

Aggregate Capital Tied-up by Investment Projects—The Possibility of a Simple Estimation

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The aggregate capital needs are a new business economics category which provides a new aspect to evaluate investment projects. The literature does not deal with this category as the project's total financial resource requirement. It is the total capital tied-up for the project in its lifetime. For calculation of it, the yearly capital tie-ups are being added together. Based on this, it can be examined the total capital amount, which results in a given net present value, or the total capital amount, which operates according to the given rate of profitability. The paper interprets the category, presents its relationship with the interest rate, and also presents the method of calculation based on model editing. In the case of the internal rate of return, the estimation may be greatly simplified. Instead of determining the yearly amounts and summation of these, the estimation can be carried out also with a simple division of two data. The paper demonstrates the possibility of simplification and shows an example to present the interrelations of data.

Keywords: net present value (NPV), internal rate of return (IRR), capital tied-up, return requirement, yield structure

Purpose and Method

This paper deals with interpretation and quantification of aggregate capital needs. It is a new business economics category and is useful information for investment project evaluations. The main purposes are as follows:

- To introduce the aggregate capital needs as a financial resource tied-up by the project.
- To outline the general model of the calculation method alongside the flexible interpretation of the yield structure.
- To explain and to prove a possibility of a very simple calculation of this indicator for the case of internal rate of return (IRR).

The main research methods are content analysis, methodological analysis, and model construction. Both logical and mathematical processes are used to provide proof.

The analyses and the findings are all concerning for investment projects with orthodox cash flow pattern. (These cash flow patterns are named also normal, regular, typical, and conventional). The point is that the series of the difference between annual revenues and annual expenditures start with negative amount or amounts and the sign of these differences changes only once. This narrowing of the scope of the examination is necessary because of the fact that the net present value (NPV) and the IRR method lead to a real result only in

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this investment project circle. In the case of unorthodox cash flow pattern, both methods lead to false results. It should be emphasized: Unlike the general perception of the literature, the NPV also contains false information in the case of unorthodox cash flow patterns (Illés, 2014; 2016a).

The paper uses that business economics perspective, in which the business economics functions as an independent discipline and not any of the branches of microeconomics (Illés, 2016b). This approach interprets and manages the economic information and the database itself according to the real economic conditions, furthermore uses basically corporate terminology.

Aggregate Capital Needs as a New Business Economics Category

The indicator of aggregate capital needs shows all the capital tied-ups of an investment project. This is one of the important economic features of the investment project as it shows the sum of financial resource needs. For this reason, it should be listed among the most important information of these projects. Best of the author's knowledge, the aggregate capital needs do not occur in this context either in business economics or business practice literature.

This information is useful especially when using the net present value (NPV) or the internal rate of return (IRR) methods. The category is interpretable also from an accounting point of view according to the accounting database. The background mechanism of the NPV and IRR method in a correct way takes into account the yearly capital tie-ups as the return requirement, and the yearly capital tie-ups are the basis for charging the profit requirement or for profitability calculation according to the IRR. These methodological solutions are not visible on the surface. The main question of business efficiency is whether the return requirement is met. This question, of course, can be answered without knowing the aggregate capital needs. The methodology treats the total capital tied-up as the non-interesting information. The information on the capital tied-ups remains in the background.

In the case of some ranking creating tools, when it would be justified to take into account the aggregate capital needs, for this purpose, there is used the amount of initial investment. Solomon (1956, p. 127) said, "When comparing two projects requiring different outlays, it is necessary to compare 'present value per dollar of outlay' rather than the absolute present value of the projects". In the quoted text, "outlay" is the investment. This concept is still alive even today. It can be seen mainly in textbooks. For example, Damodaran's (2010) ranking creating tool is the NPV divided by initial investment (in this book, this indicator is named profitability index). The same index is included in Garrison, Noreen, and Brewer's (2009) book, as the project profitability index. The generally used profitability index (that is the summed present value of yearly capital yields divided by the initial investment) can be rearranged as $[1 + \text{NPV divided by the initial investment}]$. This is suggested as a ranking-forming indicator for example by Brealey and Myers (1988), Albrecht, J. Stice, E. Stice, and Swain, (2008), and Watson and Head (2009). The above two methods lead to the same ranking.

The indicator of aggregate capital needs is formed by three factors. These are the initial investment, the rapidity of the return, and the payback period or the lifetime (in case of NPV is the payback period; in case of IRR is the lifetime). The higher the initial investment, slower the return, and longer the payback period is (or the lifetime), the greater the total capital tied-up by the project is. Highlighting one of the three factors cannot lead to a clear economic result.

In order to quantify the aggregate capital needs, the capital tied-up must be determined for each year and then summed these. The yearly capital tie-ups are that parts of the initial investment, which are not yet returned

until a given year. These parts are gradually decreasing in the case of a continuous capital return. The aggregate capital needs take into account simultaneously all of the yearly existing capital tie-ups and consequently also the initial investment and the tied-up time. According to this method, the aggregate capital needs show such content as if this amount would be invested for one year. Consequently, aggregate capital needs of different projects are comparable.

This conception gives a new viewpoint to the investment project evaluation. In this way, it is possible to examine how much is the total capital tied-up that result in the given NPV, or how much is the total capital tied-up that operates with the given IRR. In this case, NPV is more favorable; the smaller aggregate capital needs resulted in the higher NPV are, the higher discounted surplus profit is. By contrast, for IRR, it is preferable that the larger aggregate capital needs operate with the higher IRR, that is, with the higher profitability rate (Illés, 2014). A project with a low capital tied-up can result in low profits even by relatively high profitability.

With the question of how much capital of an investment project has not been recovered until the end of a given year, that is, how much is the capital tied-up in the given year is dealt with several publications. In these works, the quantification happens clearly on the IRR basis. To the author's best knowledge, the first considerable work on this subject is Boulding's (1935) article. According to today's wording, he managed to split the yearly yields to capital face value return and to profit, with simultaneously quantifying the yet not recovered investment for every year. He solved the problem with a detour method; to this, he relies on a kind of quasi market-value. As a consequence of this problem-solving method, that is, using this sort of market-value, many misunderstandings have arisen.

Noteworthy the Crean's (2005) work presents in the language of business economics, how is formed the structure of the yearly yield in the return process when is used the IRR. For this, naturally, there was required to quantify the yearly capital tie-ups as well. The demonstration of these content relationships happens with a great detail and through examples. The article several times refers to the similarity which is valid during the repayment of the loan. The similarity is as follows: In the case of a loan, one part of the repayment is the interest payment and the rest as the other part is loan capital repayment (The interest concerns to the unpaid capital in all cases).

Hazen (2003) and Magni (2010) quantified the present value (i.e., the discounted amount) of the yearly capital tie-ups. However, this discounted amount is used in other topics as a kind of calculation aid, and not in the sense as basic information of the financial resource needs of a project. For this latter case, the discounting would be a definitely incorrect solution (The explanation is later).

Basic Relationships

Breakdown of Yields

In the case of orthodox cash flow patterns, the yield is the positive difference between the annual revenues and annual expenditures. The yield can cover the initial investment and the profit requirement. This relationship is indeed similar to bank lending transactions when the repayment includes the loan face value and the interest. However, in the case of loan repayment, the accounting officially separates the yearly amounts to the two components. Repayment of the nominal value of the loan is considered to be "capital movement"; the interest constitutes a cost. The structure of the annual equal repayments changes from year to year. The main reason for this changing is that the amount of yet non-repaid capital is steadily declining. As the yearly capital tied-up is

decreased, the yearly interest sum also is decreasing. Consequently, in the constant repayment amount, the capital part is getting bigger. The annual yields of the projects generally are variable amounts, but the structural changes of these are influenced by similar relationships.

The yield can be examined from different points of view, according to different components. The examination purpose determines the yield structure to be examined. For example, although the yield is not an accounting category, from an accounting point of view, the yield structure consists of two parts: amortization (that is, capital money) and pre-tax profits. In this point of view, the aggregate capital needs are the sum of the row of book values of the assets. The yield of the assets which are described for zero is profit fully.

In the case of business efficiency examination, the matter of separating into appropriate content elements depends on not only the examination purpose but also the examination method. When the NPV method is used, the yield may consist of three components:

- profit according to the required rate of return;
- investment face value return;
- surplus profit.

Before meeting the return requirements, the yield consists of two parts: The first one is a profit part according to the required rate of return and the second is the investment recovering. In that year, when is fulfilled the return requirement, the yield can consist of all the three components. After the fulfillment of the capital-based return requirements, the content of the resulting yield is evidently surplus profit. According to these, in a given year's yield, surplus profit may only arise if beforehand is fulfilled the capital-based return requirements, i.e., if the nominal value of the initial investment and the profit requirement there are covered. (When the NPV is negative, of course, there is not generating any surplus profit, and if the project is loss-making, then even profits no will be).

From the perspective of the IRR method, the yield consists of two components all along of the duration:

- profit according to the IRR;
- investment face value return.

This follows from the method of the IRR. Since the IRR includes all profits in the form of a ratio, in this case, there is no surplus profit.

Link Between Aggregate Capital Needs and Interest Rate

In the case of a given initial investment and a given yield row, the amount of annually recovered capital is determined by the profit needed according to the interest rate. The higher the interest rate is, the smaller the part for capital reimbursement remains. With a lower yearly recovered capital, the initial investment will be recovered over a longer period of time and aggregate capital needs will be higher. Under otherwise unchanged conditions, the smallest aggregate capital needs come at the case of zero interest rate. In this situation, the total amounts of the annual yields can be interpreted as a capital recovering, thus the capital tied-up time is shorter. After recovering of initial investment, the economic content of yields is profit (These connections are also explained through some examples in Illés, 2014).

The IRR is the highest interest rate, with which all the initial investment and the profit according to the interest rate can be returned. In the case of the efficient investment project, this interest rate generates the highest aggregate capital needs. If the interest rate used in the calculation is higher than the IRR, the return requirement is not met.

The Matter of Discounting

According to the above, in order to estimate the capital return of a given year, as the first step the profit requirement, or the profit according to IRR must be set out. If the yield is higher than the profit requirement or the calculated profit with IRR respectively, then the difference counts as an investment reimbursement in the examined year (if for a given year, the yield is lower than the profit requirement, the difference must be added to the capital tied-up). The recovered capital of the previous year reduces the capital tied-up for the given year. So, the annually tied-up amounts can be calculated step-by-step for every year of the pay off period or of the lifetime respectively. The aggregate capital needs are the amount of the annual capital tie-ups (as it mentioned above).

It is a very important relationship that the profit according to the concerned interest rate has been taken into account in the process of quantifying the annual capital tie-ups. Therefore, during the summation, already it should not be discounted. In the case of discounting the annual capital tie-ups, there would be taking into account the profit requirement or the profit according to IRR respectively twice, and according to this, the aggregate capital needs would be less than the factual one.

As a supplementary explanation, the similarity to the loan transaction may also be referenced. After the yearly loan repayments having been separated to face value repayments and interests, the simple sum of the yearly face value repayments must be equal to the sum of the borrowed capital. In this case, the yearly principal repayments can be summed up without discounting, and like this one, the annual capital tie-ups as well.

Models for Calculating Aggregate Capital Needs

Construction of a Calculation Model for the Case NPV Method

The starting relationships:

(1) It follows from the essence of the orthodox cash flow pattern that after the initial investment being paid, the project does not require another capital involvement.

(2) The pay off period is z year. During this time, the initial investment (E_0) and the profit according to the required rate of return will be recovered (when the project is efficient).

(3) During the year t , the amount of the capital tied-up is that part of the initial investment, which is not recovered until the end of the previous year: E_{t-1} .

(4) In the $0 < t < z$ years, the yield consists of two parts: the return of the required profit and the capital face value return.

(5) In the year z , the yield can consist of three content parts. The third one is the surplus profit.

(6) In the year t , the profit requirement is $E_{t-1} i$.

(7) In the $1 < t \leq z$ years, the sum of the yearly capital recovering can be calculated as the difference between the yield and the profit requirement: $H_t - E_{t-1} i$.

Symbols:

E_0 = initial investment occurring at the zero point of time;

E_{t-1} = the capital tied-up during the t -th year;

H_t = the yield (that is the difference between the revenues and the expenditures) in year t , where the value of H_t is always positive by the terms of orthodox cash flow pattern projects;

t = serial number of years ($0 < t$);

i = required rate of return;

z = the last serial number of the year of the dynamic payback period.

The yearly capital tie-ups:

- In the first year of operation ($t = 1$), the full amount of initial investment is tied-up in the project (E_0).
- For the second year, the first year capital tied-up is decreased with the capital returned in the first year:

$$E_1 = E_0 - (H_1 - E_0 i)$$

For the third year, the capital tied-up is decreased with the capital returned during the second year's operation: $E_2 = E_1 - (H_2 - E_1 i)$

During $1 < t \leq z$ years, the amount of capital tied-up is

$$E_{t-1} = E_{t-2} - (H_{t-1} - E_{t-2} i) \quad | \quad t = 2 \dots z \quad (1)$$

Based on all these, in the case of NPV, the index number of aggregate capital needs (E_{AN}) is as follows:

$$E_{AN} = \sum_{t=1}^z E_{t-1} \quad (2)$$

This index number includes the effect of initial investment, the pay of period, and the rapidity of capital payback.

Basic Model Construction for the Case of IRR Method

The IRR shows that the total nominal value of the profit how many percent profit abilities mean. Return of the capital face value lasts until the end of the duration. In this case, there is a profit calculated according to IRR and not a profit requirement. Consequently, in this case, the relationships for NPV are modified as follows ($r = \text{IRR}$):

- All along of the duration, the yield consists of profit calculated according to the IRR and investment face value return.
- In the year t , the calculated profit according to IRR is $E_{t-1} r$
- In each year of the total lifetime, the amount of capital return is the difference between the yield and the calculated profit.

After the first year, until the end of the lifetime, to each year, a calculation is needed to determine the capital tie-ups according to the following formula:

$$E_{t-1} = E_{t-2} - (H_{t-1} - E_{t-2} r) \quad | \quad t = 2 \dots n \quad (3)$$

(n = lifetime of the project.)

The aggregate capital needs by the IRR (E_{AI}) is described in Formula (4).

$$E_{AI} = \sum_{t=1}^n E_{t-1} \quad (4)$$

Simplification Possibility for the Case of the IRR Method

In the case of IRR, the calculation of the aggregate capital needs can be significantly simplified. This possibility is because the total profit sum calculated according to the IRR and the true total profit sum generated

during the project lifetime is the same. This follows from the content background of the NPV formula and the solution of it to zero (Illés, 2014).

As a result of the calculation method of aggregate capital needs, the face value of the profits generated during the whole lifetime of the project is allocated for each year according to the IRR. Consequently, the profits calculated at the nominal value for each year of the project operation are as follows:

$$M_{rt} = E_{t-1}r \quad (5)$$

M_{rt} = profit in year t calculated with the IRR.

Summing up:

$$\sum_{t=1}^n M_{rt} = \sum_{t=1}^n E_{t-1}r \quad (6)$$

The calculated and the real total profit sum is the same:

$$\sum_{t=1}^n M_{rt} = M \quad (7)$$

(M = the difference between the total sum of the nominal value of sales revenues and the total sum of the nominal value of all expenditures).

$$\sum_{t=1}^n E_{t-1}r = M \quad (8)$$

After rearranging Formula (8):

$$r E_{At} = M \quad (9)$$

It follows from the Formula (9) that the aggregate capital needs can be calculated also as the division of the profits sum with the IRR.

$$\frac{M}{r} = E_{At} \quad (10)$$

According to the above, in the case of the IRR, relatively lengthy calculations can be interchangeable by a simple division. Furthermore using the Formula (10), it is easy to verify the correctness of the analytical calculation of the aggregate capital needs for the case of IRR.

Overview Through an Example

The purpose of the example presentation is interpreting the main relationships through numbers. The example: There are two project variants and one of them can be chosen. Project A requires an initial investment of 200 units; Project B requires 500 units. Both projects have a lifetime of three years, and both have an IRR of 18%. Risks are already handled through appropriate correction of revenue rows. The required rate of return is 10%. According to the IRR of 18%, the profitability of both projects is good.

The revenue and expenditure rows as necessary starting data for the calculation are shown in Table 1. The detailed calculation materials are in Table 2.

Project B's initial investment is twice as large as the Project A's one. The lifetime and the IRR are the same. However, despite the smaller initial investment, the total nominal profit sum for Project A is higher (see Table 1, last row). Behind these the different return rapidity is. The capital tied-up of Project A is larger because of its slower return. It is very important information, that in Project A, the higher capital tied-up operates with 18% profitability, that is, more capital works with the same high profitability as Project B.

Methodological relationship: multiplication of aggregate capital needs and the IRR really results in the whole amount of nominal profit:

$$5,873 \times 0.18 = 1,057 \text{ and } 5,472 \times 0.18 = 985$$

The data in Table 2 also show how much computation is needed for an analytical determination of the aggregate capital needs. According to the above, this calculation can be considerably simplified. The last row in Table 3 shows the simplified calculation. The profit sum divided by IRR quantifies the aggregate capital needs indeed. The two amounts are the same as the result of the analytical calculation in the last row of Table 2.

Table 1

*The Revenue and Expenditure Rows and the Nominal Profit Sums of the Two Project Variants**

Year	Project A			Project B		
	Expenditures	Sales revenues	Revenues— expenditures	Expenditures	Sales revenues	Revenues— expenditures
0	2,000	0	-2,000	5,000	0	-5,000
1	8,400	8,800	400	3,400	8,900	5,500
2	8,400	8,800	400	7,500	7,900	400
3	4,000	6,257	2,257	7,800	7,885	85
Nominal sums	22,800	23,857	Profit = 1,057	23,700	24,685	Profit = 985

Note. * Dimension of amounts is unit.

Table 2

*Analytical Calculation of the Aggregate Capital Needs of the Two Project Variants**

Year	Capital tied-up	Project A			Capital tied-up	Project B		
		The yield and its structure ($r = 0.18$)				The yield and its structure ($r = 0.18$)		
		Yield	Profit	Recovered capital		Yield	Profit	Recovered capital
1	2,000	400	360	40	5,000	5,500	900	4,600
2	1,960	400	353	47	400	400	72	328
3	1,913	2,257	344	1,913	72	85	13	72
Σ	$E_{AI} = 5,873$	3,057	1,057	2,000	$E_{AI} = 5,472$	5,985	985	5,000

Note. * Dimension of amounts is unit.

Table 3

*Quick Estimation of Aggregate Capital Needs for the Two Project Variants**

Appellation	Project A	Project B
The total sum of the nominal value of profits	1,057	985
IRR	0.18	0.18
Aggregate capital needs	$\frac{1,057}{0.18} = 5,872$	$\frac{985}{0.18} = 5,472$

Note. * Dimension of amounts is unit.

Of course, the further profitability opportunities can also effect on the decision (There are 3,000 units of difference between the two initial investments. At the end of the first year 5,500 units exits from Project B.)

Conclusions

The initial investment is an inadequate feature of the project's financial resource needs. The ratios of aggregate capital needs may differ significantly from the ratios of the initial investments. Computer programs

can be edited for calculation of aggregate capital needs, but for the case of IRR, it can be easily calculated without it also. The simplified calculation can be easily understood by practitioners as well. The aggregate capital needs are one of the key features of the project and also are important information in the ranking process.

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