Chapter 5

Abandonment

5

Abandonment

5.1 INTRODUCTION

Basic Concepts and Terms

As discussed in Chapter 1, abandonment costs are the costs of abandoning wells and facilities and cleaning up and restoring the production site after production ends. They are also referred to as "decommissioning" or "site restoration" costs.

Although rules for funding abandonment take many forms, there are two basic kinds of abandonment regimes. One requires a single "lumpsum" payment at the end of the production. We term this payment an **abandonment payment**. For any given project, we will always express this in the singular. The abandonment payment can occur in the last year of economic production (or "commercial production" – we use the terms interchangeably) – or sometimes later, if there is a delay between this last year and the actual decommissioning activity.

The other kind of abandonment regime also requires a single abandonment payment to be made at the end of production, but requires – or permits – the payment to be funded in advance, by periodic contributions which the producer makes over the production period, before the actual abandonment payment is due. We term these periodic contributions **abandonment contributions**.

Avoid Double-Counting Cash Outflows

When modeling a regime in which there are no abandonment contributions, but rather only one lumpsum abandonment payment, the payment is counted as a cash outflow from the producer's perspective, and is discounted accordingly when determining project NPV.

In contrast, when modeling a regime in which abandonment contributions fund a later abandonment payment, it is important to bear in mind that – while we calculate both the contributions and the payment – we only count the periodic contributions as cash outflows. To count both the contributions and the payment would be double-counting:

- Once a producer has made an abandonment contribution to an account – either a normal bank account (or a purpose-specific escrow account, trust fund, bond, etc.) – the producer may no longer use it; it is no longer part of the producer's discretionary cash. Thus the dates when *contributions* are made are when the cash outflows, from the producer's perspective, occur; these contributions are what are discounted when calculating the producer's NPV.

- Whereas when the abandonment *payment* – which is made up of money to which the producer has already said goodbye – is made later, the payment does flow out of the account to pay the decommissioning contractor, but this is not an outflow from the producer's perspective, and is not discounted when calculating project NPV.

The only exceptions to these principles occur if, for whatever reason, the cumulative abandonment contributions either are too small to meet the actual abandonment costs, or exceed those costs. In these cases, adjustments that *do* constitute cashflows to the producer are necessary:

- If the abandonment contributions are too small, then the difference, to be made up at abandonment time, will be a cash outflow for the producer.

- If the abandonment contributions exceed requirements, then the difference will constitute a cash inflow for the producer in the form of cash returned, unless regulations state that those contributions are already assigned to the government to conduct the abandonment operations. Then, surplus funds may not return to the producer.

As the examples in this chapter show how abandonment contributions can be calibrated to ensure they match the amount needed for the abandonment payment, we do not treat these exceptional cases. But you should be aware of them. After all, our examples here are based on forecasts, which are inherently fallible.

How We Will Handle the Economic Limit in This Chapter

An abandonment payment occurs after economic production ends, which in turn depends on the economic limit, i.e., the last year in which production is economic. As we have seen in Chapter 1, determining the economic limit requires its own calculation (i.e., the calculation of the economic limit test, or "ELT"). Because in this chapter we want to concentrate on the mechanics of calculating abandonment funding, however, here **we will simply state the economic limit as an input assumption**. This is of course not sound practice for full economic models, but for these abandonment-focused illustrative models, it allows us to avoid unnecessary, distracting detail.

Thus in this chapter's models, you will see message boxes, with arrows pointing to input cells for the last economic production year, which say "normally this would be calculated," or words to this effect.

This will get our present lessons across, as the calculations we explain here depend on the economic limit date, not on whether that date is merely stated or properly calculated. (Just remember that when doing full modeling, the date does need to be properly calculated!)

5.2   LUMPSUM ABANDONMENT PAYMENTS

An example calculation of a lumpsum abandonment payment at the end of production, with no prior abandonment contributions, is shown in the file "Ch5_aband_lumpsum_w inflation.xls."

The basic strategy is as follows:

1. To use the economic life flag (ELF) to *time the abandonment payment*. Recall from Chapter 1 that the ELF is an expression of the economic limit, in the form of a row of annual 1s and 0s ("a binary flag"), where a 1 means the field is still economic and thus "alive," and a 0 means it is no longer economic and thus "dead."

2. To *adjust the size of the payment* according to an assumed inflation rate.

> Refer to the file "Ch5_aband_lumpsum_w inflation.xls," the Base Scenario of which is reproduced in **Figure 5.1**, found on page 1 of the file "Ch5_aband_supplement.pdf."

Our assumptions include:

- a production forecast (before considering the economic limit) in row 4;

- the economic limit in cell D5;

- whether the abandonment payment is paid in the same year as the last economic production year, or one year later (cell D7);

- the abandonment payment in Real 2015 $ mm (cell D8) – recall from Chapter 1 that this is the format in which analysts are most likely to receive abandonment cost estimates; and

- an inflation rate (cell D9), used to convert Real 2015 dollars into MOD ("money-of-the-day," or inflated) dollars.

In the Calculations section:

- The formulas in row 11 make the ELF a 1 in the years up to and including the last economic production year (cell D5, or 2021 in our Base Scenario example), and a 0 in the years thereafter. We have named the range F11:N11, "ELF".

- Post-ELF production in each year (row 13) equals pre-ELF production (row 4) times the ELF; this has the effect of truncating post-ELF production, in our example, to end in 2021.

- The timing of the abandonment payment is calculated in cell D14 as the sum of the last economic production year (cell D5) and any delay in making the abandonment payment (cell D7; or one year, in our example, meaning the payment will occur in 2022).

- The formulas in row 15 place the abandonment payment, in Real 2015 dollars (Real 2015 $50 mm in our example), in time according to the result in cell D14.

- The MOD dollar abandonment payment in row 17 (MOD $60.2 mm, in our example) is the inflated version of the results in row 15, calculated using a mid-year inflation index, as described in Section 1.2 of Chapter 1.

Split the screen so that the spinners which control the last production year, the abandonment payment delay factor and the inflation rate are visible at the top of the screen, and the interactive chart starting in row 27 (reproduced in Figure 5.2) is visible at the bottom. This will show you that the model is working as it should.
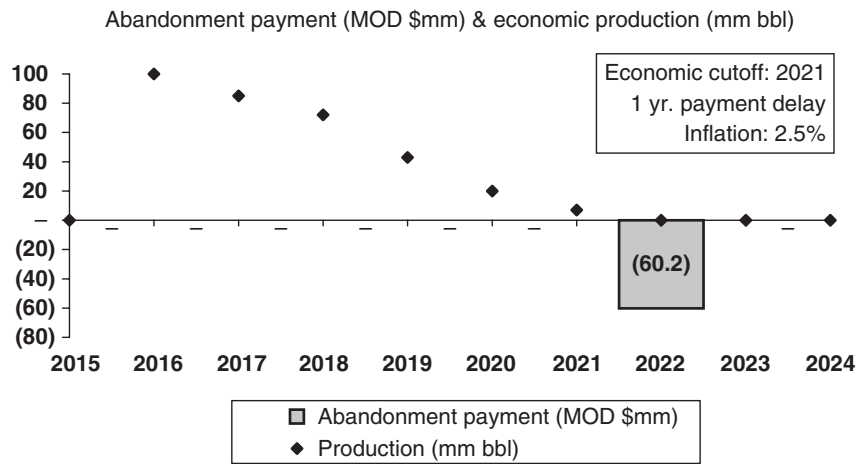
Figure 5.2   Basic lumpsum abandonment calculation, from the file "Ch5_aband_lumpsum_w infla-tion.xls"
Note: Reflects the Base Scenario settings.

(Note that the scale on the Y-axis (from −80 to 100) is in MOD $ mm when referring to the gray column, and is in mm bbl when referring to the black diamonds.)

Does production respond properly to changes in the economic limit? Does the payment timing? Does it make sense that the earlier the payment occurs, the lower its value is?

5.3   EQUAL ABANDONMENT CONTRIBUTIONS MADE OVER THE PRODUCTION PERIOD

As mentioned, producers are often required to fund the abandonment payment through periodic abandonment contributions, made prior to the actual decommissioning. According to one basic variant of this approach, the contributions must be the same size, and must be made each year of the economic production period.

It is important, in both this and the following sections, to clarify the term "production period." In an annual model, we define the **economic production period** as all years starting from the first year in which there is economic production, through the last year in which there is economic production, inclusive.

This might sound obvious, but we spell this out to emphasize that the economic production *period* is *not* defined simply as any period during which economic production occurs, because this definition would then exclude any intervening production "gap period(s)" during which there is no production, due to maintenance or some other interruption. (Granted, in an annual model, any year-long production gap(s) would be very unusual; nonetheless, it is good practice to make the model robust enough to handle them.)

This is important to get right because the number of abandonment contributions equals the number of years in the economic production *period*, not the number of years of economic production. For example, if the economic production period is 10 years, and includes one year of no production, there will be 10 equal abandonment contributions, not nine.

Calculation

> Refer to the file "Ch5_aband_eq pmnts over prod life.xls," the Base Scenario of which is reproduced in **Figure 5.3**, found on page 3 of the file "Ch5_aband_supplement.pdf."

As shown in Figure 5.3, the Assumptions section is the same as in the previous model. In the Calculations section, the basic strategy is:

- To use (as in the last example) the ELF (again, the economic life flag) to time the Real $ abandonment payment, thereby inflating it to MOD $.

- To define the economic production period, which allows us to:
  - divide the MOD $ value of the abandonment *payment* into the number of years in this period;
  - then use this to determine the number, timing and MOD $ value of equal annual abandonment *contributions*.

The steps shown in Figure 5.3 are as follows:

- The ELF and the post-ELF production profile (ending in 2021) are calculated straightforwardly in rows 10 and 12.

- Each of the annual cells in row 13 use the same formula to determine the <u>first year of the economic production period</u>.
  - For example, the formula for 2016 (cell G13) is

    =IF(AND(G12>0, SUM($E12:F12)=0), year, 0) .

  - This means that if production in 2016 (cell G12) is greater than 0, AND if the sum of production in all previous years – that is, the sum of cells $E12:F12 – equals 0, then the year corresponding to G12 is the first year of "non-zero" production; i.e. it is the year production starts.

    - When both conditions are met, the result of the formula is the corresponding year within the named range, year (cells F2:N2). Because both conditions are met in our example formula in cell G13, the answer in cell G13 is **2016**.

    - In each of the other annual cells in row 13, both conditions are never met simultaneously met, so the answer in each of these cells is 0.

○ Therefore, there will only one non-zero value in the annual cells of row 13, and this value will be the year of first production. This example's answer of **2016** is then "captured" in cell D13, with the formula =SUM(F13:N13) .

○ Note that the annual formulae in row 13 all refer to the blank cell E12. This is intentional. This cell should be kept blank.

- Cell D14 equates the last year of the economic production period to the last economic production year as defined in cell D5 (so, 2021), unless there is no economic production at all, in which case the last economic production year is defined as 0. The latter provision is there in case the model user carelessly changes the production assumptions in row 4 to end before the last economic assumption year in cell D5.

- The annual cells in row 15 create binary flags to show whether a given year falls within the economic production *period* (as distinct from showing each year of economic *production*; as mentioned above, we would not want the model to be "fooled" by any gaps in economic production). If the year is between the economic production period start and end years, inclusive, the flag is a 1, meaning the year is within the economic production period; otherwise it is a 0. We will call this formula the **Period-flag formula** . The period flags are then summed in cell D15 to give the number of years in the period (six years in this example).

- The timing of the abandonment payment and its conversion from Real 2015 $ to MOD $ are determined in rows 16–19, in the same way as in the example from Section 5.2.

- The MOD $ value of each equivalent annual abandonment contribution is calculated in cell D20. It is equal to the MOD $ value of the abandonment payment (cell D19), divided by the number of years in the economic production period. In our example, this is MOD $60.17 mm/ 6 = MOD $10.03 mm. (Note in cell D20, for example, the use of the Error-trap expression =IF(D15=0, 0, . . . to suppress error messages in case total economic production is 0.)

  ○ Note further that the abandonment *payment* delay factor of one year (cell D6) will not affect the *timing* of the annual abandonment *contributions* – these occur over each year of the economic production period, regardless of when the actual abandonment payment is made.

  ○ The delay factor, however, *will* affect the equal *value* of each annual abandonment *contribution*, because this value is based on the MOD $ value of the abandonment *payment*, which, due to inflation, will be lower in early years and higher in later years.

- The formulas in the annual cells in row 21 calculate the abandonment contributions as the value reached in cell D20, times the relevant year's economic production period flag (in row 15). The result in our example is that payments of MOD $10.03 mm are made between 2016 and 2021, inclusive.

- *Crucially*, note that the checksum formula in cell A21 ensures that the sum of the MOD $ abandonment contributions (cell D21) equals the MOD value of the abandonment payment (cell D17). Reaching that result is the point of the whole exercise!

Abandonment transactions (MOD $mm) & Economic production (mm bbl)
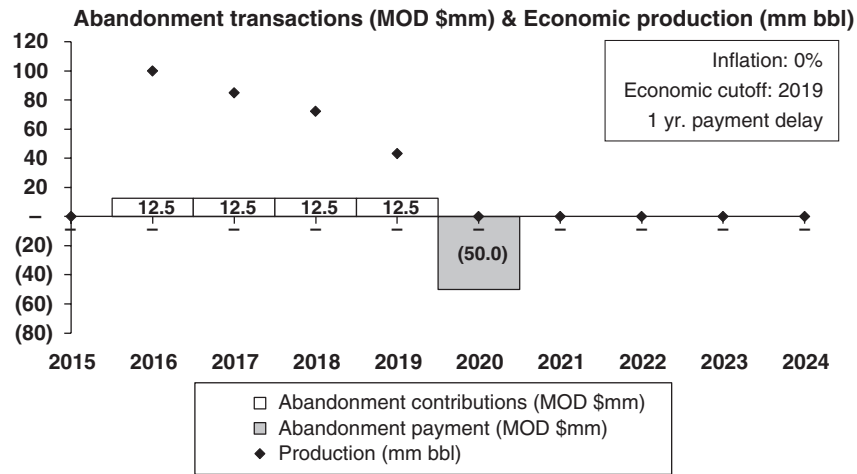
Figure 5.4 Implementing Step 5 (with economic cutoff set to 2019) in "Ch5_aband_eq pmnts over prod life.xls"

Visual Check

Arrange the screen so that rows 5–8 are visible, along with the chart starting in row 32, shown in Figure 5.4. (Note that only the white columns represent actual cash outflows from the producer's perspective, as discussed in the subsection "Avoid Double-Counting Cash Outflows," above.) Does the chart behave sensibly when you make the following cumulative changes?

1. Use the button in row 6 to show the Base Scenario. Scroll the economic limit (cell D5) from 2021 to 2016. (Are the absolute values of the two columns equivalent?)
2. Change the abandonment payment delay (cell D6) from 1 year to 0.
3. Set the economic cutoff to 2022.
4. Set the abandonment payment delay to 1.
5. Set inflation (cell D8) to 0%. These are now Real 2015 dollars. You can easily work out mentally that the abandonment contributions sum to the abandonment payment, when the economic cutoff year is set to 2020, 2019, 2017 or 2016.

Handling Cases with Prior Production, or When Forecasts Change

Be sure to account for any production years/abandonment contributions occurring prior to the period modeled. Just as such prior production was relevant to our calculation of fiscal mechanisms covered in Chapters 2 and 3, such as royalties and bonuses based on cumulative production, respectively, it matters here as well. This is because prior production determines the number of total years in the economic production period, thus influencing the size of each future annual contribution. Contributions already paid also influence the size of each future annual contribution. We will treat this soon in a new example.

Interpret the term "equal contributions" loosely. The size of each contribution equals the total abandonment payment (in MOD), divided by the number of years in the economic production period. This period, as the name suggests, is based on the economic (post-ELT) production forecast. Thus, in models where there is no prior production to account for (such as our last example), the producer must base the size of each annual contribution on its *forecast* of when the economic limit will kick in, triggering abandonment. In practice, this forecast will often change over the course of the field life, as more becomes known about actual costs and production capacity, as well as in response to the commodity price outlook. If the forecast of the abandonment date changes once production has started, then the annual contributions actually made will not be equivalent after all.

To illustrate, suppose that three years after a producer made the model shown in the last example, the producer decided that the economic limit would actually be in 2020, not 2021 as originally forecast. No other assumptions changed. On page 4 of the file, "Ch5_aband_supplement.pdf", Figure 5.5, from the file "mod_aband_02_eq pmnts over prod life_v07b_forecast changes.xls," shows how this new model, dated January 1, 2018, would look.

> Refer to the file "Ch5_aband_eq pmnts over prod life_forecast_changes.xls." Click the "Show Revised Base Scenario" button in row 8 to obtain the view reproduced in **Figure 5.5**, found on page 4 of the file "Ch5_aband_supplement.pdf."

As seen in the model, or in Figure 5.5:

- The years have been divided into two groups: History (columns F–H) and New forecast (columns I–N).

- Historic abandonment contributions have been value-pasted into cells F4:H4. Note that these match the forecasts made in cells F21:H21 of the previous model, as seen in Figure 5.3 (they were good forecasts).

- The inflation year numbers for the remaining forecast years (2018–2023) have been adjusted to reflect the new model date of January 1, 2018 in cells I5:N5.

- The economic limit, as mentioned, has been lowered from 2021 to 2020 (cell D7; provided you have clicked the "Show Revised Base Scenario" button in row 8).

- The remaining number of years (three) of the *forecast* production period are summed in cell D17.

- The rest of the model works exactly as before, except that the historic abandonment contributions in cells F4:H4 have been carried down to cells F23:H23. The forecast contributions (cells I23:N23) are still calculated as the value of the Real 2015 $ abandonment payment (inflated to 2021, when it will be made), divided by the number of remaining contributions to be made (i.e., the number of years remaining in the revised economic production life forecast). But now, they each equal MOD $11.49 mm, versus MOD $10.03 mm before.

- The important checksum in cell A23 shows that the sum of MOD abandonment contributions still matches the value of the MOD abandonment payment.

From row 23, you can see that the revised forecast contributions are equal to each other, but not to the historic contributions. Also, the total value of the MOD contributions (cell D23) falls to $54.4 mm from $60.2 in the old model, as the Real $ value of the abandonment payment is exposed to less inflation (due to the shorter time until the abandonment payment is made).[1]

Usually governments "forgive" such inequality of payments if the producer's reasons for revision appear reasonable, as governments are mainly concerned that the producer is making a good-faith, systematic effort to set aside enough money to fund the abandonment payment when that payment is actually required.

If the forecast of the abandonment date changes, then the only model in which the contributions are forecast to be equivalent would be the first model, before any revisions.

5.4   UNEQUAL ABANDONMENT CONTRIBUTIONS, BASED ON ANNUAL PRODUCTION AS A PERCENTAGE OF ULTIMATE PRODUCTION

Unlike the annual contributions we have just seen, annual contributions arising under this kind of abandonment funding regime, which we have seen used in Africa, are not equal. The contributions' value in a given year is based on that year's production, as a percentage of total economic production expected (i.e., forecast remaining reserves) over the life of the field, or **ultimate production**. This approach is sometimes referred to as the "**unit of production method**".

If, for example, a field's ultimate production is forecast to be 100 mm bbl (or mmb), the value of the abandonment payment is MOD $100 mm, and production in Year 1 is 10 mm bbl, the Year 1 abandonment contribution payment will be (8 mm bbl/100 mm bbl)*MOD $100 mm = 8%*MOD $100 mm = MOD $8 mm. Thus the more the production in a given year, the higher the annual contribution. If (as is typical) production starts high and then declines, annual contributions will do the same, leading to a "frontloading" of abandonment contributions in the early years. In terms of discounted cashflow, this is not favorable for the producer.

Calculation

The basic calculation strategy is:

- to determine the timing and thus the MOD $ value of the abandonment cost, as we have done before; and then

- to calculate the annual abandonment contribution for each year of economic production, as just described above.

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[1] Do *not*, incidentally, conclude from this that earlier abandonment payments are necessarily better from the producer's perspective than later ones, as we will discuss later.
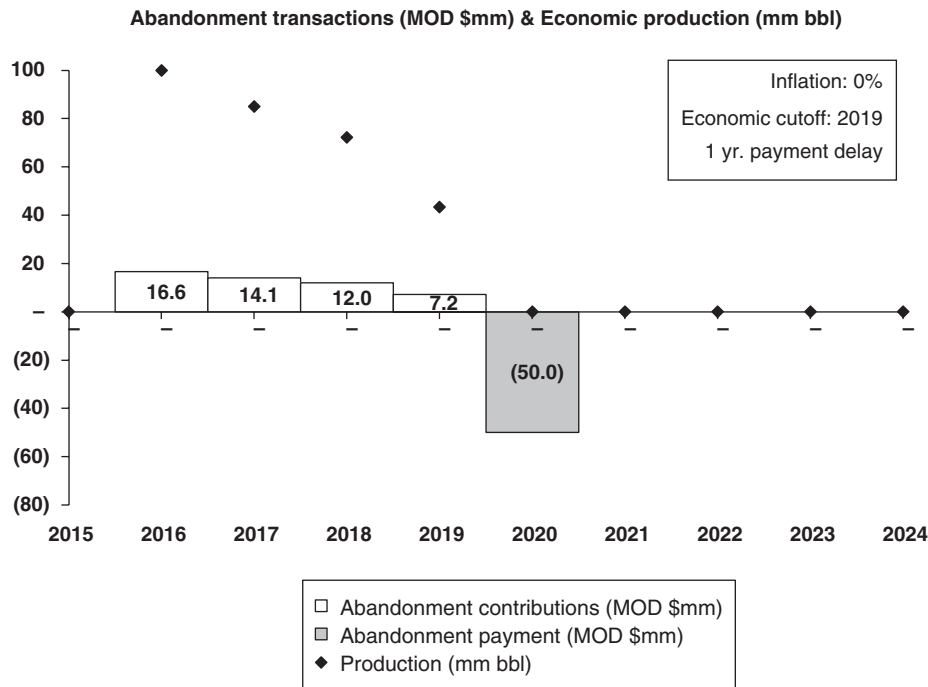
Figure 5.6   Frontloaded abandonment contributions, from the file "Ch5_aband_depletion_coeffs.xls," with model set as described below

Exercise

Try this one yourself. On the "Solution setup" sheet of the file "Ch5_aband_depletion_ coeffs.xls" are input assumptions. Set the economic cutoff to 2022, the abandonment payment delay to 0 years and inflation to 2.5%. Then fill in the Calculation section, which will cause results to show up in the chart we have prepared for you starting in row 22. Compare your solution for annual abandonment contributions against that provided on the "Solution" sheet.

Now set the economic cutoff to 2019, the payment delay to 1 year and the inflation rate to 0%. The chart should look like Figure 5.6, above. Compare it to Figure 5.5, which is based on the same assumptions. Note the marked "frontloading" of abandonment contributions in Figure 5.6.

5.5   EQUAL ABANDONMENT CONTRIBUTIONS, STARTING WHEN DEPLETION REACHES A SPECIFIED THRESHOLD

This method is based on **depletion**, which in a given year equals year-end cumulative production as a percentage of ultimate economic production. Equal annual contributions start once depletion passes a threshold, or "trigger" specified by legislation or contract.

Calculation

> Refer to the file "Ch5_aband_cuml_prod_trigger.xls," which is reproduced in **Figure 5.7**
> on page 5 of the file "Ch5_aband_supplement.pdf."

In our example file, the percentage depletion threshold, or "trigger" for abandonment payments
to start, is assumed to be 45% (cell D8, which is named "Cuml_prod_trigger").

Because the calculations shown in Figure 5.7 have many steps in common with the model
"Ch5_aband_eq pmnts over prod life.xls" from Section 5.3, we will only treat the new steps
here in detail:

- The economic production period is calculated in rows 14–16 using the first-period and
  period-flag formulas.

- Cumulative economic production in millions of barrels (row 17) is calculated in a way
  *designed to fall to and stay at 0 for each year after the end of the economic production
  period* (for reasons we will explain in a minute). For 2019 (cell J17), for example, the first part
  (in parentheses) of the formula $=(I17 + J13)*J16$ is the **Standard-accumulation formula**,
  i.e., the cumulative value of the prior year + the annual value of the present year, where, in
  this case, I17 and J13 are the cumulative and annual values for 2018 and 2019, respectively.
  The second part of the formula multiplies the result of the first part by the binary period flag
  in row 16, so that when the flag returns to 0 after production ends, cumulative production
  also returns a 0. We will call this modified formula the **Truncated-accumulation formula**.[2]

- Annual cumulative economic production as a percentage of the ultimate total is calculated
  in a straightforward way in row 18.

- The abandonment payment is timed and inflated in rows 19–22.

- Another binary flag – this one to show when abandonment contributions are due – is in
  row 23. For example, for 2019 (cell J23), this is calculated as $=IF(J18>=Cuml_prod_
  trigger, 1, 0)$, which means that if cumulative percentage production in 2019 (cell J18)
  equals or exceeds our specified 45% trigger, the answer is 1, meaning a contribution is due;
  otherwise, it is 0. In this case, cumulative percentage production is 92%, so the answer is 1.

- The size of each equal contribution is calculated in cell D24, as the MOD $mm abandonment
  payment, divided by the number of payments due. In this example, each payment is MOD
  $10.77 mm.

- Lastly, the annual abandonment contributions are calculated in row 25, as the size of any
  equal payment (cell D24) times the binary flag for the appropriate year in row 23. Thus,
  in this example, there are five payments of MOD $10.77 mm each, spanning 2017–2021,
  inclusive.

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[2] Truncated-accumulation formulas do not have to use a flag, but in this case we already had the flag in row 16 handy, so it is easy
enough to use it. Instead of a flag, you could multiply the standard accumulation part of the formula by anything that has the same
effect. For example, you could rewrite cell the J17 formula, $=(I17 + J13)*J16$, as $=(I17 + J13)*IF(J13>0, 1, 0)$.

Now for the reason why, in the second step, we used the truncated-accumulation formula. We did so to prevent paying out too many contributions. If we had *not* done so, and instead had used the standard-accumulation formula, then cumulative production for 2022–2023 would have been recorded in cells M17:N17 as 327 million barrels. This would have caused 2022–2023 cumulative production, as a percentage of ultimate production, to equal 100% in the row below. This in turn would have resulted in abandonment contributions being flagged as due in 2022–2023 (cells M23:N23) and therefore to be paid out as two "extra" contributions of MOD $10.7 mm each (cells M25:N25). So in this case, the truncated-accumulation formula prevented this error (saving the producer MOD $21.2 mm in the process).

Visual Check
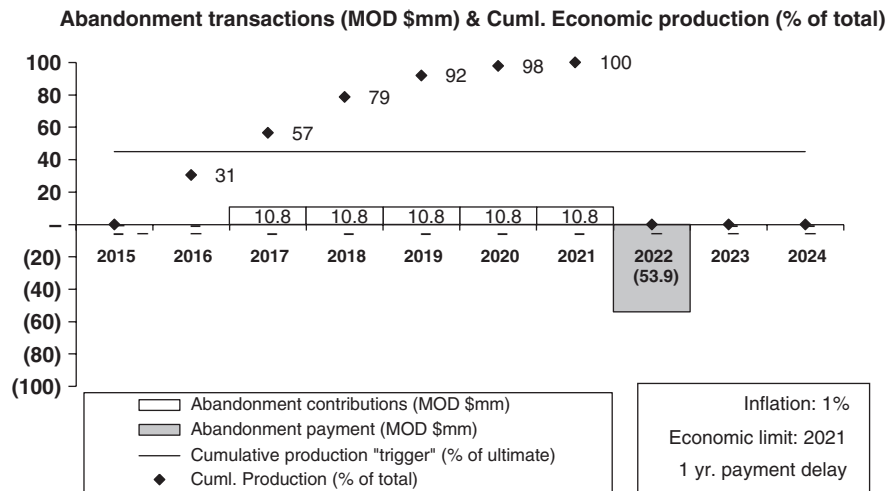
Figure 5.8   Results from depletion threshold-based abandonment regime, from the file "Ch5_aband_cuml_prod_trigger.xls"
Note: Results reflect the input assumptions shown in Figure 5.7.

The interactive chart starting on row 37 provides a visual check. It is reproduced in Figure 5.8.

Note that the labels on the Y-axis should be read:

- as MOD $ mm, with reference to the white abandonment contribution columns and the gray abandonment payment column;

- as percentages (with a range of 0–100%), with reference to:

  ○ the diamonds signifying cumulative production as a percentage of total ultimate production (again, bear in mind that once production stops, we make this return to 0%); and to

  ○ the black horizontal line showing the "trigger," expressed as a percentage of ultimate production, for abandonment payments to start. You will only see a white column below a diamond when the diamond is directly on, or higher than, the trigger line. Play with the trigger control (cell D8) while watching the chart to see this work.

5.6 EQUAL ABANDONMENT CONTRIBUTIONS STARTING FROM A SPECIFIED NUMBER OF PERIODS BEFORE ECONOMIC PRODUCTION ENDS

In Section 5.3 we saw an abandonment funding regime in which equal annual contributions are due each year of the entire economic production period. A common variant of this is to make equal annual contributions due only in a certain portion of those years. The portion is specified as the number of years before the end of economic production.

Calculation

The calculation is basically the same as in the Section 5.3 example model, with these additional steps:

- making sure the contributions start on time,

- while handling those cases when the economic production life is shorter than that implied by the specified contribution start year – for example, when the payments are to start in the seventh year of economic production, but economic production only lasts five years. In this context, we call this a **start-year conflict**.

Refer to the file **"Ch5_aband_eq pmnts_ over X yrs.xls"** which is reproduced in **Figure 5.9**, found on page 6 of the file "Ch5_aband_supplement.pdf."

The formulas in this model, from the start through row 16, and in rows 21–25, work the same as in the Section 5.3 model. Here is what is new this time:

- The number of years of economic production life remaining at the start of each year is calculated in the annual columns of row 18. In essence, this is just counting down the number of years of economic life. In each year, the economic production period flags (in the prior row) for the current and all following years are summed. You can see this, for example, in the first part of the formula for 2019 (cell J18), $\boxed{\text{=SUM(J17:\$N17)*J17}}$. The second part of the formula, i.e., multiplying by the production period flag in cell $\boxed{\text{J17}}$, makes the whole formula work like a truncated-accumulation formula (except that the accumulation works in reverse, starting with the highest value instead of ending with it), in order to prevent over-counting. For example, if in the formula for 2015 (cell F18) – a year before production begins – the sum was *not* multiplied by the flag of 0 in cell F17, the result would incorrectly read seven years.

- In cell D18, taking the maximum of the annual results in cells F18:N18 just serves as a check; the result needs to equal the number of years of the economic production period, as calculated in cell D17. The checksum in cell A18 tests if this is so.

- As mentioned, we need to account for any start-year conflicts. For example, the equal abandonment contributions are supposed to start when the economic production period has seven years left (cell $\boxed{\text{D8}}$), but the actual economic production life is only six years (cell $\boxed{\text{D17}}$). We have to choose the shorter of the two periods. So we calculate the number

of annual contributions due in cell D19 as $\boxed{\text{=MIN(D17, D8)}}$. We have named cell D19 "Number_of_contributions."

Analysis

Find this section in the file "Ch5_aband_sect5.6_analysis.pdf."

5.7 EQUAL ABANDONMENT CONTRIBUTIONS STARTING WHEN THE PRODUCER CHOOSES

Some countries require producers to make equal annual abandonment contributions over the economic production period, but allow the producer some discretion over when to start – for example, any year within the last seven years of economic production. Suppose a producer wants to know which year would be the best to start paying annual contributions. Here, we would define the "best" start year – all other things being equal – as the one which results in the lowest discounted value of the accumulated contributions.[3]

In light of material we have already covered, this is not hard to determine. Here is the basic solution strategy:

- Start with a model exactly like the one used in Section 5.6. Recall that this model lets the user set the abandonment contribution start year, in terms of the number of years before economic production ends. (Like that model, the one used here needs to be able to handle any start-year conflicts.)

- Once you have calculated the annual MOD contributions, discount them using the mid-year discounting method. This is done in rows 31–35 of our example model for this section, "Ch5_aband_eq pmnts_ over chosen X yrs.xls."

Exercise

Open the example model. Click the "Base Scenario" button in row 7. Note the assumptions for the economic cutoff year, the abandonment payment delay, the inflation rate and the discount rate (input in rows 6, 7, 11 and 12, respectively). Play with the spinner, which lets you determine when to start making annual abandonment contributions (cell D9) while watching the "Discounted value of abandonment contributions" result in cell D34, and the left chart which starts in cell B37.

As long as the discount rate is greater than 0%, the start year which results in the "best news" (i.e., the lowest present value of total contributions) will be the latest start year possible (i.e., the lowest value in cell D9). Thus in this example, the best course would be to make only one contribution, which would occur in 2021.

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[3] Be aware, however, that in a full discounted cashflow model – as opposed to the shortened, simplistic one used for illustrative purposes here – you would also have to consider any NPV impacts from the tax deductibility of abandonment payments or – in a production sharing regime, as introduced in Chapter 6 – the cost recoverability of such payments.

Discounted value of total abandonment contributions @ 10% disc. rate
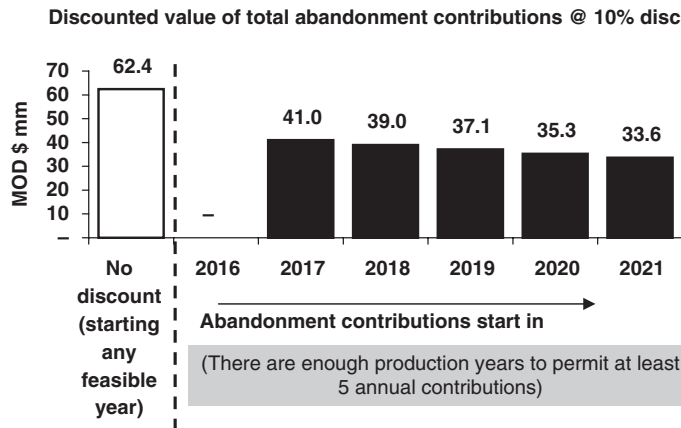
Figure 5.13   Base Scenario from the file "Ch5_aband_eq pmnts_ over chosen X yrs.xls"

This is because the fewer the number of years before the abandonment payment is due that you start making abandonment contributions, the later those contributions occur; and the later they occur, all other things being equal, the lower their discounted value will be.

Rather than scroll through the values in cell D9 while watching cell D34, you can use Excel's Data Table function (introduced in Chapter 1) to make a chart showing, all at once, the discounted value of total abandonment payments under different start-year scenarios. We have created this for you, starting in cell F37. It is shown in Figure 5.13, reflecting the results in the model when you select the "Base Scenario" button in row 7. Notice how, for example, the MOD $41.0 mm shown for 2017 matches the model's Base Scenario values in cells D29 and D34. The values in these two cells will match those shown for 2018 in the chart, if, for example, you change the value in cell D9 to 4.

(For the Data Table function to work, be sure Excel's calculation mode is set to automatic.)

Adjust the spinners in rows 6–12 to see whether the charts update sensibly. Note that there will be no black column or corresponding value label for years when there is not enough economic production life to permit abandonment contributions to start in that year.

Also, be aware that the gray caption at the bottom of the right chart can explain any start-year conflicts (here, the difference between the value in cell D9 and the number of black columns in Chart Y).

Can you guess/explain what happens when you vary:

- the economic cutoff (cell D6)?

- the abandonment payment delay (cell D7)?

- the number of abandonment contributions (cell D9)?

- the inflation and discount rates (cells D11:D12)?

The lesson from this short analysis is, as mentioned earlier, **that the time value of money means that producers often have a strong incentive to fund abandonment later rather than sooner, as this can minimize the discounted cost**.

5.8 MULTIPLE METHODS, USING WHICHEVER ONE MAKES ABANDONMENT CONTRIBUTIONS START EARLIER

Some regulators require more than one set of abandonment funding rules to be assessed. For example, we have seen one country with major offshore production which requires producers to model abandonment contributions two ways. The first way starts equal abandonment contributions a specified number of years before the abandonment payment, as shown in Section 5.6. We will call this **Method 1** in this section. The second method, **Method 2**, is based on a "depletion" regime of the kind covered in Section 5.5. The government requires the producer to apply whichever method results in earlier payments.

The modeling solution strategy is:

1. to model both methods, ignoring which will ultimately be applied; and then

2. to build in logic which chooses between the two.

This section continues in the file "Ch5_aband_sect5.8_analysis.pdf."

5.9 ABANDONMENT CONTRIBUTIONS WHICH EARN INTEREST (SINGLE RATE)

Our examples so far have ignored the fact that many countries allow abandonment contributions to earn and accrue interest from the time they are made until the abandonment payment occurs. This helps producers because, all else being equal, the accumulated interest provides a financial boost which lets them make smaller contributions to fund the same ultimate liability.

Here we provide an example that uses the basic abandonment funding regime from Section 5.3, in which equal contributions are made over the economic production period. Our example file for this section, "Ch5_aband_interest_single_rate.xls," is adapted from the Section 5.3 model, "Ch5_aband_eq pmnts over prod life.xls." Here is what is new in the present version, which you should set to the Base Scenario (cell K9).

- The abandonment payment delay (cell D7) can now extend up to three years. The cell has been named "Payment_delay."

- An assumed rate of interest, payable on abandonment contributions, is in cell D10, which has been named "Interest_rate". This single rate is assumed to be constant in all years. (It feeds what is essentially a duplicate of this cell (cell D24.))

- Determining the size of each annual contribution is now done with a more complex formula (cell D25) to be discussed soon.

- Other cells – which use formulas you have seen before – which have been named (to make the complex formula easier to understand) are "Number_of_contributions" (cell D19) and "Accumulated_funds_needed" (cell D22).

Calculation

The solution strategy consists of:

- using methods covered in Section 5.3 to calculate the timing and MOD value of the abandonment payment, and the number and timing of the MOD abandonment contributions;

- calculating the size of each equal annual abandonment contribution, so that, when taking into account interest earned on these contributions, total cumulative funds (contributions + interest) exactly match the value of the abandonment payment when it becomes due (this is where the complex formula comes in); and

- placing these contributions in time, and calculating the interest they earn.

> Refer to the file "Ch5_aband_interest_single_rate.xls," which is reproduced in **Figure 5.20**, found on page 7 of the file "Ch5_aband_supplement.pdf."

Using the PV Function to Find the Size of the Abandonment Contribution

The first formula used in this section's example model which we have not covered before is the most important and complicated one. It is in cell D25. It calculates the size of each equal abandonment contribution, taking into account that the contributions earn interest, and that the sum of the contributions plus accumulated interest must equal the abandonment payment. Here we call each such contribution a **levelized abandonment contribution**.

It is calculated in cell D25 as

> $= \text{IF(Number\_of\_contributions} = 0, 0,$
> $(\text{Accumulated\_funds\_needed}/(1 + \text{Interest\_rate})^{\wedge}(\text{Number\_of\_contributions}$
> $+ \text{Payment\_delay})/\text{PV(Interest\_rate, Number\_of\_contributions,} -1, , 0))$

Note the deliberate use of two commas near the end of the last expression, just before the zero. We shall explain this shortly.

Let us break this down into a few digestible steps. But before we do, be aware that while this long formula might be *challenging to understand*, the good news is that it is *easy to see that it works*. Skipping for a moment to the end result, we can see that, under our Base Scenario, the checksum formula in cell A30 shows a 0, which means that **the total funds (contributions + interest) accumulated at the abandonment payment date** (cell D30) equal MOD \$66.2 mm – **exactly match the amount needed at that date** (cell D22). This is the whole point. You will see that this match is achieved, no matter what variables you choose in cells D6:D10.

There are four distinct parts to this levelized abandonment contribution formula:

1. $\boxed{\text{=IF(Number\_of\_contributions=0, 0, ..}}$. This simply returns a zero value if the model calculates that no contributions are required.

2. $\boxed{\text{(Accumulated\_funds\_needed/(1 + Interest\_rate)}^{\wedge}\text{(Number\_of\_contributions + Payment\_}}$ $\boxed{\text{delay) . . .}}$. This is a discount formula which removes the interest payment contribution from the accumulated abandonment funds required. It does this by discounting the accumulated abandonment value, using the interest rate as the discount rate for the number of interest earning periods involved (in this case, nine: the six payment periods (or number of contributions), plus the three-year abandonment payment delay). This discounts the accumulated abandonment value back to its value at the start of the first contribution year, which is 2016, under the Base Scenario.

3. $\boxed{\text{PV(Interest\_rate, Number\_of\_contributions, -1, , 0)}}$ discounts the number of contributions using Excel's PV ("Present Value") function – the syntax of which is described below – using the interest rate as the discount rate. (You will soon see in this description that the two commas separating the −1 from the 0 are *not* typos, but rather are required by this Excel function's syntax. Note also that minus 1 in the third argument of the PV function ensures a positive number is returned by the calculation.)

4. Component 2 is divided by Component 3. Both numerator and denominator in this quotient need to be discounted by the same discount rate (i.e., the interest rate) to provide a levelized cost.

Notes

A. A **levelized cost** is the present value of a future cost or payment converted to equal periodic payments. Costs are usually levelized in real dollars (i.e., adjusted to remove the impact of inflation), which is what this formula achieves.

B. The Excel PV function uses this syntax:

　　　PV(Rate, Nper, Pmt, Fv, Type), where
　　　**Rate** is the interest rate per period.
　　　Nper is the total number of payment periods required.
　　　Pmt is the payment made each period (note that if Pmt is omitted, you must include the Fv argument).
　　　**Fv** is the future value. (Note that if Fv is omitted, as it is in the formula used here, you *must* include the Pmt argument.)
　　　Type is the number 0 or 1, which indicates when payments are due (0 means end of period; 1 means beginning of period). Do not get confused by the fact that we are assuming all payments occur at mid-year – in this case, the use of Type 0 means the *beginning* of the 12-month periods which start in the *middle* of the year when the abandonment payment is made.

　　Figure 5.21 is a screenshot which shows how these arguments work in our model under the Base Scenario. Note that "Invalid" next to the "Fv" box actually means that it has been omitted, as described above, and does not mean there is an error.

You can see this screenshot in the model by first selecting cell D25 and then, in the formula bar, placing the cursor after the "V" in "PV." Then (a) in Excel 2003, press the Function button f_x or, using the menu, go to Insert/Function; (b) in Excel 2007 and Excel 2010 go the Formulas tab/Insert Function f_x.

C. On the sheet, cells O44 to O46 show the calculation of Steps 2, 3 and 4 separately. Play with the spinners, particularly the interest rate and the economic limit, to satisfy yourself that you understand what the different components of this levelized cost formula are doing.
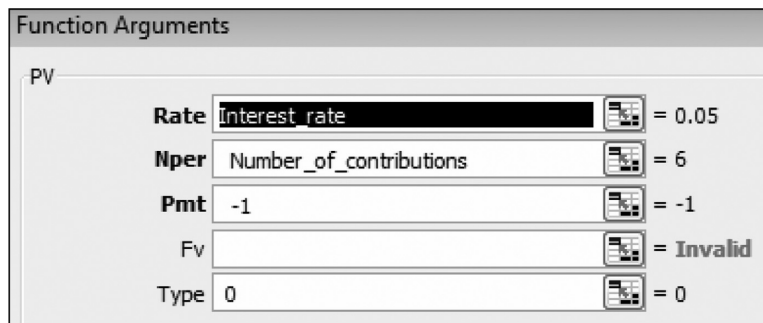
Figure 5.21   PV function arguments as used in cell D25, under the Base Scenario, of the file "Ch5_aband_interest_single_rate.xls"

Calculating the Contribution and Interest Payments

The last steps, thankfully, are pretty straightforward:

- Annual contributions (row 27) are assigned to the relevant years in the same way we have seen before – they equal the MOD $8.4 mm annual contribution in cell D25, times the corresponding annual binary economic production period flag (i.e., 1 or 0) in row 17 (which doubles here as a contribution payment flag for the relevant year). In our Base Scenario, example, this results in contributions of MOD $8.4 mm being made each year between 2016 and 2021, inclusive, and no contributions in the other years.

- Interest payments are calculated as follows, **taking as an example 2020 (cell K28)**, which uses the formula =IF(year>$D18, 0, Interest_rate*J29) :

  - Interest payments continue up to and including the year of the abandonment payment, which can be some years after the last abandonment contribution is made, depending on the delay factor (cell D7). Therefore the first part of the formula says that if the year of 2020 is after the abandonment payment year of 2024 (cell D18), the answer is 0. This is not the case, so the answer is not 0.

  - In any given year, interest payments are calculated as a percentage of the prior year's end balance of accumulated funds. Thus, in our example, the second part of the formula says that if the year of 2020 is before, or is the same year as, the abandonment payment year

of 2024 specified in cell $\boxed{\text{D18}}$ – which is the case here – then the answer for 2020 is the $\boxed{\text{Interest\_rate}}$ (named cell D24) of 5%, times the balance ending in the previous year of 2019 (cell $\boxed{\text{J29}}$). This balance is MOD \$36.2 mm. So in this example, the answer for 2020 in cell K28 is 5% × MOD \$36.2 mm = **MOD \$1.8 mm.**

- A given year's end balance, in turn, is cumulative, calculated as the present year's contribution and interest, plus the prior year's end balance. Thus, for example, the cumulative 2019 balance which acts as the base for the next year's interest payment is calculated, in cell J29, as $\boxed{\text{=IF(year > \$D18, 0, J27+J28+I29)}}$. The second part of the formula sums – when the year is before, or is the same as, the abandonment payment year of 2024 found in cell $\boxed{\text{D18}}$ – the items just mentioned, i.e., the present year's contribution in cell $\boxed{\text{J27}}$, the present year's interest in cell $\boxed{\text{J28}}$, and the prior year's end balance in cell $\boxed{\text{I29}}$. The first part of the formula stops interest from accumulating after the year when the abandonment payment is made – in this case, in 2024 (again, found in cell $\boxed{\text{D18}}$).

Reminder: ask about tax implications

You should always ascertain whether (a) interest earned on abandonment contributions is counted as revenue for income tax purposes, and (b) whether abandonment contributions are income tax deductible (they usually are).

Visual Check

Figure 5.22 shows the chart found starting row 44 of the file. There will be both stacked columns and a dashed line each year, up to and including the year of the abandonment payment. Note that the total height of the stacked column (i.e., cumulative abandonment contributions + cumulative interest = total cumulative funds available) equals the dashed line in the last
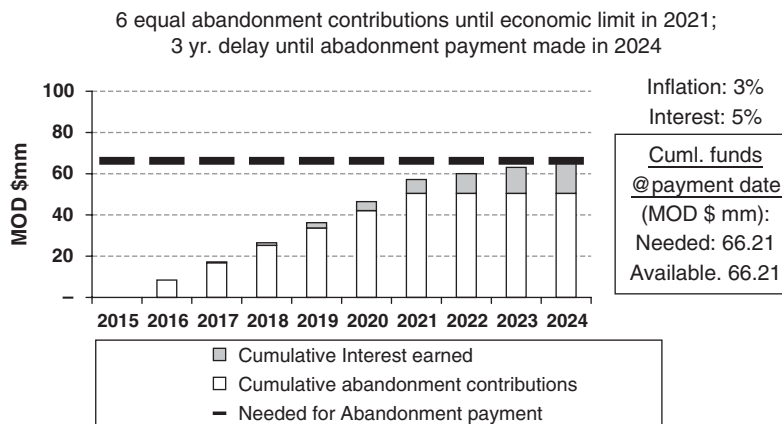
Figure 5.22   Base Scenario from "Ch5_aband_interest_single_rate.xls"

year. This is an important check that the model works. So are the matching "Needed" and "Available" values in the boxed caption on the right side of the chart.

Split the screen and, starting with the Base Scenario (use the button in row 8), play with the inputs while watching the chart and the levelized cost components (cells O42 to O44). Raise the interest rate (cell D10) to 10%. The total height of the stacked columns does not change, but, appropriately, the interest portion grows while the abandonment contributions shrink. This is because higher interest earned means lower contributions are needed to reach the target (i.e., the level of total funds needed when the abandonment payment is due).

Be sure you understand the effect on the chart of other changes, such as a change in the economic cutoff, the payment delay and the inflation rate.

Exercise

Because calculating the equally sized abandonment contributions is somewhat tricky, in that it involves a complex levelized cost formula, we have given you a practice example in the file "Ch5_aband_cuml_prod_trigger_exercise.xls," which is based on the model from Section 5.5. Assumptions and a chart are already in place on the "Setup" sheet. Have a try at filling in the blanks, and compare your answers to those on the "Solutions" sheet.

5.10   ABANDONMENT CONTRIBUTIONS WHICH EARN INTEREST (VARIABLE RATES)

Models like the last one assume, for convenience and simplicity, that the interest earned on abandonment contributions is the same every year. But if the analyst has a view of how interest rates will change over time, a more flexible model is needed. The one presented in this section accounts for variable interest rates, i.e., a different rate for each year.

This section continues in the file "Ch5_aband_sect5.10_analysis.pdf," which concludes the chapter.