and tools over the time interval, $-n < t < 0$.

3.2 The Stream of Cash Revenues

The stream of cash revenues related to the project consists of three distinct streams through the production phase: 1) the revenue associated with the sales of the products; 2) tax shields of depreciation; and 3) the revenue related to the disposal of assets invested during the initial investment phase.

First, we examine revenues from the sales of products. The flow of revenues from selling at time t can be expressed as

$$R_S(t)=P(t)\,Y(t), \quad \text{for } 0<t<N, \qquad (5)$$

where P(t) denotes the selling price per unit products at time t and Y(t) is the production function and a subscript, S, represents the relationship with sale. Under stable price state, P(t) is constant during production phase, that is, $P(t)=P$ for $0<t<N$. Considering learning effect, equation (2) substitutes for the production function, Y(t). Then, $R_S(t)$ can be written as

$$R_S(t)=P\,Y_c\,[1+\gamma\,\{1-\exp(-t/\tau)\}], \quad \text{for } 0<t<N. \qquad (6)$$

Second, we consider tax shields of depreciation. The depreciation, which is a means to account for the cost of a capital asset in determining taxable income, provides tax shields. A part of the original investment to the capital asset, such as facilities and tools, is subtracted from the income each year. This allowance, or depreciation, is calculated in a number of different ways depending on the regulations for a particular item. The tax shield from depreciation equals to the product of depreciation and a corporate's income tax rate. Thus, the tax shield at the end of year t can be written as

$$R_T(t)=tx_e\,D(t), \quad \text{for } t=1,2,\ldots,N, \qquad (7)$$

where a subscript, T, relates to tax saving and tx_e denotes the corporate's effective income tax rate; and D (t) denotes the depreciation for the t-th year.

Finally, the revenue from disposal of facilities and tools at the end of the project is defined as the following equation.

$$R_D(t)=SV \text{ for } t=N, \qquad (8)$$

where a subscript, D, represents disposal and salvage value (SV) is the fraction of the initial investment, that is, $SV=\alpha n I$.

3.3 The Stream of Cash Disbursements

The stream of cash disbursements consists of two distinct streams through production phase: 1) costs of manufacture and assembly of products; and 2) tax for the capital gains at the end of the project.

First, the production cost at time t in the production phase is

$$C_P(t)=V(t)\,Y(t) \quad \text{for } 0<t<N, \qquad (9)$$

where $C_P(t)$ represents the disbursement at time t from production itself; and V(t) denotes the production cost per unit at time t. Under stable price state, V(t) is constant during the production phase. Then, the production cost at time t can be written as

$$C_P(t)=V\,Y_c\,[1+\gamma\,\{1-\exp(-t/\tau)\}], \quad \text{for } 0<t<N. \qquad (10)$$

Next, at the end of the project, we dispose the facilities and tools for the project. If an asset is sold for more than a book value, the difference is a capital gain and the gain is taxed at capital gain tax rate (tx_g). Otherwise, the difference is a capital loss and the loss may be deducted from ordinary income – tax saving occurs at coporate's effective income tax rate (tx_e). Thus, this stream at the end of the project is

$$C_T(t)=tx\ (SV-BV)\ \text{at}\ t=N, \quad\cdots\cdots (11)$$

where $tx=tx_g$ if $(SV-BV)>0$ and $tx=tx_e$ if $(SV-BV)<0$.

3.4 The Combination of Three Cash Flows

The disbursements and revenues can be combined into overall net present value of the project;

$$NPV(r)=-IC+(1-tx_e)\int_0^N (P-V)\ Y(t)\ e^{-rt}\,dt+\sum_{t=1}^{N} tx_e\ D(t)\ (P/F,r,t)$$
$$+SV\ (P/F,r,N)-tx\ (SV-BV)\ (P/F,r,N),\ \text{for}\ -n<t<N. \quad\cdots\cdots (12)$$

In equation (12), the first term is the present value of costs on the initial investment phase. Other terms are related to the production phase. The second term is the present value of the after-tax cash flows of contribution margins(sales price – production cost); the third term is the present value of the tax shields originated from depreciation; the fourth term is the present value of salvage value at time N; and the last term is the present value of the tax levied on the capital gain (or loss). By equation (2), equation (12) can be expressed as

$$NPV(r)=\ -I\ (F/\bar{A},r,n)+(1-tx_e)\ (P-V)\ Y_c\ \{(1+\gamma)\ (P/\bar{A},r,N)-\gamma\,(P/\bar{A},r+\frac{1}{\tau},N)\}$$
$$+\sum_{t=1}^{N} tx_e\ D(t)\ (P/F,r,t)+SV\ (P/F,r,N)-tx\ (SV-BV)\ (P/F,r,N),$$
$$\text{for}\ -n<t<N, \quad\cdots\cdots (13)$$

where $(P/\bar{A},r,N)=(e^{rN}-1)/re^{rN}$ and $(P/F,r,N)=e^{-rN}$. To estimate the break-even production function, let NPV $(r)=0$ and solve this equation for Y_c. Then, Y_c is

$$Y_c=\frac{1}{1-tx_e}\left\{\frac{I\ (F/\bar{A},r,n)-SV\ (P/F,r,N)}{MG}\right.$$
$$\left.-\frac{\sum_{t=1}^{N} tx_e\ D(t)\ (P/F,r,t)-tx\ (SV-BV)\ (P/F,r,N)}{MG}\right\} \quad\cdots\cdots (14)$$

where $MG=(P-V)\ \{(1+\gamma)\ (P/\bar{A},r,N)-\gamma\,(P/\bar{A},r+\frac{1}{\tau},N)\}$

In (14), first term's numerator within the large brackets is the present value of the facilities and tools for the project, and the second term's numerator in the brackets is the present value of the tax shields from depreciation and tax for the capital gain or loss. Thus, the break-even production fuction is materialized as (14) substitutes for Y_c in (2). Unlike the conventional break-even analysis, the break-even productivity varies over the production period because of the learning effect.

The break-even production quantity for the project is obtained by the integral of this equation over the interval, $0 < t < N$, as

$$Q=\int_0^N Y(t)\,dt=Y_c\,\{(1+\gamma)\,N-\gamma\,(P/\bar{A},\frac{1}{\tau},N)\}. \quad (15)$$

If we don't consider learning effect, $Y(t)=Y_c$ because $Y_f=0$ in (2). Then the break-even productivity is

$$Y(t)=\frac{1}{1-tx_e}\{\frac{I\,(F/\bar{A},r,n)-SV\,(P/F,r,N)}{(P-V)\,(P/\bar{A},r,N)} - \frac{\sum_{t=1}^{N} tx_e\,D(t)\,(P/F,r,t)-tx\,(SV-BV)\,(P/F,r,N)}{(P-V)\,(P/\bar{A},r,N)}\}. \quad (16)$$

And the break-even production quantity is the product of the production period, N, and the constant productivity, $Y(t)$. That is, $Q=N\ Y(t)$. And, in equation (16), the first term within the brackets coincides with the concept of Shashua and Goldschmidt's model. But, their break-even productivity may be underestimated or overestimated without including income tax, tax shields from depreciation and so on. Furthermore, if we don't consider tax, depreciation and time value of money, then break-even quantity can be written as $Q=nI\,(1-\alpha)/(P-V)$. This result coincides with conventional break-even analysis.

4. Break-even Analysis Under Inflationary State

Under inflationary condition, all the items related to the cash flows rise continuously, so that these items are functions of time. The cost of capital for a project also rises, mainly to compensate for the decline in the purchasing power of money. In this section we consider the break-even production function under inflationary state.

The cost of capital for a project under inflation, r^*, may be different from the one under stable state. We assume that the initial investment cost, the cost of production and the selling price increase at constant rate 100a %, 100b %, and 100c % respectively. As we examined in section 3, we can analyze related terms with inflationary state.

4.1 The Stream of Investments

The initial cost under inflation is

$$IC^*=\int_{-n}^{0} I(t)\,e^{-r^*t}\,dt=\int_{-n}^{0} Ie^{at}\,e^{-r^*t}\,dt=I\,(F/\bar{A},r^*-a,n). \quad (17)$$

This relation is different from the one under stable price state. But, if inflation is fully anticipated as $r^* = r + p$ and the rate of increase in initial investment equal to the average inflation rate, that is, $a = p$, then this equals to the one under stable price state.

4.2 The Stream of Cash Revenues

Under inflationary condition, the streams of cash revenues related to the project are directly and indirectly influenced by inflation because of the changeability of the cost of capital.

First, the sales price per unit products at time t is

$$P(t) = P\, e^{ct}, \text{ for } 0 < t < N. \quad \cdots\cdots (18)$$

Then, the revenue from selling products at time t is expressed as

$$R_S(t) = P\, e^{ct}\, Y_c\, [1 + \gamma \{1 - \exp(-t/\tau)\}], \text{ for } 0 < t < N. \quad \cdots\cdots (19)$$

Next, under inflationary state, tax shields of depreciation at the end of year t are unchangeable as

$$R_T(t) = tx_e\, D(t), \quad \text{for } t = 1, 2, \ldots, N, \quad \cdots\cdots (20)$$

Finally, we consider revenues from salvage value with inflation. We note that values of the facilities and tools will continuously rise 100a% per unit time. Then, the revenue from disposal of facilities and tools at the end of the project is defined as

$$R_D(t) = SV^* \text{ at } t = N, \quad \cdots\cdots (21)$$

where $SV^* = \alpha n I e^{aN}$.

4.3 The Stream of Cash Disbursements

Similar to the procedure of section 3, the production cost per unit product at time t can be represented as

$$V(t) = V\, e^{bt}, \text{ for } 0 < t < N \quad \cdots\cdots (22)$$

where $V(t)$ denotes the production cost per unit at time t. By (2) and (22), the disbursement related to production at time t is

$$C_P(t) = V\, e^{bt}\, Y_c\, [1 + \gamma \{1 - \exp(-t/\tau)\}], \text{ for } 0 < t < N. \quad \cdots\cdots (23)$$

Also, tax linked to capital gain (or loss) with inflation is

$$C_T(t) = tx\, (SV^* - BV) \text{ at } t = N. \quad \cdots\cdots (24)$$

4.4 The Combination of Three Cash Flows

Under inflationary condition, the cash flows related to the project can be combined into

$$NPV(r^*) = -IC^* + (1-tx_e)\ [\int_0^N P\ e^{ct}\ Y_c\{1+\gamma(1-e^{-t/\tau})\}\ e^{-r^*t}\ dt$$
$$-\int_0^N Ve^{bt}\ Y_c\{1+\gamma(1-e^{-t/\tau})\}e^{-r^*t}\ dt] + \sum_{t=1}^{N} tx_e\ D(t)\ (P/F, r^*, t)$$
$$+SV^*(P/F, r^*, N) - tx\ (SV^* - BV)\ (P/F, r^*, N),\ \text{for } -n < t < N. \cdots\ (25)$$

By definition, Y_c is rearranged as

$$Y_c = \frac{1}{1-tx_e}\{\frac{I\ (F/\bar{A}, r^*-a, n) - \alpha\, nI\ (P/F, r^*-a, N)}{MG^*}$$
$$-\frac{\sum_{t=1}^{N} tx_e\ D(t)\ (P/F, r^*, t) - tx\ (SV^* - BV)\ (P/F, r^*, N)}{MG^*}\},\ \text{for } 0 < t < N, \cdots\ (26)$$

where $MG^* = [\ (1+\gamma)\ \{P(P/\bar{A}, r^*-c, N) - V(P/\bar{A}, r^*-b, N)\} - \gamma\{P\ (P/\bar{A}, r^*-c+\frac{1}{\tau}, N)$

$$-V\ (P/\bar{A}, r^*-b+\frac{1}{\tau}, N)\}\ ].$$

Also, the break-even production function can be easily obtained as (26) substitutes for Y_c in (2).

In equation (26), the first term within the large brackets reduces as the first term under stable price condition (equation (14), when the following conditions hold: 1) the cost of capital for the project follows the Fisher rule when inflation is fully anticipated; that is, the project's cost of capital is $r^* = r + p$, 2) the rates of increase in disbursements related to initial investment, production costs and sales prices are the same as the average inflation rate; that is, $a = b = c = p$. This result coincides with the one of Shashua and Goldschmidt's model. But the second term in the brackets does not agree with the one in equation (14) because tax shields from depreciation charges and capital gain (or loss) are inflated. Thus the equation is different from equation (14), even if the above two conditions are actualized. Therefore, inflation is not neutral and can't be disregarded in break-even analysis.

5. Numerical Example

In previous sections, most of the equations seemed to have complicated relationships, but their computations were trivial. We consider a following case. A car company has uniformly invested \$50 million for one year to execute an electric car project. The company plans to produce electric cars for five years ahead. The cost of the capital for the project is 10%. After five years, at the end of the electric car project, this company shall dispose facilities and tools related to the project with salvage values of 10% of the initial costs. This company uses straight-line depreciation method.

The car is expected to be sold for $ 5,750 and production cost per unit may be $ 5,000. The effective income tax rate for this company is 50% and tax rate of capital gains is 30%. The parameters of the learning effect for this production process are assumed as $\tau=0.2$ and $\gamma=0.5$ from past experiences. The parameters linked to inflation are anticipated as $p=a=b=c=5\%$ and $r^*=15\%$.

Break-even productivities and quantities in three states are computed respectively as shown in table 1. In row (2), the break-even productivity at time t varies because of the learning effect. If a learning effect is confirmed, the break-even quantity is underestimated under the stable price state. By Shashua & Goldschmidt's suggestion inflation must be a neutral factor in this example, because inflation is fully anticipated and the rates of increase in costs and prices are the same as the average inflation rate. Nevertheless, inflation is not neutral by row (2) and (3) as we mentioned previously. Even if changing the variables generates other solutions, we nevertheless note that break-even productivities are not constant because of a learning effect and inflation is not neutral because of inflated tax shields.

Nature of State \ Y (t) & Q	(1) Break-even Productivity Y (t)	(2) Break-even Quanty Q
(1) Stable Price State	22,174	110,868
(2) Stable Price State w / Learning Effect	$15{,}032\ \{1+0.5\,(1-e^{-5t})\}$	111,237
(3) Inflationary State w / Learning Effect	$15{,}141\ \{1+0.5\,(1-e^{-5t})\}$	112,046

Table 1. Results of the Numerical Example (unit: a car)

6. Conclusions

Break-even analysis is a simple and powerful method in financial analysis. But its use is limited to short-term period and it is not adaptable for the new project. In this paper we tried to overcome this weakness by considering following factors, such as time value of money, depreciation, tax, and capital gains. And using Towill's learning effect model [18], we describe a production system with learning effect and suggest a model which has different break-even quantities per period for the system. Also we showed that the break-even quantity fluctuates according to several factors. With consideration of the learning effect, the break-even analysis can suggest proper break-even productivity and overall quantity in new production system.

Shashua and Goldschmidt [16] suggested that inflation was a neutral factor when inflation was fully anticipated and factors such as interest, value of the original investment, selling price, and production cost, increased at the same rate. Although these conditions are given, we show that inflation is not a neutral factor because tax shields from depreciation charges and capital gain (or loss) are inflated.

References

1. Bohlen, G. A. and Barany, J. W., "A Learning Curve Prediction Model for Operators Performing Industrial Bench Assembly Operations," *International Journal of Production Research*, Vol. 14, No. 2, pp. 295–303, 1976.
2. Brealey, R. and Myers, S., *Principles of Corporate Finance*, 2nd Ed., McGraw Hill, New York, 1981.
3. Conway, R. W. and Schultz A., "The Manufacturing Progress Function," *Journal of Industrial Engineering*, Vol. 10, No. 1, pp. 39–54, 1959.
4. Dhavale, D. G. and Wilson H. G., "Break-even Analysis with Inflationay Cost and Prices," *The Engineering Economist*, Vol. 25, No. 2, pp. 107–121, 1980.
5. Fama, E. F., "Interest Rates and Inflation: The Message in the Entailes," *The American Economic Review*, Vol. 67, No. 3, pp. 487–496, 1977.
6. Fama, E. F., "Short-term Interest Rates as Prediction of Inflation," *The American Economic Review*, Vol. 65, No. 3, pp. 269–282, 1975.
7. Gitman, J. L., *Principles of Managerial Finance*, Harper & Row, New York, 1985.
8. Grant, E. L., Ireson, W. G. and Leavenworth, R. S., *Principles of Engineering Economy*, 7th Ed., John Wiley & Sons, New York, 1982.
9. Jones, B. W., *Inflation in Engineering Economic Analysis*, John Wiley & Sons, New York, 1982.
10. Kaloo, U. and Towill, D. R., "Time-dependent Changes in the Production Levels of Experienced Workers," *International Journal of Production Research*, Vol. 17, No. 1, pp. 45–59, 1979.
11. Levy, F. K., "Adaptation in the Production Process," *Management Science*, Vol. 11, No. 6, pp. 136–154, 1965.
12. McIntyre, E. V., "Cost-Volume-Profit Analysis Adjusted for Learning," *Management Science*, Vol. 24, No. 2, pp. 149–160, 1977.
13. Milutinovich, J. S. and Dempsey, W. A., "The Learning Curve, R & D Management, and Marketing Strategies for New Products," *R & D Management*, Vol. 8, No. 3, pp. 177–183, 1978.
14. Nicholas Baloff, "Extension of the Learning Curve – Some Empirical Results," *Operational Research Quarterly*, Vol. 22, No. 4, pp. 329–340, 1971.
15. Reinhardt, U. E., "Break-even Analysis for Lockheed's TriStar: An Application of Financial Theory," *Journal of Finance*, Vol. 28, No. 4, pp. 821–838, 1973.
16. Shashua L. and Goldschmidt, Y., "Break-even Analysis under Inflation," *The Engineering Economist*, Vol. 32, No. 2, pp. 79–88, 1987.
17. Thuesen, G. J. and Fabrycky, W. J., *Engineering Economy*, 6th Ed., Prentice Hall, New Jersey, 1984.
18. Towill, D. R., "Transfer Functions and Learning Curves," *Ergonomics*, Vol. 19, No. 5, pp. 623–638, 1976.
19. Tucker, S. A., *The Break-even System*, Prentice-Hall, New Jersey, 1963.