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DISCOUNT RATE IN THE ASSESSMENT OF INVESTMENT PROJECT EFFECTIVENESS

Summary: The discount rate expresses the limit rate of return expected by the investors from the capital invested by them. Calculating the discount rate on the appropriate level is important because of its effect on assessing investment projects in both absolute and relative calculation of investment effectiveness. In the article examples of changes in value of indicators of investment effectiveness assessment depending on the adopted discount rate are analyzed. In the absolute calculation of investment effectiveness, basically an increase in the discount rate reduces the attractiveness of the project. However, with a special distribution of cash flows over time, the opposite relationship may occur. In the relative calculation, a situation is possible in which, for different levels of discount rates, different projects are those most profitable.

Keywords: discount rate, investment project, NPV, MIRR.

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1. Introduction

The time value of money varies. The later specific cash flows are realized, the lower is their value, which is due to preferring current consumption to future ones. Variability of the time value of money depends on both the time passed and the rate of the resulting change in value. The interest rate is the economic parameter used in the economy to allow measuring this process and comparing the value of cash flows realized in different periods of time [Sierpińska, Jachna 2007, pp. 11, 13]. The interest rate is the remuneration of the owner of the capital who provides it for another business entity. The level of the interest rate depends mostly on the supply of funds to loan and demand for these funds among other factors: foreseen inflation, financial policy of the state and economic situation.

There are two values of money: future value, or the amount to be reached at a specific moment in the future by the sum of invested cash at the adopted interest rate, and current value, that is the amount currently corresponding with the value of future cash at a specific interest rate. In the latter case, the interest rate is called the discount rate, and the determination of the current value of future cash flows is called discounting.

Making cash flows from different periods comparable, in particular determining their current value, is important (among others) in assessing investment project effectiveness, because they are realized over periods longer than one year, and their time horizon sometimes spans over several dozens of years. The most important issue when discounting cash flows is a choice of appropriate discount rate. There are several approaches in this area proposed in the literature and applied in practice.

The objective of this paper is to present the effects of discount rate on assessing projects in both absolute and relative calculation of investment effectiveness in terms of dynamic methods.

2. Calculating the efficiency for an investment

Making investment decisions requires applying the proper assessment methods for investment projects. The absolute calculation of investment effectiveness is used to assess the level of profitability of one specific investment project, whereas the relative calculation consists of making a selection from several alternative projects.

Indicators used in the financial analysis for projects include static methods, which do not take into consideration the changes in the value of money over time, and dynamic methods, which take into consideration the variable value of money by discounting. Static methods include payback period and accounting rate of return, while dynamic methods include net present value (NPV), internal rate of return (IRR), modified internal rate of return (MIRR) and profitability index (PI).

NPV is the sum of all discounted net cash flows (differences between inflows and outflows). The formula to calculate NPV is:

$$\mathrm{NPV} = \sum_{t=0}^{n} \frac{\mathrm{NCF_t}}{(1+r)^t}, \tag{1}$$

where: NCF – net cash flows,
r – discount rate.

The project is profitable if NPV > 0. A positive value of NPV means that the profitability rate of the investment project is higher than the adopted discount rate, expressing the minimum rate of return from the enterprise acceptable for the investor.

The internal rate of return is a discount rate at which NPV is equal to zero, that is at which discounted outflows are balanced with discounted inflows. IRR directly expresses the profitability rate of the examined enterprises. The higher the IRR, the more attractive the project is for the investor.

The structure of the NPV formula is based on the assumption that positive net cash flows will be reinvested at the (discount) interest rate which constitutes the basis for calculating this index. In the case of the IRR, the reinvestment rate is expected to be equal to the calculated internal rate of return of the analysed enterprise. In practice, such an assumption may prove unrealistic [Sierpińska, Jachna 2007, p. 485]. This shortcoming of IRR is not present in the modified internal rate of return, in which reinvestment rate for cash surplus is independent of the effectiveness of the assessed project, but is assumed at a level of the cost of capital (the minimum required profitability rate), that is at the level of the discount rate used by the investor to calculate NPV. The formula to calculate MIRR is as follows:

$$\mathrm{MIRR} = \sqrt[l+n]{\frac{\mathrm{FVC}^{+}}{\mathrm{PVI}}} - 1 \ , \tag{2}$$

where: FVC^{+} – future value of positive net cash flows,
PVI – present value of investment outlays,
l – the number of years in the period of incurring investment outlays,
n – the number of years in the period of operational use of the project.

Future value of positive net cash flows is defined as follows:

$$\mathrm{FVC}^{+} = \sum_{t}^{n} \mathrm{NCF}_{t}^{+} \cdot (1 + r)^{n-t} \ , \tag{3}$$

where: NCF^{+} – positive net cash flows,
r – discount rate,
t – the first year of generating positive net cash flows.

Present value of investment outlays is given below:

$$P\mathrm{VI} = \sum_{i=0}^{l} \frac{\mathrm{I_i}}{(1 + r)^{i}} \ , \tag{4}$$

where: *I* – investment outlays,
r – discount rate.

Another method for financial analysis of investment projects, which uses a discount rate in its formula, is the profitability index. There are two methods of calculating the profitability index. In the first approach (used more often), *PI* is the quotient of discounted net cash flows during the period of operational use and discounted investment outlays:

$$PI_{1}= \frac{\sum_{t=0}^{n} \frac{NCF_t}{(1+r)^t}}{\sum_{t=0}^{n} \frac{I_t}{(1+r)^t}}, \tag{5}$$

where: NCF – net cash flows during the period of operational use,
I – investment outlays,
r – discount rate.

In the second approach, *PI* is the quotient of discounted inflows to discounted outflows (both during the execution and operational use of the project):

$$PI_2 = \frac{\sum_{t=0}^{n} \frac{{CF_t}^{+}}{(1+r)^t}}{\sum_{t=0}^{n} \frac{{CF_t}^{-}}{(1+r)^t}}, \tag{6}$$

where: CF^+ – inflows,
CF^- – outflows,
r – discount rate.

Interpretation of this index in both formulae is the same. *PI* larger than or equal to 1 means that the project is profitable.

Among the methods of assessing investment effectiveness, there are also methods of cost effectiveness, used especially in evaluating investment projects in the scope of protecting the environment, in which investment outlays and costs and operational use effects of the given investment are taken into account. One of the indexes used in assessing cost effectiveness of investment projects is the dynamic generation cost (DGC). DGC expresses the cost of obtaining the unit of the effect (e.g. ecological). The lower the value of DGC, the more effective the project is. The formula to calculate DGC is as follows [Rączka 2003, p.7]:

$$DGC = \frac{\sum_{t=0}^{n} \frac{I_t + C_t}{(1+r)^t}}{\sum_{t=0}^{n} \frac{E_t}{(1+r)^t}}, \tag{7}$$

where: *I* – investment outlays,
C – operation and maintenance costs,
E – (ecological) effects,
r – discount rate.

Another measure of cost effectiveness is the unit annual cost (UAC), which is the quotient of the annualised cost (*AC*) to the average annual effects generated by the project and expressed in natural units [Rączka 2003, p. 5]:

$$\text{UAC}=\frac{AC}{\text{E}}, \tag{8}$$

where: AC – annualised cost,
E – average annual effects.

The annualised cost is defined:

$$AC = I \cdot \text{CRF} + \text{OMC}, \tag{9}$$

where: I – investment outlays,
CRF – capital recovery factor,
OMC – yearly operation and maintenance costs,

The capital recovery factor is given below:

$$\text{CRF} = \frac{r}{1-(1+r)^{-n}}, \tag{10}$$

where: r – discount rate.
n – lifetime of a project.

Also, the value of the annualised cost alone may be the indicator used in assessing investment projects. The lower the value of UAC or AC, the more effective the project is.

3. Choosing the discount rate

Depending on whether the efficiency calculation is performed from the point of view of a private investor or from the point of view of the society, there are financial discount rates and social discount rates, respectively.

The financial discount rate may be estimated on the basis of the proceeds concept using the profitability of risk-free investments, and on the basis of the cost concept using the cost of capital. In the proceeds concept (real) the discount rate is the sum of the risk-free rate and the bonus for risk. Determining the risk-free rate requires a decision to be made as regards the appropriate financial instrument (securities) whose profitability will be the basis for its estimation and the period of its maturity. No-risk investments most often mean securities issued by the State Treasury [Rogowski 2004, p. 61], that is treasury bills and bonds.

In the cost concept, the discount rate may be estimated differently depending on whether the assessment of investment effectiveness is done from the point of view of all capital providers for the project (the owners of the business and creditors) or only from the owners of the business [Sierpińska, Jachna 2007, p. 479]. In the first case, indicators of investment effectiveness are calculated on the basis of the so-called *free* *cash flows to the firm* and the discount rate is determined at the level of the weighted average cost of capital (WACC), while in the second case the basis is the so-called *free cash flows to equity* and the discount rate is determined using the level of cost of equity.

Discounting cash flows at the firm's WACC is inappropriate if the project differs in terms of its riskiness from the rest of the firm's assets. However, using a unique firm-level WACC is quite common [Krüger et al. 2011].

While financing an investment with external capital only, the discount rate may be based on the interest rate of the debt [Rogowski 2004, p. 65].

Another approach used to determine the financial discount rate is its arbitrary determination by businesses or other institutions. For example, the discount rate recommended by the European Committee in financial analysis is 5%, although adopting a higher rate is possible if it is properly justified, e.g. with the necessity of taking into account a higher expected rate of return by a private investor in the case of executing an investment within a public and private partnership.

The proper estimation of a social discount rate may pose some difficulties as well, expressing preferences of the society as regards future costs and benefits. Literature offers various approaches to calculating this rate. The issue is whether it is appropriate to discount public investments in the same way as private investments [Arrow, Lind 2014, p. 29] The social discount rate in view of intergenerational analysis, based on the assumption that the effects of the investment project will be used by the same generation which is to incur costs of conducting the project, may be determined using the level of:

- consumption interest rate, which reflects the tendency of the society to postpone current consumption in favour of future consumption,
- weighted mean of consumption interest rate and return on investment before taxation,
- alternative cost, that is rate of return for the society from discontinued investments in the private sector.

The social discount rate from an intragenerational analysis approach, which assumes achieving benefits from the execution of a project by future generations, may be a value determined with a function of social welfare or marginal productivity of the capital in the economy [Foltyn 2002, pp. 42–51].

In practice, in assessing investment projects by public institutions which provide financial support, a social discount rate is determined top-down by these institutions as a flat value applicable for all the projects assessed in the given evaluation period. For example, the social discount rate recommended at present by the European Committee for calculations for costs and benefits analysis is 5.5% in case of countries that are beneficiaries of the Cohesion Fund and 3.5% for other countries.

The Federal Treasury Board Secretariat (TBS) in Canada in 1976 recommended the use of social discount rate of 10%, with sensitivity analysis using 5% and 15%. In 2007 the TBS revised its guidelines and recommended a social discount rate of

8%, with sensitivity analysis at 3% and 10%. However, the TBS allows sometimes much lower social discount rates (0 to 3%) for health and environmental cost-benefit analyses [Boardman et al. 2011, p. 264].

4. Discount rate in the absolute calculation of investment effectiveness

The selection of the discount rate affects effectiveness of a specific individual project assessed using NPV, PI, IRR, MIRR, DGC or AC (or UAC) indexes.

In the case of annualised cost, increasing the level of the discount rate causes an increase in the value of the capital recovery factor and, as a consequence, an increase in capital and annualised costs. The unit annual cost (at unchanged values of annual effects) shall also increase, which leads to the cost effectiveness of the project worsening.

Determining a specific value for the discount rate is not really necessary to calculate the IRR of the project, but is necessary for assessing the profitability of the project as the discount rate is the parameter with which the IRR of the project is compared. The higher the discount rate taken as a point of reference for IRR, the lower is the profitability of the investment project.

The higher discount rate, the higher is the value of MIRR is (see Figure 6), but at the same time the higher is the parameter with which the MIRR of the project is compared. An increase in the discount rate reduces the attractiveness of the project. In the case of project S from Figure 6, at the discount rate of 4%, the value of MIRR is 9.3% and at the discount rate of 14%, the value of MIRR (13.2%) is lower than the required rate of return that means project is not profitable for the investor.

In the other analysed methods of assessing investment effectiveness, i.e. NPV, PI and DGC, for typical projects: the higher the discount rate is, or the higher the required rate of return from the project is, the less attractive the project will be for the investor. A typical project means incurring investment expenditures (negative net cash flows) at the beginning of the project life in relatively large amounts, and positive net cash flows at a later time.

However, an example is always possible of a project with non-typical distribution in time of inflows and outflows (costs) in which, along with increase in discount rate (or increase for a certain discount rate bracket), effectiveness is improved. Table 1 gives data necessary to calculate the DGC index for a certain investment project using two variants. Figure 1 presents the dependant value of this index with the adopted discount rate. In the first variant (project A), investment outlays incurred at the beginning are higher and operation and maintenance cost are lower than those in the second variant (project B).

For project A the higher the discount rate, the cost effectiveness of the project worsens. In project B for a discount rate between 0% and 23%, the increase in discount rate diminishes the value of DGC.

Table 1. Investment outlays, operation and maintenance costs and effects for projects A and B

Year	Project A			Project B		
	Investment outlays	O&M costs	Effects	Investment outlays	O&M costs	Effects
0	350 000	–	–	130 000	–	–
1	–	10 000	20 000	–	10 000	20 000
2	–	17 000	20 000	–	20 000	20 000
3	–	24 000	20 000	–	30 000	20 000
4	–	31 000	20 000	–	40 000	20 000
5	–	38 000	20 000	–	50 000	20 000
6	–	45 000	20 000	–	60 000	20 000
7	–	52 000	20 000	–	70 000	20 000
8	–	59 000	20 000	–	80 000	20 000
9	–	66 000	20 000	–	90 000	20 000
10	–	73 000	20 000	–	100 000	20 000
11	–	80 000	20 000	–	110 000	20 000
12	–	87 000	20 000	–	120 000	20 000
13	–	94 000	20 000	–	130 000	20 000
14	–	101 000	20 000	–	140 000	20 000
15	–	108 000	20 000	–	150 000	20 000
16	–	117 000	20 000	–	160 000	20 000
17	–	125 000	20 000	–	170 000	20 000
18	–	132 000	20 000	–	180 000	20 000

Source: own elaboration.

Table 2 presents, in turn, outflows and inflows of another project, with three variants:

- a typical one, with the highest outflows incurred at the beginning of the project (project C),
- non-typical ones, where positive net cash flows are generated in the initial period of the project, and major outflows occur at the end of the project (projects D and E).

Figure 2 presents the changes in NPV depending on the discount rate for these projects. In projects D and E "specific" distribution of cash categories over time makes the project more profitable at a higher cost of capital (the expected rate of return): in the case of project E steadily along with the increase of discount rate and in the case of project D, only for the range between 0% and about 20%.

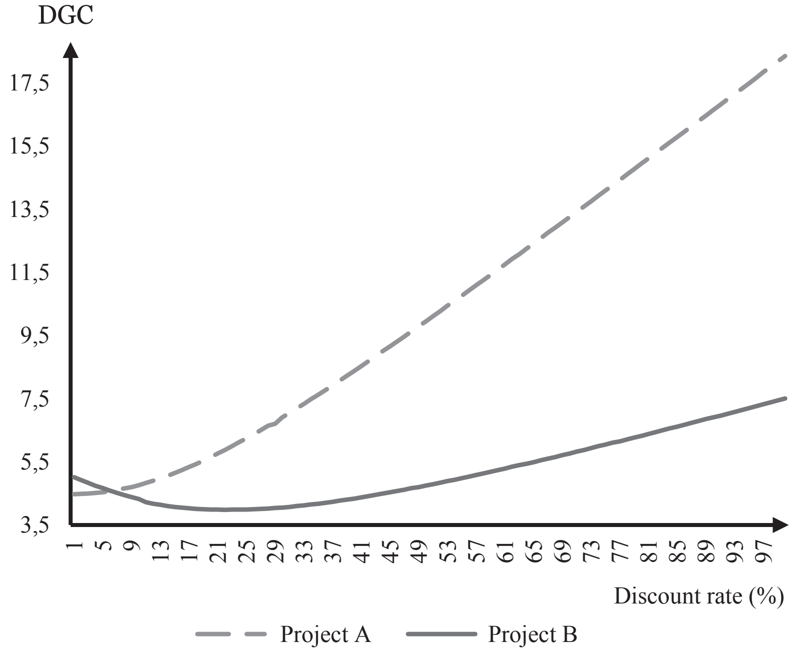

Figure 1. Dynamic generation cost profiles for projects A and B

Source: Table 1.

Table 2. Outflows and inflows for projects C, D and E

Year	Project C		Project D		Project E	
	Outflows	Inflows	Outflows	Inflows	Outflows	Inflows
0	1 500	–	–	750	–	750
1	–	750	–	750	–	750
2	–	750	–	750	–	750
3	–	750	–	750	–	750
4		750	1 500	–	5 000	–

Source: own elaboration.

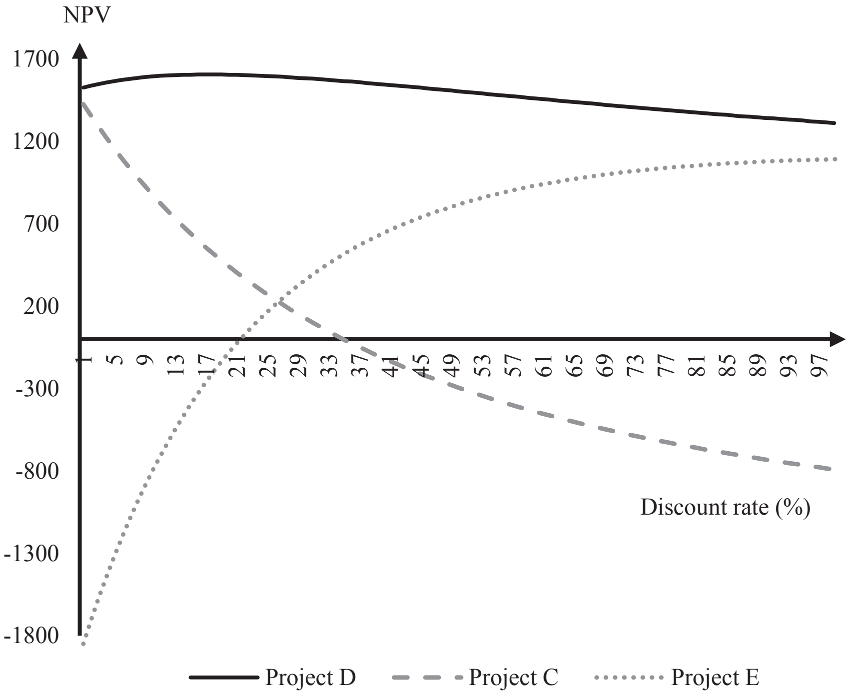

Figure 2. Net present value profiles for projects C, D and E

Source: Table 2.

5. Discount rate in the relative calculation of investment effectiveness

Selecting a discount rate for the calculation of the discussed indexes used for assessing investment project effectiveness may have an effect on selecting the most profitable project. The exception to this is the internal rate of return, in the case of which the decision criterion in the relative calculation of investment effectiveness is selecting the project with the highest IRR value. Depending on the value of cash flows and their distribution over time of the compared investment projects, two situations may be named:

- irrespective of the adopted discount rate, the given project is always the most profitable one from among other competitive projects,
- for a certain discount rate bracket, one project is best, while a different project (or projects) are best for another bracket or brackets.

Figures 3 and 4 present these situations for NPV in two projects.

In the case from Figure 4, project K is more profitable with a discount rate lower than r_i, and project L is more profitable for a higher rate. In the literature, the

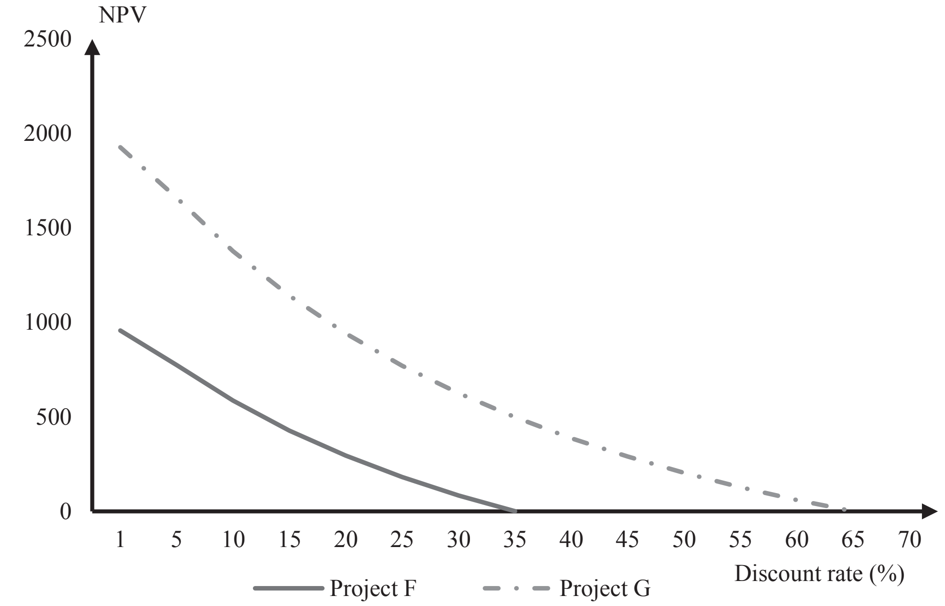

Figure 3. Dependence on the level of discount rate and the level of NPV for two projects (variant 1)

Source: [Sierpińska, Jachna 2007, p. 481].

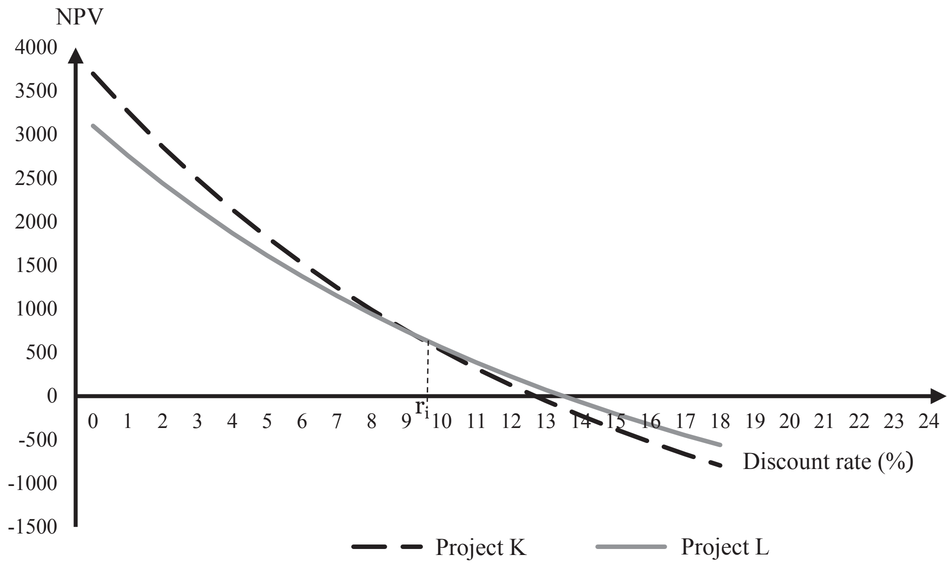

Figure 4. Dependence on the level of discount rate and the level of NPV for two projects (variant 2)

Source: [Sierpińska, Jachna 2007, p. 481].

discount rate for which net present value in two projects is equal is called a cross-over rate or "Fisher intersection." A cross-over rate for NPV in two projects may be determined through trial and error or on the basis of IRR in the so-called differential cash flows, which means the difference between net cash flows from the two projects [Sierpińska, Jachna 2007, p. 500].

A cross-over rate may be used to define the relationship between NPV and IRR. If the appropriate discount rate happens to be lower than this cross-over rate, there is a conflict in project ranking between NPV and IRR. If the appropriate discount rate happens to be higher than the cross-over rate, then both criteria produce the same ranking [Dayananda et al. 2002, p. 100].

The Fisher intersection is discussed in the literature in the context of the relationship with the discount rate for NPV in different projects. However, this also often occurs in other indexes: PI, MIRR, DGC and UAC (AC), in which for some values of cash flows (or costs and effects) and their specific distribution over time, the selection of the most effective project depends on the adopted discount rate.

Table 3 includes data related to inflows and outflows in two competitive projects. Figure 5 presents PI profiles for these enterprises. For a discount rate of about 19.5% (which may be determined through trial and error), the profitability index for both projects is identical. For a discount rate lower than the cross-over rate, the PI level is higher in project M, and in project N for a higher rate.

The profitability index of the analysed projects has been calculated as the quotient of the sum of discounted inflows and the sum of discounted outflows. A cross-over rate is also possible when comparing projects using PI, calculated according to the other version of the formula (5). The values of the profitability indexes in two projects will be the same if:

- the ratio of the sum of discounted investment outlays of the first project to the second project will be equal to the NPV ratio of the first project to the second project (the first PI formula),
- the ratio of the sum of discounted inflows of the first project to the second project will be equal to the ratio of discounted outflows of the first project to the second project (the second PI formula).

Table 3. Outflows and inflows for projects M and N

Year	Project M		Project N	
	Outflows	Inflows	Outflows	Inflows
0	70 000	0	70 000	0
1	25 000	80 000	60 000	120 000
2	25 000	100 000	50 000	160 000
3	25 000	100 000	50 000	160 000
4	25 000	100 000	50 000	160 000
5	25 000	100 000	50 000	160 000

Source: own elaboration.

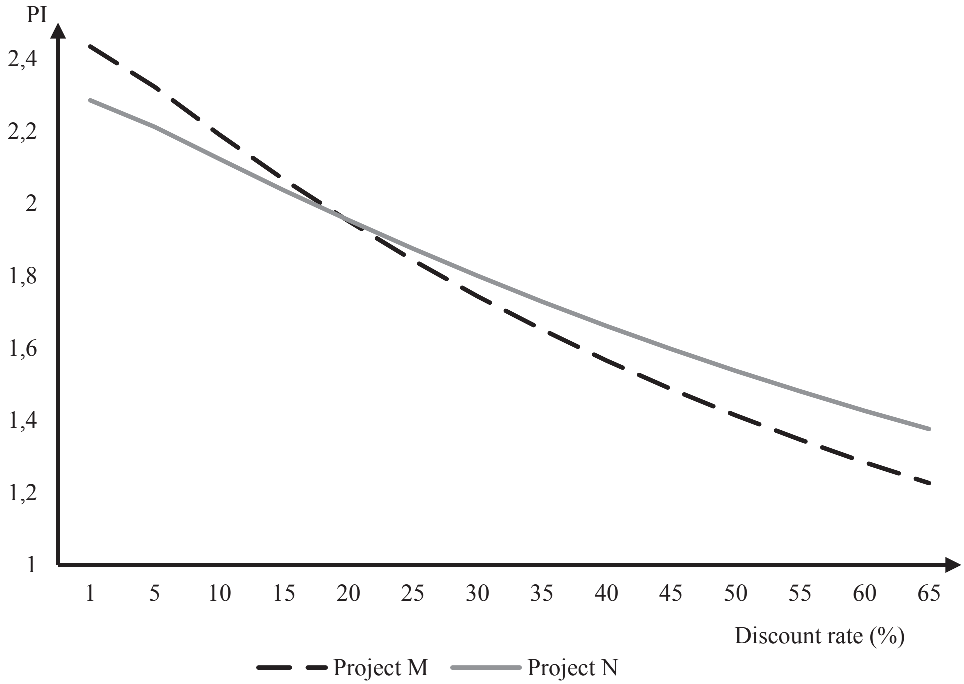

Figure 5. Profitability index profiles for projects M and N

Source: Table 3.

Table 4. Investment outlays and positive net cash flows for projects S and T

Year	Project S		Project T	
	Investment outlays	Positive net cash flows	Investment outlays	Positive net cash flows
0	1 500	–	1 500	–
1	3 000	–	3 000	–
2	–	400	–	1 000
3	–	600	–	1 100
4	–	1 000	–	1 100
5	–	1 200	–	1 100
6	–	1 400	–	1 100
7	–	1 600	–	1 100
8	–	2000	–	1 100

Source: own elaboration.

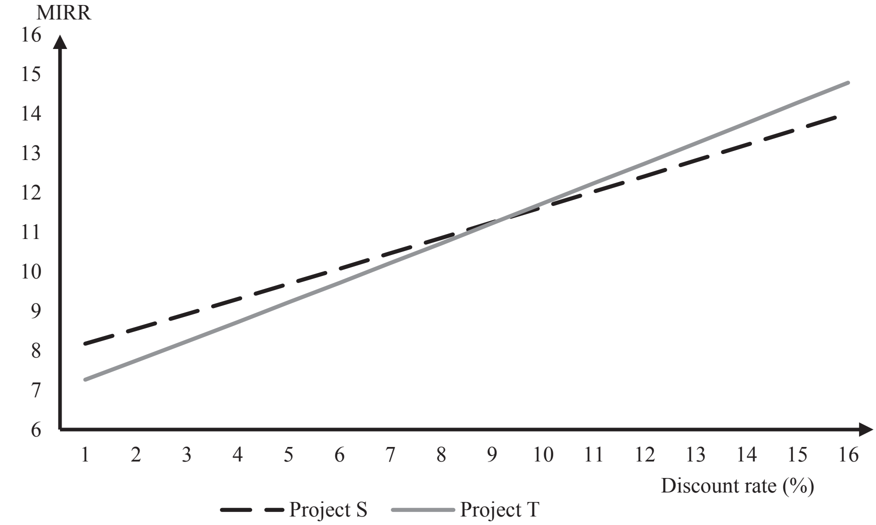

Figure 6. Modified internal rate of return profiles for projects S and T

Source: Table 4.

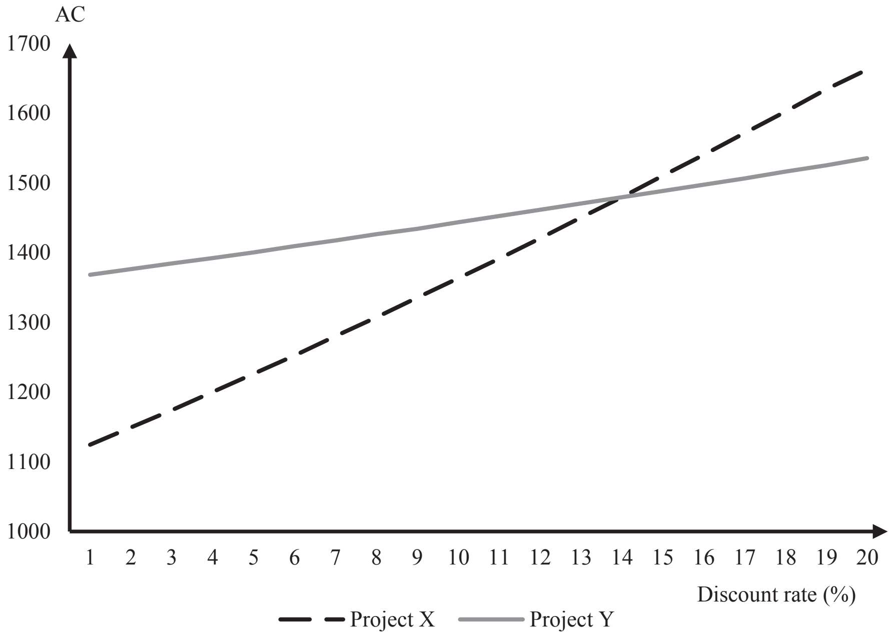

Figure 7. Annualised cost profiles for projects X and Y

Source: Table 5.

Table 5. Capital and operational costs for projects X and Y

Parameter	Project X	Project Y
Lifetime (years)	7	5
Investment outlays	4 200	1 300
Yearly operation and maintenance costs	500	1 100

Source: own elaboration.

A similar situation may occur in the case of DGC, whose formula is similar to that for PI. Tables 4 and 5 include data necessary for calculating MIRR and *AC*, respectively, for the two projects, and Figures 6 and 7 present the charts for these profiles. The adopted discount rate also has an effect on the selection of the best project in these cases. The discount rate for which MIRR for the two projects (and AC or UAC) are equal, may be calculated through trial and error.

6. Conclusions

The discount rate is the percentage rate used to discount future amounts of cash flows. It is used in dynamic methods of assessing investment projects in order to maintain comparability of cash flows from different periods of execution and operational use of the investment project. This rate also expresses the limit rate of return expected by the investors from the capital invested by them. Determination of the appropriate discount rate is not an easy task, but a complex one. The literature names different approaches to estimating financial and social discount rates.

Calculating the discount rate on the appropriate level is important because of its effect on assessing investment projects in both absolute and relative calculation of investment effectiveness. This effect depends on two other parameters which characterise the investment project: the value of cash flows (or costs and effects) and their distribution over time. In the absolute calculation of investment effectiveness, basically (in typical investment), an increase in the discount rate reduces the attractiveness of the project. However, with a special distribution of cash flows over time, the opposite relationship may occur. In the relative calculation, a situation is possible in which, for different levels of discount rates, different projects are those most profitable.

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STOPA DYSKONTOWA W OCENIE EFEKTYWNOŚCI PROJEKTÓW INWESTYCYJNYCH

Streszczenie: Stopa dyskontowa wyraża oczekiwaną przez inwestorów graniczną stopę zwrotu z zaangażowanego przez nich kapitału. Kalkulacja stopy dyskontowej na właściwym poziomie jest istotna ze względu na jej wpływ na ocenę projektów inwestycyjnych zarówno w bezwzględnym, jak i we względnym rachunku efektywności inwestycji. Ten wpływ zależy od dwóch pozostałych parametrów charakteryzujących projekt inwestycyjny: od wielkości przepływów pieniężnych (lub kosztów i efektów) i ich rozłożenia w czasie. W artykule przeanalizowano przykłady zmiany wartości wskaźników oceny efektywności inwestycji (w zależności od przyjętej stopy dyskontowej. W bezwzględnym rachunku efektywności inwestycji zasadniczo wzrost stopy dyskontowej zmniejsza atrakcyjność projektu. Jednak przy specyficznym rozłożeniu przepływów pieniężnych w czasie może wystąpić odwrotna zależność.

Słowa kluczowe: stopa dyskontowa, projekt inwestycyjny, NPV, MIRR.