Comparative Analysis of NPV and IRR Indicators Based on Practical Applications

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Abstract. The current essay briefly reviewed the definitions of NPV and IRR, investigated the functions, practical uses and which is better in financial market. After describing the limitations of NPV, this paper will also give some approaches, which might be mentioned in other materials, in order to alleviate effects of some limitations. However, for perpetuity, the calculation should use the formula of perpetuity, which will be a little bit more difficult. After doing these improvements, NPV can be used to compare very different projects. Nonetheless, there are few resources about improving IRR, thus, the approaches to improve IRR were not proposed by the author. Although there is no enhancement can be made, IRR is easily to calculate the projects with short time period and single direction of cash flows, also distinctly illustrates their profitability. According to their features, NPV is more suitably used in long-term investments, and results of IRR would be more accurate and effective in short-term investments.

Keywords: Efficiency, Profitability, Project Lifetime, NPV, IRR.

1. Introduction

After the 2008 Financial Crisis, the global financial system was improved in many ways, although accompanying with some new problems [1]. The US financial market became maturity which means capitals invested in projects tend to correspond to its return, and other financial markets also occurred such growth trend. Therefore, approaches to measure whether it is worth investing some projects are a significant topic in finance. The current essay mainly elaborates on many aspects of NPV and IRR, such as assumptions, use cases, limitations and improvements that can be made. As for the materials investigated, some of them suggested that NPV is better than IRR. A comment on specialist website – bay answering the question "Which is better? IRR or NPV?" said that both are complementary, but NPV is the first and necessary step [2]. From author's understanding, the Accountant Analyst means that they are both used, but NPV is calculated first, if NPV is less than 0, then no matter how IRR looks like, reject the projects. And there is another article on Linked in compared the advantages and disadvantages of both NPV and IRR, finally get such conclusion – NPV is much better than IRR, based on four reasons [3]. Briefly, the reason 1 is single discount rate, 2 is calculations can get several IRRs, 3 is the meaning of negative IRR, 4 is an advantage of NPV – positive NPV means addition in shareholders' wealth, but IRR does not have this meaning. Although IRR has restrictive use, Sardana underestimated the role of IRR and overestimate the uses of original NPV model. The original NPV model also assumes cost of capital (r) remains the same, so firstly reason 1 does not hold. For the third reason, a definition of negative IRR is given on a website – Accounting Tools, in short, aggregate cash inflows is less than the initial investment [4]. And it is apparent that negative IRR illustrates that the investments is not worth being invested in. As for the fourth reason, it is unstrict, because NPV and IRR is different model, and the forms of results are also different, so they cannot indicate the same thing, both have their own uses. When it comes to the focus of the current paper, it will argue that it is not easy to say which is better in reality; it depends on the many factors, such as sizes of companies, type of investments, the proportion of one project in total amount of an investment portfolio, etc.

2. NPV

2.1. Definition

Net Present Value (NPV) is a method to discount future cash outflows and cash inflows at present time, which is known as the gold standard to make financial decision. It is an absolute value, and the formula is shown below:

$$\mathrm{NPV} = \sum_{n=0}^{N} \frac{CF_n}{(1+r)^n} \quad (1)$$

In the equation above, CF_n represents total cash inflows or outflows (positive or negative) in time n, r represents discount rate (also can be understood as cost of capital). And time period n means the beginning of that period (period n).

2.2. Assumptions

One assumption is that the present money value is different as future money value due to inflation cost and opportunity costs. It is universally acknowledged that in Economics the cost also includes opportunity cost. Even if the money was not invested in financial markets, individuals just put it into bank, they would also receive interest rate returns. Therefore, the money remaining after spending today will be valued less in future if people just hold it in hand and do nothing. In NPV model, cash flows are anticipated to occur on time. As mentioned before, time is an important factor, thus, deferred cash flows or unanticipated cash flows will influence the time cost of money.

The most unpractical assumption is that r (cost of capital) remains the same during the investments period. In reality, the cost of capital will change dynamically, and there might be better investment projects in the future, which depends on the economic trend. To determine the r, under most situations the managers will utilise the data from financial market with the same risk level. Therefore, stable financial market is a premise. For example, although there was someone anticipating the 2008 financial crisis, when it really occurred, it also substantially damaged the financial market. Under this case, because of economic recession, cost of capital decreased, causing an increase in present value of remaining cashflows, nonetheless, many companies went bankruptcy, leading to that plenty of cash inflows would not occur.

2.3. Limitations

2.3.1 Determination of the r

The process of determining the r is relatively subjective and can be biased by the managers. The cost of capital sometimes depends on situation of a company, i.e., one company can have better choice than investing in financial markets. In this case, the return rate of that better choice is the cost of capital to invest in the chosen project, which can be underestimated in order to persuade stakeholders to accept the financial decisions made by the managements.

2.3.2 Magnitudes of Initial Investments

The NPV does not take into account magnitudes of investment. Because more initial investment usually means more returns, therefore, higher cost of investments usually means the higher NPV. As shown in Table 1, according to NPV rule, project B is better than project A. However, the initial investment of project B is more than twice of project A. NPV of the project B is less than twice of it of project A, which means that efficiency of project A to earn money is much more than it of project B. What's more, in reality there will be numerous alternatives. Under the real situation, efficiency is more important than the just absolute value, because money not used can be invested in other projects. In the table below, NCFn represents net cashflow at time period n.

Table 1. Comparison between Project A and Project B

Project	A	B
NCF0	-26900	-55960
NCF1	10000	20000
NCF2	10000	20000
NCF3	10000	20000
NCF4	10000	20000
IRR (%)	18	16
NPV (12%)	3470	4780

2.3.3 Improvement

There are some improvements that the author suggests corresponding to limitation 2 and practical use of NPV. Firstly, to take into account the scale of investments, one direct method is to divide NPV by the absolute value for total present value of cash outflows, and then a ratio will be calculated. The total cash outflows are the total expenditures on the projects. Present value of the cash outflows is calculated in order to unify values of cash flows at the current time point. Dividing these two can give a ratio that means present returns rate from the projects. Comparing these rates, managers can realise which project utilise the capitals more efficiently, and the method is called NPV efficiency rate. Although it does similar function with IRR, it can calculate the situations when there are several inflows and outflows, and calculation is much simpler than IRR whose formula is an exponential equation. An example of this method is shown in Table 2. In the table, E Rate represent NPV efficiency rate.

Table 2. Using the Method of NPV Efficiency Rate

Project	A	B
NCF0	-26900	-55960
NCF1	10000	20000
NCF2	10000	20000
NCF3	10000	20000
NCF4	10000	20000
IRR (%)	18	16
NPV (12%)	3470	4780
E Rate (%)	12.90	8.54

As for practical use of this method, when a financial institution that has plenty of endowments and is able to diversify its capitals into countless projects, choosing projects with the higher NPV efficient rate in priority are better choices, generating higher profitability. Nonetheless, for a company with limited capitals, it cannot choose such substantial amounts of projects. If the company choose projects according to the rate, the remaining money might be underutilised. In this case, there is another method, but a little bit more sophisticated, which is about combination. Firstly, managers should list out all potential projects and their NPVs, and then try to make various combinations of projects in order to reach the maximal total NPV generated. Finally, choose the combination with the highest NPV. The problem is that with an increasing number of potential projects, the difficulty of listing combinations increases a lot. Thus, it would be much complicated for medium-size companies. A specific example is shown in the Table 3. In the table below, I represent present value of total investments of the projects, E Rate is NPV efficiency rate measure in percentage point.

Table 3. Choices between Several Projects

Project	A	B	C	D	E	F
I	1000	1500	2000	2500	3000	3500
E Rate	30	46.67	40	48	43.33	42.86
NPV	300	700	800	1200	1300	1500

Using data from Table 3, if an investor is given 4500 units of endowment, after comparing different combinations of projects, for instance, investing in Project A, B and C (generate total NPV of 1800), or Project C and D (generate total NPV of 2000), finally he/she would choose to invest Project C and D. This is a specific situation for this example, however, in reality, sometimes there are extremely high-return projects, under which situation, company could earn considerable profits without utilising all endowments.

When it comes to another improvement, to overcome the constant r (cost of capital) assumption and make the formula more practical, NPV formula should be upgraded to a more specific level as shown in Formula (2), in which r is changing with the time period. Because in different time period, there will be some predictable events, cost of capital in a certain year can be evaluated at a certain extent. For example, the football World Cup held every four years will promote the economic growth of the host country due to more foreign tourists, which will lead to demand-pulled inflation, causing higher cost of capital. Nonetheless, one problem with differentiating the r (cost of capital) for each year is that the longer cashflows to now will make the predictions of NPV more inaccurately. Although this is a problem, the method is the way to make NPV more reliable and accurate.

$$\mathrm{NPV} = \sum_{\mathrm{n}=0}^{\mathrm{N}} \frac{\mathrm{CF_n}}{(1+r_n)^{\mathrm{n}}} \tag{2}$$

Table 4. NPV with Different r (cost of capital)

Project	A	B	r (%)
NCF0	-26900	-55960	
NCF1	10000	20000	10
NCF2	10000	20000	15
NCF3	10000	20000	14
NCF4	10000	20000	12
IRR (%)	18	16	
NPV	2857.24	3554.48	

The Table 4 demonstrates how different r are applied in NPV model.

From author's perspective, the priority of high NPV efficiency rate and combinations of a variety of projects can make the project portfolio more profitable. Although the rate gives relative profitability comparing cash inflows and outflows, it loses its original characteristic – absolute value and cannot help medium-size companies to make processes of choosing projects more easily. Nevertheless, replacing constant r with various r according to different time period will increase the accuracy of the NPV model.

2.3.4 Use Cases

Before the improvements, its use case is greatly restricted. When the initial investment is the same and under the premise of that several projects are mutually exclusive, the results of NPV are meaningful. And when there are many IRR for a project, financial managers and investors will also choose NPV [2].

After the improvements, its use case is largely extended. The model is applicable in most situations, even projects seem very different. For large financial institutions, they can invest in projects with the highest present return-expenditure rate per year, which helps them utilise the most of capitals much more effectively. Even there is few capitals remaining, it has little impact on overall profits. For medium-size or small companies, although they need to calculate fewer projects due to limited potential projects, making combinations of different projects is supposed to be done.

3. IRR

3.1. Definition

IRR is the r (discount rate) in NPV that makes the equation equal to zero, which is annual rate of return of a project, measuring profitability [6].

$$0 = \text{NPV} = \sum_{n=0}^{N} \frac{CF_n}{(1+\text{IRR})^n} \tag{3}$$

There is a standard – hurdle rate along with IRR. Hurdle rate is expressed as weighted average cost of capital plus risk premium and known as minimum acceptable return of return. When making decisions, IRR is compared with the hurdle rate. If IRR > hurdle rate, then accept the project, vice versus.

3.2. Assumptions

The most important is reinvestment assumptions, which is unpractical in the real world. To further explain it, here is a simple example. Initial investment is 100, at the first year get return of 10, and at the second year get original investment and return of 110 in total. The IRR of the project is 10%. But the actual return is obviously 120 which should be 121 if the annual rate of return is 10%. The reason why this situation happens is that the return of first year is not reinvested in this project again. The author's understanding about "internal" in its name is that if the returns received during the project lifetime are reinvested in the project with the same return rate again, then the rate of return is the same as the actual rate of return. The following equations illustrate the point more specifically. The second step means reinvestment at the same return rate.

$$100 = \frac{10}{1.1} + \frac{110}{1.1^2}$$

$$100 = \frac{10 \times 1.1 + 110}{1.1^2}$$

The other assumption is the same as NPV, IRR is supposed to be the same during the whole project lifetime.

3.3. Limitations

3.3.1 Reinvestment Assumption

In reality, reinvesting in the same project or at the same IRR is not always the case. If an investor gets some returns, he/she will re-decide the project that is worth being invested in owing constantly changing financial market or can choose to consume for daily life. Under this situation, the IRR is usually higher than actual rate of return.

3.3.2 Neglect the Size of Investments

It is a ratio not absolute value, so ignores the scale of investments. Some small projects might seem more attractive so that make investors miss the projects offering the high absolute return [5]. Sometimes financial managers and investors would like to know specific return in order to allocate bonus or profits, not all the time efficiency means everything, the total quantity is also vital.

3.3.3 Several Cash Outflows and Inflows

When there are several cash outflows and inflows (sign of terms change), the equation may have plenty of solution. So, its use case is seriously restricted, and it will make investors confused when there are several IRRs. More specifically, it is applicable when there is just one initial borrowing or investments, after that all transactions are single direction - cash outflows or inflows.

3.3.4 Capital Cost Creates Inaccuracy

The IRR has nothing to do with r (cost of capital), it is just about the return of the project. Because of this, hurdle rate is supposed to be set, which is relatively subjective and complex to decide [7].

3.3.5 Tedious Equation

According to the formula, after simplifying it, the formula becomes exponential equation. If the lifetime of one project increases by 1, the index of the equation will also increase by 1. When the power of equation becomes larger, it is sophisticated to get the results. What's more, an increasing power of equation is more likely to lead to multiple IRR, causing that a financial calculator is needed [8].

3.3.6 Use Cases

Although IRR has so many limitations, it is also widely used by investors [5]. From author's perspective, long-term investments are not always in decision making, because the value of the projects tends to be substantially high, a few companies can afford to do numerous long-term projects. When it comes to short-term projects, besides the projects with several cash inflows and outflows, it obviously shows the profitability of a project, is simply calculated owing low power of equation, and impact of the biggest limitation - reinvestment assumption is also reduced. Therefore, IRR is suitable for short-term investments, especially for projects within one year, and is extensively used as NPV [9].

4. Comparison between NPV and IRR

First of all, both NPV and IRR are cash flow discounted models. Therefore, unanticipated cash flow will affect accuracy of the results, which are the drawback of both.

As for accuracy of the results, NPV is usually better than IRR, because NPV has no reinvestment assumption which is the biggest limitation of IRR. As a result, reinvestments will not affect the results of NPV analysis for projects [10]. And after improvements of NPV, it can gain the relatively high-efficient projects through calculation and predict the present value of projects more accurately. It seems definitely that NPV is more suitable for long-term projects, while for simple projects (short-term – within one-year, single cashflows after the initial cashflow), IRR is not difficult to be calculated and can clarify the profitability.

And after investigation, an article written by Vaidya on WallStreetMojo said that NPV is more understandable by the public, while IRR is more used by the business managers [11]. The frequency of short-term investments is more than long-term investments, not only in that short-term investments tend to have fewer initial investments so that can trade more, but also less risk [12]. It is universally acknowledged that large financial institutions are more focused on the safety of capitals; they concentrated on stable, safe, expected return. It is not clear that which of the two methods are extensively used in financial market, because after investigation the author cannot find the materials stating that which of both is utilised at a higher frequency. Although there are articles said that NPV is better than IRR, each of them is better in a certain situation after specific analysis of the current paper on NPV and IRR.

5. Conclusion

In general, the essay concludes that NPV is better used in long term, while IRR is better used in short term, due to their characteristics – IRR have reinvestment assumption restricting its ability to estimate long-term projects, while NPV is not suffered from this issue. Although IRR has substantial limitations that are hard to improved, it is also a good approach to interpret profitability especially for simple (defined in section 4) projects. And for large financial institutions, the efficiency of earning money is more important than just an absolute value of investments' returns. In terms of NPV after improvements, although it does similar function with IRR, but the calculations become more sophisticated. For short-term projects, the calculation of IRR will be obviously easier than improved NPV model. When it comes to NPV after improvements, it can measure and compare projects with different initial investments. But one problem not avoidably is that with the lengths of projects increasing, the uncertainty becomes larger, and the results will be subjective and inappropriate,

leading to suggestion of inappropriate financial actions or decisions. The reason why NPV is golden rule to invest in financial market is that NPV takes into account time value and cost of capital of money, directly reflects the current value of projects and decides whether it is worth investing some projects. What's more, the paper does not talk about projects with how long lifetimes are better to be estimated by NPV than IRR, which is supposed to be investigated further.

However, both methods are not difficult to be understood, thus, they are always used together in order to help managements make more appropriate decisions. Besides NPV and IRR, there are a lot of methods to invest in financial markets, this paper just chooses two of them to discuss and compare. Thus, more research on other methods such as payback period, accounting rate of return, etc. It is vital to understand their nature and interpret in an understandable way so that can make them easy to be understood by managements.

References

[1] McKinsey Global Institute. (2018) What's changed since the 2008 financial crisis in four charts. https://medium.com.

[2] Mostapha, E. (2016) Which is better? IRR or NPV? https://specialties.bayt.com.

[3] Sardana, K. (2018) NPV vs IRR: Which is better and why. https://www.linkedin.com.

[4] Accounting Tools. (2022) Negative IRR definition. https://www.accountingtools.com.

[5] Lovenna. (2022) IRR vs NPV in the Context of Financial Decision-Making. https://www.efinancialmodels.com.

[6] CFI team. (2022) Internal Rate of Return (IRR). https://corporatefinanceinstitute.com.

[7] Shultz, Harris, & S. (2005). Internal rate of return. Mathematics Teacher, 98(8), 531-533.

[8] Moten Jr, J. M., & Thron, C. (2013). Improvements on secant method for estimating internal rate of return (IRR). Int. J. Appl. Math. Stat, 42(12), 84-93.

[9] Green, J. M. (2021) Net Present Value vs. Internal Rate of Return.

[10] Banerjee, P. (2021) Reinvestment Rate Assumption in NPV versus IRR. https://www.tutorialspoint.com.

[11] Vaidya, D. (2021) NPV vs IRR. https://www.wallstreetmojo.com.

[12] Pina, R. (2022) What are Short Term Investments: Grow your Money Now. https://themodestwallet.com.