Developments of the payback method

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Abstract

In spite of its theoretical deficiencies, the payback (PB) method is commonly used for appraisals of capital investments in companies. Sometimes the method is used when aspects such as liquidity and project time risk are focused, but it is also commonly used in pure profit evaluations as a single criterion. The two main deficiencies of the PB method are that it does not measure the time value of money in a correct manner and that it ignores cash flows after the payback period (PP). These deficiencies can be reduced if the maximum acceptable PP is chosen in a somewhat more sophisticated way. In practice the maximum acceptable PP is often chosen as a fixed value, e.g., three years. In some cases the limit value of the PP has been related to the economic life of the investment, e.g., a PP shorter than half the economic life. If these two rules of thumb are combined, a more theoretically correct evaluation of investments can be achieved. Such a combined PB method is based on the assumption of constant yearly cash flows. However, the method can be developed to handle cases with varying cash flows, but then some of its simplicity is lost. Due to the fact that the decision situations in the evaluation of capital investments typically are uncertain concerning the time pattern and the duration of the cash flows, this can justify the use of a simple but more robust PB method even if there would be time for more advanced analyses.

Keywords: Payback; Project evaluation techniques; Capital budgeting criteria

1. Introduction

In many companies the payback period (PP) is used as a measure of the attractiveness of capital investments. Its use as a single criterion seems to have decreased over time, but it is still commonly used as a secondary measure. In fact this type of use seems to have increased [1]. Often the payback (PB) method is used as a first screening device. The obvious cases of profitable and unprofitable investments are sorted out, leaving only the middle group to be scrutinised by means of more advanced and more time consuming calculation methods based on discounted cash flows (DCF), such as the internal rate of return (IRR) and net present value (NPV) methods. However, there are also many companies, even of considerable size, where the PP is used as the single criterion in investment evaluations [2]. Such use of the PB as the only or as the primary method seem to be somewhat more common in small and medium-sized companies [3–5].

Some recent overviews of various studies of the use of the PB method in investment evaluations in companies are presented by Lefley [6] and Northcott [7]. The results from different studies at different points of time are not totally consistent. The method seems to be somewhat more frequently
used in Europe than in the U.S. [8–10]. To some extent the differences in results may be a consequence of how the research has been conducted. Studies directed towards corporate headquarters seem to show a higher rate of more advanced methods than if users on lower levels are included as in the two Swedish studies mentioned above [9,10]. The overall conclusion seems to be that the PB method is still frequently used for investment appraisals, and therefore it seems worthwhile to see if some of its deficiencies can be reduced.

2. Two main deficiencies of the PB method

Some have argued that the PB method does not measure the profitability of projects at all but rather their time risk and their effects on liquidity [6]. Even if PB most often is used as a first sieve or as a restriction [11] the method is still quite often used as the single or at least primary method for investment evaluations. The two main deficiencies of the PB method are that it does not take into account cash flows after the project’s payback period and that it ignores the time value of money, which is discussed in most textbooks on capital budgeting e.g. [12,13]. As a solution to the latter deficiency it has been suggested that the simple PB method could be modified by looking at a discounted payback period (DPB), thereby searching the payback period when the accumulated present value of the cash flows covers the initial investment outlay. The recommendations of what discount rate to use varies somewhat. Either a risk-free interest rate can be used or else a risk-adjusted discount rate such as the company’s weighted average cost of capital [14]. Others take it more or less for granted to use a cost of capital including a risk component [15]. In the latter case the DBP method could be seen as a variation of the NPV method. An investment with a PP shorter than the economic life of the investment will always have a positive NPV, if the same discount rate is used in both calculations. If a lower risk-free discount rate is used when discounting the DPB cash flows, obviously the acceptable PP must be shorter than the economic life.

Regardless of what type of discount rate is being used, it seems to be common practice to use the DPB method with a required payback within a fixed number of years in the same way as with the simple PB [2]. For instance, instead of demanding payback within three years with the simple method, the maximum acceptable PP when using DPB might be prolonged to four years. However, if the yearly cash flows are constant and if the salvage value is negligible, it can easily be shown that there is a simple relation between the two criteria. With a discount rate of 12.59%, a discounted PP of four years is exactly comparable to a non-discounted PP of three years. Using the DPB method in this way is not much of an improvement. It is very similar to the simple method with the same drawbacks, but without its simplicity. The only improvement is that the DPB method will handle situations with varying cash flows somewhat more correctly than with the simple PB method. Both methods are used in investment evaluations, but the simple method still seems to dominate, at least in Sweden [2].

3. Solutions to reduce PB deficiencies

In theory and in practice some other solutions to the problems with the simple PB method have been tried, such as attempts to relate the PP to the estimated economic life of the investment. With the simple PB method, the demanded PP has to be shorter than the economic life of the investment because of the time value of money. Also, as mentioned above, the maximum acceptable PP when using the DPB method, should be equal to the economic life of the investment if the cost of capital is used as a discount rate, or shorter than the economic life of the investment if the cash flows are discounted by a risk-free discount rate.

The author has seen a couple of large companies in the food-production industry in Sweden handling these problems by using the simple PB and demanding the PP to be shorter than half the economic life time of the investments. However, this type of criterion also has deficiencies, although in a sense opposite to those of the simple PB with a demanded payback within a fixed number of years. While a demanded PP within a fixed number of years seems to discriminate against investments with long economic life, a decision rule with
demanded PP within half the economic life seems to discriminate against those investments with short economic life. This is shown in Table 1 and Fig. 1. The internal rate of return of investments with constant yearly cash flows are studied.

**Parameters**

- **I** Investment outlay
- **L** Economic Life
- **CF** Annual cash flow, assumed to be constant
- **PP** Payback period

IRR is defined as a discount rate that will make the NPV equal to zero.

$$-I + CF \sum_{i=1}^{L} \frac{(1 + IRR)^{-i}}{1} = 0.$$  

In a case with constant cash flows the PP is determined by the ratio \(I/CF\) and the expression above can be simplified to an expression for a finite geometric series, a present value annuity factor, giving us the following expression:

$$PP = \frac{I}{CF} = \frac{1 - (1 + IRR)^{-L}}{IRR}.$$  

In Table 1 the values of IRR for the two cases with PP = 3 and PP = \(L/2\) are shown. These relationships are illustrated in Fig. 1.

### 4. A combined PB method

Obviously neither of the above two ways of determining maximum acceptable PP is ideal. A demanded payback within three years will discriminate against investments with long economic lives, while a demanded payback within half the economic life will discriminate against investments with short economic lives. However, Fig. 1 depicts that some type of average or combination of the two rules could be useful. In the following, a simple PB method based on such a combination PP, is called the combined payback method (CPB), although it still is the simple PB method if one looks at the calculation model. The two different ways of determining the maximum acceptable payback period shown in Fig. 1 are:

$$PP_{\text{fy}} = B \text{ years (index fy for fixed year PP)}$$  

$$PP_{\text{hl}} = L/2 \text{ years (index hl for half life PP)}$$

Looking at the minimum annual cash flows in each case you will find:

$$CF_{\text{min}}^{fy} = \frac{I}{B}$$  

$$CF_{\text{min}}^{hl} = \frac{I}{0.5L}$$

Now you can calculate the average cash flow of the two in order to reach a combination.

$$CF_{\text{min}} = 0.5 \left[ \frac{I}{B} + \frac{I}{0.5L} \right] = \frac{I(2B + L)}{2BL}.$$  

If the minimal annual cash flows reach this level the following is true about the maximum PP:

$$PP_{\text{max}} = \frac{2BL}{(2B + L)}.$$  

---

Table 1 Internal rate of return (IRR) of investments reaching different types of payback criteria

<table>
<thead>
<tr>
<th>Type of demanded PP</th>
<th>Economic life, (L) years</th>
<th>Within half economic life (%)</th>
<th>Within 3 years (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>34.90</td>
<td>12.59</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>28.65</td>
<td>19.86</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>24.29</td>
<td>24.29</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>21.08</td>
<td>27.12</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>18.62</td>
<td>28.98</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>16.68</td>
<td>30.24</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>15.10</td>
<td>31.11</td>
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<tr>
<td>11</td>
<td>13.79</td>
<td>31.72</td>
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<tr>
<td>12</td>
<td>12.69</td>
<td>32.16</td>
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<td>13</td>
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<td>32.70</td>
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<td>9.63</td>
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<tr>
<td>19</td>
<td>8.15</td>
<td>33.19</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>7.75</td>
<td>33.23</td>
<td></td>
</tr>
</tbody>
</table>

*Constant yearly cash flows and negligible salvage values are assumed.*
As there is no obvious logic behind the choice of the constant $B$, it could just as well be replaced with another constant $K$ twice as big, e.g., $K = 2B$. Then the combination hurdle rate for the PP could simply be written as:

$$PP_{\text{max}}^\text{o} = KL/(K + L).$$  \hspace{1cm} (9)

By stating the maximum acceptable PP in this way, one reaches a fairly constant demanded minimum IRR regardless of the economic life, $L$. This can be analysed by looking at how the internal rate of return of investments just reaching the minimum return varies with $K$ and $L$. This is shown in Fig. 2. With a fixed value of $K$, IRR is fairly constant regardless of $L$. By varying $K$ the demanded return can be varied. A higher $K$-value means a lower demanded return.

When this type of combined payback method (CPB) was presented to some of the chief executive officers of one of the major groups in the Swedish food industry, where the “half life criterion” was used as a supplement to NPV, it was received with considerable enthusiasm, especially as their demanded cost of capital when using DCF methods was about 15%. Thus they could use the CPB method with $K = 10$, which made it quite easy to calculate the acceptable PP. For an investment with a 12 year economic life, a reasonable PP is thus $10 \times 12/(10 + 12) = 120/22 = 5.45$ years.

The CPB method could also be looked at in a more formal manner. First it should be noted that the analysis is based on the assumption of constant yearly cash flows. The expression of the maximum acceptable PB above could be seen as an approximation of the present value annuity factor. The theoretically correct way of calculating the maximum PP in a case with constant yearly cash flows is the following:

$$PP_{\text{max}}^\text{theo} = \frac{1 - (1 + c)^{-L}}{c}$$  \hspace{1cm} (10)

where $c$ is the cost of capital and $L$ the economic life as before (no salvage value is considered). Using the parameters above ($c = 15\%$ and $L = 12$ years) the theoretically correct value of the required payback period is thus 5.42 years, which is close to the approximation value 5.45 years.

This theoretical way of determining the maximum acceptable PP based on the corresponding present value annuity factor has been mentioned several times before, for instance in [16,17]. One problem is that you have to have a suitable table with annuity factors at hand when determining the
maximum acceptable PP. The CPP can be seen as an approximation of an annuity factor.

The CPB method has some limitations however. One problem is that it is not always possible to find a suitable integer value of the constant $K$. For instance, if the cost of capital had been 16% a $K$ value of 9.2 would be appropriate, which makes the decision rule somewhat more difficult to remember and to use. Another type of limitation is that the method is based on the assumption of constant yearly cash flows. If the cash flows vary over time, the method will be less useful. However, very often in evaluations of investments ex ante cash flows are often assumed to be constant, in spite of the fact that they, ex post, turn out to have considerable variations over time. Later we shall see how the CPB method can be developed to take variations in cash flows into account. However, some of the simplicity of the method is then lost. Finally the problem of ranking mutually exclusive
investments is not really solved by using the CPB method instead of the simple PB method. This can only be handled by means of the NPV method.

5. Consideration of tax effects

Another problem with the CPB method is that you do not get a demanded level that is totally independent of \( L \). As can be seen in Fig. 3 you get a curve shape. The method will make the heaviest demands on investments with economic lives in the middle region with a maximum at \( L \)-values of five or six years and thereafter somewhat lower demanded levels with increasing economic life. However, this downward sloping pattern is not necessarily an unjustified favouring of investments with long economic life. The tax laws in many countries allow investments to be depreciated within a shorter period than the economic life. For instance, in Sweden investments in machinery and equipment can be depreciated in five years even if the economic life is much longer. This is not true for investments in buildings, but such investments are rarely evaluated by means of PB. If the depreciation for tax purposes exceeds the decrease in value of an asset, one can create an interest-free tax credit, which decreases the cost of capital compared to the case when the book value for tax purposes equals the real value and all debt that will require interest. If this type of tax effect is taken into account, one should use a lower cost of capital for investments with long economic life. In Fig. 3 this is shown in the case that was discussed above. The theoretical derivations behind the calculations are summarised in Appendix A.

Thus, a “theoretical” calculation of maximum acceptable PB based on the expression above, using a constant cost of capital of 15\%, regardless of the economic life time does not necessarily mean a more correct calculation than a use of the presented combined PB criterion. If the economic life is 12 years, it would be correct to use nominal cost of capital of 14.03\% (lower curve) instead of 15\% if the effect of interest free the tax credit is taken into account.

From Fig. 3 it also becomes clear that in this case it would be more correct to use a value of the constant \( K \) of 10.3 rather than 10.0. This will in fact get more correct answers with the CPB method.
than by making a DCF calculation based on a 15% non-adjusted cost of capital.¹

To summarise, the CPB method has some interesting features as a rule of thumb and seems to have some important advantages compared to the simple PB method and the DPB method. Its tendency to demand somewhat lower minimum IRR from investments with a longer economic life is not necessarily a worse modelling of the economic environment than a method demanding the same minimum IRR of all investment regardless of their economic life.

Still, the method has some drawbacks. First, it is hard to find an economic interpretation of the constant $K$. One way to get some idea of this is to go back to Table 1. Looking at the declining values in the column, “Within half economic life”, the introduction of the constant $K = L$ is a way of “freezing” the declining pattern of the values in that column at such a value that will bring the desired level close to the cost of capital. If the cost of capital is 10%, the corresponding value in the middle column of Table 1 is found on the row where $L = 15$. This means that if $K = 15$, the CPB method is identical with the half-life model in just that point. Thus, choosing a $K$ value of 15 will keep the demanded minimum IRR at approximately the same level for investments with other $L$-values, especially those in the neighbourhood of 15.

A second drawback of the combination method is that it is somewhat more difficult to calculate the demanded payback level than with the simple PB method, especially if integer values of the constant $K$ cannot be used. In the case when the constant $K = 10$, which corresponds to a cost of capital of about 15.5%, this problem is kept under control. The proposed modified method can be seen as an improvement, if only to make a simple rule of thumb a little better.

6. Handling of decreasing annual cash flows

The CPB method as presented above is based on the assumption of constant yearly cash flows. As discussed above the cash flows tend to vary over time, although the exact pattern is seldom known at the time of the investment appraisal. However, a crude estimate of the cash flow pattern might be known. For instance, increasing competition and/or increasing maintenance cost may decrease cash flows over time. An assumption of constant yearly cash flows may then be less realistic.

In Fig. 4 two time patterns of cash flows are shown, first a case with constant annual cash flows of 20 during 10 years, then a case with cash flows that decrease by 10% annually. The values are chosen in such a manner that the NPV in both cases is 100 when using a 15% discount rate. If the initial investment outlay is 100, both cash flow streams will give a total investment with an NPV of 0 and an IRR of 15% (or rather 15.1% to be more precise).

In the case with constant cash flows, it would be correct to demand a PP of maximum 5 years (5.02 years to be more precise). The stream of constant cash flows above will just meet this requirement. However, the stream of decreasing cash flows will have a PP = 4.32 years, although its NPV is also 0. Obviously the acceptable PP will have to be shortened from 5 years to 4.3 years if the cash flows decrease by 10% per year. These effects can be analysed in a more formal manner which is shown below. First the parameters are summarised.

Parameters
Capital investment, $I$
Economic life, $L$
Annual net cash flow in year, $i \ CF_i$
Cost of capital, $c$
Annual change in $CF_i$, $q$ (typically $q < 0$)
$CF_i = CF_0(1 + q)^i$, cash flow in year $i$, where $CF_0$ is a constant
Secondary parameter, $r = (1 + c)/(1 + q) - 1$

A capital investment is considered to be acceptable if its NPV $\geq 0$. This can be stated as

$$\sum_{i=1}^{L} CF_i(1 + c)^{-i} - I \geq 0.$$  (11)

¹In opposition to this, it could be argued that one should use higher discount rates for investments with longer economic lives because of the upward sloping pattern of the so-called yield curve. Even if this is true, it does not seem to be common practice to use time adjusted cost of capital when using DCF methods. In the region of economic lives that are typical for investments, which are evaluated by means of PB (4-15 years), the yield curve is generally fairly flat.
This sum can be developed in the following manner:

\[
\sum_{i=1}^{L} CF_i (1 + c)^{-i}
\]

\[
= CF_0 \left[ \frac{(1 + q)}{(1 + c)} + \frac{(1 + q)^2}{(1 + c)^2} + \cdots + \frac{(1 + q)^L}{(1 + c)^L} \right].
\]

Now the parameter \( r \) can be used. The borderline case where the NPV = 0 is studied. Then the expression (11) will equal 0.

\[
\frac{CF_0}{r} \left( 1 - (1 + r)^{-L} \right) = I,
\]

\[
\frac{I}{CF_0} = 1 - (1 + r)^{-L}.
\]

In order to reach the same conclusion about the limit value of \( CF_0 \) the PP should be determined by

\[
\sum_{i=1}^{PP} CF_i = I.
\]

This sum can now be developed:

\[
\sum_{i=1}^{PP} CF_i = CF_0 \left[ (1 + q) + (1 + q)^2 + \cdots + (1 + q)^{PP} \right]
\]

\[
= CF_0 \left( 1 + q \right)^{PP+1} - (1 + q).
\]

This gives us the expression

\[
\frac{I}{CF_0} = \frac{(1 + q)^{PP+1} - (1 + q)}{q}.
\]

If these two expressions for \( I/CF_0 \) are combined, you will get the following:

\[
\frac{(1 + q)^{PP+1} - (1 + q)}{q} = 1 - \frac{(1 + r)^{-L}}{r}.
\]

From this you will reach

\[
PP = \ln \left[ \frac{1 - (1 + r)^{-L}}{r} \left( q + (1 + q) \right) \right] - 1.
\]

In the case with \( q = 0 \) we come back to the expression

\[
PP = \frac{1 - (1 + c)^{-L}}{c}.
\]

If a \( q \) value less than 0 is introduced, the maximum acceptable PP will have to be shortened. However, the sensitivity of PP for changes in \( q \) is moderate. Let us look at the case discussed above in Fig. 4 with the following parameter values:

\( L = 10 \) yr, \( c = 15\% \).
Two values of \( q \) are studied, \( q = 0\% \) and \( q = -10\% \). The two series of cash flow shown in Fig. 4 below will both have an NPV of 0 if the initial investment outlay is 100. The corresponding values of PP for different \( q \) values will be: \( \text{PP}(0\%) = 5.02 \text{ years} \) and \( \text{PP}(-10\%) = 4.32 \text{ years} \).

A refinement of the CPB method can be made by taking this type effect into account. As we are discussing different rules of thumb, some kind of simplification will be necessary. If the exact expression (16) above were to be used one could just as well make a proper NPV calculation. The goal here is only to get a general idea of the effects of the parameter \( q \) and to find some approximate ways of taking this into account.

The adjustment of the PP because of the fact that \( q \neq 0 \) could be determined. The limit value of PP is almost independent of the cost of capital, \( c \), but the needed reduction of PP to reach an adjusted PP (APP) is directly proportional to \( q \) and \( L \). The ratio of the APP as a percentage of the unadjusted PP (APP/PP) in relation to different values of \( L \) and using \( c \) as a parameter is shown in Fig. 5.

The next step is to study the relationship between APP/PP and \( q \). As shown in Fig. 6 there is approximately a linear relationship between the adjustment of the PP and the economic life \( L \). The adjustment is also linearly dependent of the yearly change in the cash flows, \( q \). If these two observations are combined, a total linear approximation can be found. An expression for the relative adjustment is sought, e.g., for \( (\text{APP} - \text{PP})/\text{PP} \) or \( \Delta \text{APP}/\text{PP} \). In the case with \( c = 15\% \) the following expression will give a reasonable approximation:

\[
\frac{\Delta \text{APP}}{\text{PP}} = 0.13Lq. \tag{18}
\]

In the previous example with \( L = 10 \) and \( q = -10\% \), the needed reduction in PP would be:

\[
\frac{(\text{APP} - \text{PP})}{\text{PP}} = 0.13 \times 10 \times (-0, 10) = -13\%.
\]

The original value was 5.02 years, thus giving the reduction with \( -0.13 \times 5.02 = -0.65 \) years, which was observed in the example (5.02 - 0.65 = 4.37). The deviation from the correct adjustment (4.32 - 5.02 = -0.70), can be explained by the fact that the approximation line in Fig. 5 lies above the true curve for high values of \( L \).

![Fig. 5. Adjusted PP (APP) in relation to unadjusted PP for different values of the economic life \( L \) and different values of the cost of capital. Thick line is a linear approximation (lap).](image-url)
In many situations those capital investments which are evaluated by means of PB methods tend to have a rather short economic life. Consider the following set of parameter values: 

\[ L = 6 \text{ years}, \quad c = 15\%, \quad q = -8\%. \]

Using \( K = 10 \) with CPB method the demanded PP based on the assumption of constant cash flows \((q = 0\%)\) would be \( \text{PP}(0\%) = 10 \times 6/(10 + 6) = 3.75 \) years. With \( q = -9\% \) and \( L = 6 \) years, this should be adjusted with: \( 0.13 \times 6 \times (-9\%) = -7.02\% \) to 3.49 years. Using exact calculations (16) in this case the corresponding theoretical values would be \( \text{PP} = 3.78 \) years in the case with \( q = 0\% \) and \( \text{PB} = 3.54 \) years when \( q = -9\% \). Thus, when using one decimal, the values are the same, \( \text{PP} = 3.8 \) years without adjustment and \( \text{APP} = 3.5 \) years with the adjustment.

In real evaluation situations it does not seem to be practical to adjust the PP for every individual investment but rather to make an adjustment corresponding to the average situation, e.g., for the average value of \( q \). Then it seems easier to adjust the constant \( K \) or in the more general case to adjust the discount rate, thus using a higher value than the cost of capital. This will be discussed below.

7. Adjustment of \( K \) for declining cash flows

Instead of adjusting the PP one could see what adjustment of \( K \) that would be needed when taking the \( L \) and \( q \) values into account compared with the case with \( q = 0 \). Thus we look for the value of \( \kappa(q) \) where \( \kappa(0) = K \). Using the approximation (18) above you will get

\[ \frac{KL}{K + L} \left(1 + 0.13Lq\right) = \frac{\kappa L}{\kappa + L}. \]  (19)

Solving for \( \kappa \) you will get

\[ \kappa = K \frac{1 + 0.13LqL}{1 - 0.13Kq}. \]  (20)

An expression for the relative adjustment is sought. An approximation of this is shown below:

\[ \frac{\Delta K}{K} = 0.115 \ q(K + L). \]  (21)

For instance with \( K = L = 10 \) and \( q = -10\% \), the relative adjustment of \( K \) will be \(-23\% \) thus giving \( \kappa = 7.7 \). Using this value will give \( \text{APP} = 7.7 \times 10/(7.7 + 10) = 4.35 \), which is similar to the value presented above.
8. Adjustment of the discount rate for declining cash flows

In Fig. 5 we saw that in a case with declining cash flows the limit PP has to be shortened compared to a case with constant yearly cash flows. In the example the limit PP had to be shortened from 5.02 years to 4.32 years. This could also be seen as a need for increasing the discount rate. In order to get a PV annuity factor of 4.32 in a case with \( L = 10 \) years, the discount rate has to be increased to 19.2%. In Fig. 7 the adjusted discount rates (adr) are shown in a case with an unadjusted discount rate, the cost of capital, \( c = 15\% \) for different combinations of values of the parameter \( q \) and the economic life \( L \).

The practical usefulness of Fig. 7 is rather limited as the adjusted discount rate is only useful in the determination of the limit PP by means of an annuity factor. It could also be used to determine an adjusted value of the constant \( K \) in Fig. 3. With a discount rate of 19.2% a corresponding \( K \) will be between 7 and 8. Earlier we estimated the adjusted \( K \) value to 7.7.

The discussion of the adjusted discount rate leads us to another important issue. When we discussed the effects of decreasing cash flows on the demanded PP, it was assumed that the declining cash flows were taken into account.

It was assumed that the decreasing values in the stream of cash flows, \( CF_i \) from \( i = 1 \) to \( i = PP \) were taken into account when calculating the PP. Another possibility is that only the initial cash flow value, \( CF_0 \), or maybe the estimated cash flow for the first year is taken into account and the decrease in cash flows is handled by shortening the demanded PP or by increasing the discount rate. This way of looking only at the first year cash flow

![Fig. 7. Adjusted discount rate (adr) in a case with an unadjusted cost of capital, \( c = 15\% \), for different values of the parameter \( q \) and the economic life \( L \).](image)
when calculating the PP — even when it is known that the future cash flows may differ — has been reported earlier [14] although it is not quite clear if it was a first year value or some type of estimated average that was being used.

If the PP is calculated as \( I/CF_0 \), the maximum acceptable PP obviously has to be shortened compared with the case when the decreasing values are taken into account. If the calculated PP is based on \( CF_0 \) the limit PP could simply be expressed as

\[
PP = \frac{I}{CF_0} \leq \frac{1 - (1 + r)^{-L}}{r}
\]

(22)

where \( r = (1 + c)/(1 + q) - 1 \) as before. In the case with \( c = 15\% \), \( q = -10\% \), \( r = 27.78\% \), and \( L = 10 \) yr, the PP calculated as above has to be shorter than 3.29 years. This situation could also be handled by using a lower value of the constant \( K \). With \( K = 5 \) the limit PP will be \( PP < 5 \times 10/(5 + 10) = 3.33 \) years.

9. Implications for practical investment evaluations

In practical evaluation situations the decision makers might know the initial investment outlay, \( I \), and the initial cash flow, \( CF_0 \), or maybe the first year cash flow, \( CF_1 \). They will also have an estimate of the cost of capital, \( c \). They might have some general experience of the time pattern and the duration of the cash flows, maybe for the relevant class of investments rather than for the specific investment. The knowledge about the cost of capital, the average time pattern, and the duration of the investments can be transformed into a \( K \) value. One more condition must be known: namely the way the PP is actually calculated, either as the time when the accumulated cash flows reach the initial investment outlay or simply as the ratio \( I/CF_0 \). In the example discussed above the value of \( K \) should be 7.7 in the first case and 5 in the second. In practice both ways of determining the PP seem to be used. Which of them that is preferable is not obvious and the conclusion may differ in relation to the degree of certainty in the estimations of the parameter \( q \). Anyway, it is important that the calculation procedures are being conducted consistently within a company in order to get a uniform evaluation of investments.

A final observation is that evaluations of capital investments by means of PB methods can be a reasonable way of handling the information that is available. Uncertainty about the time pattern and the duration of cash flows will make it difficult to make complete NPV calculations. Then PB methods can show a higher degree of robustness [18,11], in the sense that they can better handle uncertainty and variations in parameter values. With the modifications presented in this article some of the theoretical deficiencies of the simple PB method can be reduced by balancing a decision based on an absolute value of the time horizon and a PP directly related to the economic life of the investment.

Appendix A. Effects on the cost of capital from interest free tax credit

**Parameters**

- Inflation rate \( f \)
- Corporate tax rate \( t \)
- Cost of capital \( c \)
- Risk-free interest rate \( d \)
- Capital investment \( I \)
- Total assets \( TA \)
- Economic life \( L \)

In an enterprise in a stationary phase with in real terms constant yearly investments of \( I \), the total value of the assets, \( TA \), can be calculated as follows. As only fractions of the total assets are analysed the value of \( I \) can be left out or rather the fraction \( TA/I \) is studied.

\[
TA = \sum_{i=1}^{L} \frac{L + 1 - i}{L} (1 + f)^{1-i} = \frac{1 + f}{L} \left[ (L + 1) \sum_{i=1}^{L} (1 + f)^{-i} - \sum_{i=1}^{L} i(1 + f)^{-i} \right] = \frac{1 + f}{L} \left[ (L + 1) \frac{1 - (1 + f)^{-L}}{f} - \frac{1 + f}{f} \frac{1 - (1 + f)^{-L}}{f} + \frac{L}{f} (1 + f)^{-L} \right]
\]
The total value after maximum depreciation for tax purposes according to Swedish tax law can be calculated by using $L = 5$: 

$$
TA_{\text{tax}} = \frac{1 + f}{5f} \left[ 5 \frac{1 - (1 + f)^{-5}}{f} - \frac{1}{f} \right].
$$

Thus the interest-free tax credit $TC$ can be calculated by

$$
TC = \frac{t}{L} (TA - TA_{\text{tax}}).
$$

Finally the $TC$ as a fraction of the total assets is determined. By multiplying this with the borrowing rate you get the reduction of the weighted average cost of capital, $\Delta c$, due to the tax credit.

$$
\Delta c = d \frac{TC}{TA}.
$$

The following values were used in Fig. 3:

<table>
<thead>
<tr>
<th>Inflation rate</th>
<th>$f = 4%$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corporate tax rate</td>
<td>$t = 28%$</td>
</tr>
<tr>
<td>Interest rate</td>
<td>$d = 7%$</td>
</tr>
</tbody>
</table>

In the case with $L = 12$ years you get $\Delta c = 0.97\%$, thus reducing an unadjusted value of $c = 15.00\%$ to $14.03\%$ as shown in Fig. 3.

References