International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 6013-6018

http://www.ripublication.com

Basis of the Choice of Optimal Characteristics for Innovative Equipment

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Abstract

The world today lives in the state of the invention race. Due to that, equipment producers can use various parts and technologies for their production. As a result, they can get dozens (sometimes hundreds) of models of the equipment manufacturing the same product. These models will be different in four economic characteristics: capacity, operational life, maintenance expenses and price.
How can the equipment producer choose the best model? What should be the requirements for the designers – what capacity, operational life and maintenance expenses do they have to plan? What should be the maximum price of the equipment with the prescribed values of these characteristics? To answer all these questions, the traditional approach means the use of *NPV*. It is criticized in this article, and the author proposes a new characteristic instead of *NPV* – the index of specific value growth speed (*IS*).

Key words. Research and development. Efficiency of real investments.

Let's consider how economic characteristics of industrial innovations should be determined. We will do it using the example of some equipment utilized for the production and sale of some product, i.e. for gaining profit. There are two subjects: Equipment Producer and Equipment Buyer. Let us agree that these subjects have the classical model – maximization of the company value.

In accordance with the existing theory of financial management, to achieve the goal, the companies maximize the net present value (*NPV*) of their investments

(Brealey, Myers, Allen, 2013; Guide, 2008; State of the Practice, 2012). The producer maximizes *NPV* from selling the equipment, while the buyer maximizes *NPV* by operating the equipment. The buyer compares alternative equipment models and chooses the best one, i.e. the one that can ensure the biggest *NPV*. Based on that, the price for the innovative equipment model should allow the Buyer to get a higher *NPV* than from purchasing a competitive model.

But the author of this work proves that *NPV* application in this situation can lead to a mistake and proposes a next generation index - the index of specific value growth speed (*IS*) (Kogan, The criticism of *NPV* and *EAC*, 2014). *NPV* can't be used to compare alternative investments with different parameters, i.e. investments that are simultaneously different in three main investment parameters: amount, term and annual results. It was shown above that alternative models of equipment will be investments with different parameters for its buyer.

Let us show it using the example comparing four equipment models. Imagine that the Buyer has to choose between models *W* and *X*. Each of them will work for three years and will provide $400 000 of *NPV*. According to the rules of *NPV* application, efficiency of purchasing *W* and *X* is the same. But it is necessary to pay $2,000,000 for *W*, "and only" $1 000 000 for *X*. It is obvious that, considering the prices, *X* is a better buy. The conclusion is that *NPV* doesn't make it possible to correctly compare alternative efficiency without the investment amount consideration.

Let us consider another pair of alternatives: *Y* and *Z*. Imagine that each of the models costs $2,300,000 and will provide $900,000 of *NPV*. One would think that, according to *NPV* and even considering the prices, efficiency of investments in *Y* and *Z* is the same. But *Y* will work for four years, and *Z* will operate for five years. It is obvious that *Y* is a better buy. The conclusion is that *NPV* doesn't make it possible to correctly compare efficiency of options without the consideration of terms. But what is more profitable – *X* or *Y*? These options have different parameters, and we have to assess their efficiency, having combined three factors: *NPV*, amount and term. This very idea is included in *IS* that is calculated according to the following formula:

$$IS = \frac{NPV}{n \times I} = \frac{\sum_{t=1}^{n} NCF_t \times d_t - I}{n \times I}, \quad (1)$$

where

NCF_t is the net money flow from equipment operation;

t is the moment at which the financial results are calculated;

I is the investment made at the 0 moment (equipment purchase);

n is the service life of the equipment;

d_t is the discount factor calculated according to the formula:

$$d_t = \frac{1}{(1+k)^t}, \quad (2)$$

where

k is the discount rate.

Purchasing and operation of the equipment result in the net cash flow (*NCF*) that will most likely be ordinary. All further conclusions will be made using this assumption. An *ordinary* flow is the flow, the first element of which is a negative figure, and other elements (NCF_t, t=1, n) are positive. A *nonordinary* money flow includes several negative elements, or just one, but not in the beginning of the flow. An ordinary money flow can be *uneven* (when one or several values of NCF_t, t=1, n are different from the other values) or *annuity* (when all NCF_t, t=1, n are the same).

The *IS* index combines two economic principles: more and quicker. Measurement units for this index are "$ / $ per year". Investments are efficient, if *IS* is higher or equal to 0. In the case of several options, the option where this index is higher is more profitable. A company uses *IS*, increases their value faster than a company uses *NPV* (Kogan A. A New Way, 2014). Having calculated *IS* for equipment *W*, *X*, *Y*, *Z,* we come to the conclusion that it is more profitable to purchase model *X*:

$$IS^W = \frac{\$400\ 000}{3\ year \times \$2\ 000\ 000} = 0.07\ \$\ /\ \$\ per\ year, \quad (3a)$$

$$IS^X = \frac{\$400\ 000}{3\ year \times \$1\ 000\ 000} = 0.13\ \$\ /\ \$\ per\ year, \quad (3b)$$

$$IS^Y = \frac{\$900\ 000}{4\ year \times \$2\ 300\ 000} = 0.10\ \$\ /\ \$\ per\ year, \quad (3c)$$

$$IS^Z = \frac{\$900\ 000}{5\ year \times \$2\ 300\ 000} = 0.08\ \$\ /\ \$\ per\ year, \quad (3d)$$

It should be noted that, to compare options (equipment) with different parameters, it is proposed to use equivalent annual costs (*equivalent annual costs, EAC*) (Brealey, Myers, Allen, 2013; Guide, 2008; State of the Practice, 2012). But the author of this work proves that *IS* should be used instead of *EAC* (Kogan, The criticism of *NPV* and *EAC*, 2014).

Let us go back to the questions raised above and see how the Producer can determine economic characteristics of some new equipment. Imagine that there is equipment *A* with a certain service life (n) and price (I^A) on the market. The Producer has the task of developing a more profitable model *B* for the Buyer. The Producer has to understand at what price (I^B) it can sell the equipment to *B* if it increases its service life (m) or capacity, or reduces the costs of product manufacture (all that as compared with *A*).

To understand, what economic characteristics are needed for a model to be created, *IS* of equipment *A* should be made equal to *IS* of equipment *B*:

$$\frac{\sum_{t=1}^{n} NCF_t^A \times d_t - I^A}{n \times I^A} = \frac{\sum_{t=1}^{m} NCF_t^B \times d_t - I^B}{m \times I^B}, \quad (4)$$

For an uneven money flow, it is necessary to calculate the real cost of future proceeds from the operation of the equipment ($\sum_{t=1}^{n} NCF_t^{\mathrm{A}} \times d_t$ and $\sum_{t=1}^{m} NCF_t^{\mathrm{B}} \times$

d_t). After that, it is possible to determine other economic characteristics. For annuity money flow, direct calculation is possible. If the Producer needs to determine the minimum value $NCF^B{}_t$, having done equivalent mathematical tranformations of formula (4), we get the following formula:

$$NCF_t^B = \left(\frac{m \times NCF_t^A \times PVIFA_{k,n}}{I^A} - m + n\right) \times \frac{I^B}{n \times PVIFA_{k,m}}, \tag{5}$$

where $PVIFA_{k,n}$ is the factor of the current cost of annuity, determined according to the formula:

$$PVIFA_{k,n} = \sum_{t=1}^{n} d_t = \sum_{t=1}^{n} \frac{1}{(1+k)^t}, \tag{6}$$

The condition for determining the maximum price of the developed equipment (I^B) also arises from formula (27):

$$I^B = \frac{NCF_t^B \times n \times PVIFA_{k,m}}{m \times NCF_t^A \times \frac{PVIFA_{k,n}}{I^A} - m + n}, \tag{7}$$

Let us consider it all using a numerical illustration. Let us consider that *NCF* is calculated according to the following formula:

$$NCF_t = Prod \quad (P - C) \times \left(1 - PT \quad\right) + D, \tag{8}$$

where
Prod is productivity of equipment, units / year;
P is the price of a unit of the product manufactured using this equipment, \$/unit;
C is expenses for the production of one production unit (including depreciation), \$/unit;
PT is the rate of profit tax, %;
D is depreciation, \$, calculated according to the following formula:

$$A = \frac{I}{n}, \tag{9}$$

where
I is the cost of equipment, \$;
n is the period of useful service, years.

Table 2. Main characteristics of equipment *A*

No.	Index	Value	Unit
1	Expenses of production of one production unit (C^A)	100	$ / unit
2	Price of a production unit (P^A)	84.375	$ / unit
3	Productivity of equipment ($Prod^A$)	12,000	units per year
4	Price of the equipment (I^A)	800,000	$
5	Service life (n)	4	years

As a result, the profit tax rate being 20%, NCF^A is determined as:

$$NCF_t^A = 12{,}000 \times (100 - 84.375) \times (1 - 20\%) + \frac{800\,000}{4} = \$350{,}000 \quad (10)$$

The discount rate being 10%, we get NPV^A equal to $309,453, and IS^A equal to 0.097 $/$ per year. Having these results, further analysis can be done.

Let us consider that the Producer decided to increase the service life of *B* to 5 years. It will have to spend more for production *B*, and the price of this model has to be $1,000,000. The quality of the production does not change, which means that its price doesn't change either. Operation of the equipment in this case should provide for the following NCF^B_t, determined according to formula (5):

$$NCF_t^B = \left(\frac{5\times350\,000\times3{,}170}{800\,000} - 5 + 4\right) \times \frac{1\,000\,000}{4\times3{,}791} = \$391\,349 \quad (11)$$

To get such NCF^B_t value, it is necessary to increase productivity of *B* to 15,308 units per year with the same expenses, or to reduce expenses to $80.067 per unit with the same productivity. NPV^B will be $483520, and IS^B will be equal to IS^A:

$$IS^B = \frac{483\,520}{5\times1\,000\,000} = 0.097\ \$/\$\ per\ year \quad (12)$$

It follows herefrom that *B* will be more profitable for the Buyer than *A*, if productivity of *B* is higher than 15,308 units per year, the expenses being $84.375 per unit, or the expenses will be lower than $80.067 per unit with the productivity of 12,000 units per year.

Let us assume that as a result of designing model *B*, the Producer increased productivity to 17,000 units per year, to reduce expenses to $70 per unit and to increase the service life to 5 years. This brings up the question – at what maximum price (I^B) the equipment can be sold? To answer the question, we need to take formula (7) and do some mathematical transformations shown in formulas (13a, 13b, 13c, 13d). For this purpose, we will use formula (3) that shows that NCF_t is the net profit amount (*NetProfit*) and depreciation (*D*), calculated according to formula (9).

$$I^B = \frac{(NetProfit + \frac{I^B}{m}) \times n \times PVIFA_{k,m}}{m \times NCF_t^A \times \frac{PVIFA_{k,n}}{I^A} - m + n}, \quad (13a)$$

$$I^B \times \frac{m \times NCF_t^A \times \frac{PVIFA_{k,n}}{I^A} - m + n}{n \times PVIFA_{k,m}} = NetProfit + \frac{I^B}{m}, \tag{13b}$$

$$I^B \times \frac{m \times NCF_t^A \times \frac{PVIFA_{k,n}}{I^A} - m + n}{n \times PVIFA_{k,m}} - \frac{I^B}{m} = NetProfit, \tag{13c}$$

$$I^B \times \left(\frac{m \times NCF_t^A \times \frac{PVIFA_{k,n}}{I^A} - m + n}{n \times PVIFA_{k,m}} - \frac{1}{m} \right) = NetProfit, \tag{13d}$$

We now get a formula to calculate the maximum price (I^B) for the developed equipment:

$$I^B = NetProfit / \left(\frac{m \times NCF_t^A \times \frac{PVIFA_{k,n}}{I^A} - m + n}{n \times PVIFA_{k,m}} - \frac{1}{m} \right), \tag{14}$$

Using formula (14), we determine the maximum value I^B to be $2,132,231. If the Producer sells this equipment a little bit cheaper, it will be more profitable for the Buyer than equipment *A*.

Based on the proposed approaches, the Producer can manage values of economic characteristics of its developments in accordance with the market situation and maximize its effect. On the other side, based on these approaches, the Buyer can make an optimal choice of equipment by comparing alternative models with different parameters.

It should be noted that in some situations the optimal price for the seller is not the maximum price for the buyer, this figure is a little smaller. Price reduction can result in the fact that the equipment will be sold in bigger volumes than at the maximum price. That is why determining the optimum for the seller should be done with the consideration of elasticity of demand for the equipment. It is also necessary to take into consideration competitive offers – price reduction can take some clients from the competitors.

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