Essentials of Financial Management

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8
An introduction to futures trading and hedging using futures

8.1 Introduction to futures

In section 7.2 we covered forward contracts that allowed a company to remove exchange-rate risk by agreeing a price now for delivery (or receipt) in the future. These contracts are traded over the counter and are a private transaction between the company and the bank. Now imagine if a company had agreed to buy a currency at a certain price and the exchange rate had moved in an advantageous direction. The forward contract could be considered to have value, but it is impossible to release this value. Futures contracts solve this problem.

A futures contract is a “marketable” forward contract, with marketability provided through futures exchanges that list hundreds of standardised contracts, establish trading rules, and provide clearing houses to guarantee and intermediate contracts. Futures contracts, like forward contracts, are a binding agreement to buy or sell an underlying asset at a specified date in the future. However, they primarily differ from forward contracts in that (i) the agreement can be sold and (ii) futures contracts are available on a much wider array of assets.

Futures contracts are traded on a centrally regulated exchange, with every negotiated price being “heard” by other traders. Traditionally, futures were traded via open outcry but more
recently there has been a shift to electronic trading. In fact, on 2 July 2015, the leading futures exchange in the world, the Chicago Mercantile Exchange (CME), switched exclusively to electronic trading as a consequence of open outcry futures volumes declining to 1 per cent of daily futures volume.

### 8.2 Futures positions

In a long futures position, you agree to buy the contract’s underlying asset at a specified price, with payment and delivery to occur on the expiration date (also referred to as the delivery date). In a short position, you agree to sell an asset at a specific price, with delivery and payment occurring at expiration. Thus far this sounds very similar to a forward contract. However, the real attraction of futures contracts over forward contracts is the ease of closing out a position. In order to close out a futures position, you simply need to do the reverse of whatever you did to get in to it. If you are long in a contract, then going short on the same contract (at the same exchange) will “cancel the contract”. If you are short then going long will “cancel the position”. Of course, the promises to sell and the promises to buy are likely to have been made at different prices so there will be a positive or negative cash flow determined by the relative prices. If you stop a futures contract prior to the end of trading on the last trade date, you are not obliged to buy or deliver anything.

Futures contracts can be used to speculate or to remove risk (referred to as hedging). When you speculate, you instigate a futures trade that will profit from your future market view. That is, if you think the market will rise you go long (buy) and if you think the market will fall you go short (sell). Alternatively, imagine that you would suffer some loss if the market fell. You could also go short on the futures to cover this risk. So, if the market falls you suffer a loss on the spot sale but gain on the future. This is referred to as hedging. Of course, a corporation could suffer a loss if the market rises, in which case they could take a long position on futures to cover this risk. Again, the loss would be offset by a gain on the future.

At the time of writing, the data for gold for the available contracts were:

<table>
<thead>
<tr>
<th>Month</th>
<th>Last</th>
<th>Prior settle</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec 2015</td>
<td>1062.4</td>
<td>1064.7</td>
<td>104</td>
</tr>
<tr>
<td>Jan 2016</td>
<td>1061.6</td>
<td>1063.7</td>
<td>296</td>
</tr>
<tr>
<td>Feb 2016</td>
<td>1061.5</td>
<td>1063.4</td>
<td>88,528</td>
</tr>
<tr>
<td>April 2016</td>
<td>1062.0</td>
<td>1064.1</td>
<td>1,090</td>
</tr>
<tr>
<td>June 2016</td>
<td>1062.2</td>
<td>1064.7</td>
<td>756</td>
</tr>
</tbody>
</table>
That is, trading takes place in the current month (December 2015), the next two calendar months (January and February 2016) and any April and any June.

Hence if you went long on the December 2015 contract at a price of $1,062.4 per troy ounce, you would acquire the obligation to buy 100 troy ounces of gold on the delivery date. If you went short you would acquire the obligation to sell 100 troy ounces of gold (of minimum 995 fineness) at a price of $1,062.4 per troy ounce by the delivery date. Note that the largest volume is for the contract within the February, April, August and October cycle.

The furthest contract maturity in December 2015 was for the contract expiring in December 2021, that is, 72 months (6 years) away.

8.3 Delivery

A final feature of futures contracts to be considered is the delivery (or settlement) process. Most open futures positions are closed out before delivery by taking out an offsetting position (e.g. the seller of a contract buys an equivalent position), but the delivery process is important in ensuring that the futures price converges on the spot price on the delivery date.

If it were not for the possibility of physical delivery of the underlying cash market good by the seller of the futures contract to the buyer, there would be no mechanism to guarantee convergence of futures and spot prices. For example, at any time prior to expiration, the futures price is merely a promise to do something in the future, but on the day the contract expires it is no longer a promise to do something in the future but to do something that day.

Example

If the spot price of gold is $1,250 per troy ounce and the futures price, for delivery in three months, is $1,300 per troy ounce, it is tempting to think that an investor could buy gold in the spot market now, and simultaneously enter into a short futures position to sell the gold at the higher price and realise a profit of $50 per troy ounce. However, the investor would need to have the cash available to purchase the gold in the spot market, thus forgoing interest (opportunity cost) and would then need to store, insure and ship the gold to the required location to fulfil the terms of the futures contract. All of these costs, aside from the delivery cost, are proportional to time and will eat into, if not eliminate, any potential profit. However, if these prices existed on the delivery date of the contract then only the shipping costs would remain, and these would likely to be small relative to the size of the transaction as a whole.
8.4 Minimum performance bond requirements

Consider two investors who have differing views on the future direction of the price of corn. Investor A believes that the price of corn will rise and instigates a long position of 10 contracts. Investor B believes that the price of corn will fall and instigates a short position of 10 contracts. The face value of each contract is 5,000 bushels.

It would be rather clumsy if investor A had to deal directly with investor B, since if either investor wished to close the position before the other, they would have to establish an offsetting position with a third investor. To overcome this, futures exchanges use clearing houses that guarantee each contract and act as an intermediary by breaking up each contract after the trade has been instigated.

If in the example above the corn futures positions are established at 350 cents per bushel and the price moved to 400 cents per bushel, then the profit/loss facing investor A and B would be:

\[
\text{Investor A: } 10 \times 5,000 \times \frac{400 - 350}{100} = +$25,000 \\
\text{Investor B: } -10 \times 5,000 \times \frac{400 - 350}{100} = -$25,000
\]

It follows that investor A’s receiving their profit is dependent upon investor B. In order to guarantee fulfilment of these obligations, futures traders are required to deposit a performance bond, more commonly known as margin. There are three different types of margin: initial margin, maintenance margin and variation margin. The initial margin is an amount, per contract, that must be deposited when a futures contract is instigated.

At the end of each day, the profits/losses for each futures position are calculated. This in turn will change the balance of the margin account. The process of calculating the daily profit or loss on a futures position is known as “marking to market”. If you have gone long (bought) a futures contract at a price \( P(0) \), then at the end of the day there will be a positive or negative cash flow to your account in the amount of:

\[
[P(1)-P(0)] \times \text{face value of the contract}
\]

where \( P(1) \) is the settlement price at the end of the trading day.

If you go short (sell), the cash flows are the reverse of those above.

Margin requirements are in place to protect each counterpart in a futures contract, and logically they vary with the volatility of the underlying asset. As of 3 November 2017, the maintenance margin on corn futures, traded on the Chicago Mercantile Exchange (CME), was US$750 per contract. It is convention at the CME to set the initial margin at 110% for speculators and 100% for hedgers.

In the corn futures example above, both investors, as speculators, would need to deposit:

\[
10 \times 1.1 \times $750 = $8,250
\]
If, via the marking to market process, the margin account falls below the maintenance margin level, then investors are required to top the margin account up to the initial margin level. The amount of cash paid is referred to as variation margin.

Each corn contract is for 5,000 bushels, which at 350 cents per bushel equates to $17,500. With initial margin set at $850, for speculators, this makes the initial margin equal to about 5%, which makes speculation using futures extremely attractive.

Example

Assume you are a speculator and on 2 October 2017 you go long (i.e. buy) ten December 2017 gold futures contracts at an opening price of $1,275.8 per troy ounce. Each contract has a face value of 100 troy ounces. There is an initial margin of $4,900 per contract.

Over the next few days the settlement prices are:
- 3 October – $1,274.6 per troy ounce
- 4 October – $1,277.5 per troy ounce
- 5 October – $1,270.6 per troy ounce
- 6 October – $1,278.9 per troy ounce

On 9 October you close the position at $1,284.6 per troy ounce.

What is the daily profit/loss and the total profit from 3 to 9 October? Would the investor be required to pay variation margin?

<table>
<thead>
<tr>
<th>Date</th>
<th>Price</th>
<th>P/L</th>
<th>Margin a/c</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/10/17</td>
<td>$1,275.80</td>
<td>$53,900.00</td>
<td></td>
</tr>
<tr>
<td>3/10/17</td>
<td>$1,274.60</td>
<td>-$1,200.00</td>
<td>$52,700.00</td>
</tr>
<tr>
<td>4/10/17</td>
<td>$1,277.50</td>
<td>$2,900.00</td>
<td>$55,600.00</td>
</tr>
<tr>
<td>5/10/17</td>
<td>$1,270.60</td>
<td>-$6,900.00</td>
<td>$48,700.00</td>
</tr>
<tr>
<td>6/10/17</td>
<td>$1,278.90</td>
<td>$8,300.00</td>
<td>$57,000.00</td>
</tr>
<tr>
<td>9/10/17</td>
<td>$1,284.60</td>
<td>$5,700.00</td>
<td>$62,700.00</td>
</tr>
</tbody>
</table>

$8,800.00

Due to the accumulated losses, the margin account, before any variation margin payments, would fall below the maintenance margin level at the end of 5 October 2017. The investor would then need to pay $5,200 of variation margin on 5 October 2017.
Accumulated profit can be found using the initial price and the last price:

\[ 10 \times 100 \times \left( \$1,284.60 - \$1,275.80 \right) = \$8,800. \]

Note the final margin balance equals the initial margin plus accumulated profit and loss plus variation margin:

\[ \$53,900 + \$8,800 + \$5,200 = \$67,900 \]

The spreadsheet for this exercise can be found [here](#). Please ensure you click on Section 8 and the 8.4 tab at the bottom of the spreadsheet.

### 8.5 Hedging with futures contracts

Futures contracts provide companies with the opportunity to remove the risk associated with a rise in input costs or a decrease in revenue.

For example, a company that is exposed to a rise in the price of raw materials could use futures contracts to remove this risk. This would be referred to as a long hedge. In a long hedge, the company takes a long position in the futures contract and, on the assumption that the spot price and the futures prices are positively correlated, as the spot price rises, and hence the cost of the raw materials, the futures price will also rise. If the hedge is successful, then the profit from the long futures position will offset the increase in the cost of the raw materials.

A company that is exposed to a fall in revenue, associated with a decline in the selling price of an asset in the spot market, could also use futures contracts to remove risk. This would be referred to as a short hedge. In a short hedge, the company takes a short position in the futures contract and as the spot price falls, the futures price will also fall. If the hedge is successful, then the profit from the short futures position will offset the decrease in revenue from selling the asset in the spot market.
In both long hedges and short hedges, if the underlying movement in the asset price is favourable, then the reduced costs or increased revenue will be cancelled out by a loss on the futures position.

In a long hedge, any increased costs (and hence losses) from buying at the spot price would be offset by a profit on the futures position. However, any reduced costs, resulting from a favourable movement in the spot price, would be offset by a loss on the futures position.

In a short hedge, any reduced revenue (and hence losses) from selling at the spot price would be offset by a profit on the futures position. However, any increased revenue, resulting from a favourable movement in the spot price, would be offset by a loss on the futures position.

**Example**

A classic example of exposure to a rise in the price of a raw material is an oil refinery. Oil refineries process crude oil into products such as heating oil and kerosene. Crude oil can therefore be considered as an input to an oil refinery’s production process and, as with any input, the company will wish to avoid the risk of a price rise. One of the most heavily traded futures contracts are crude oil futures and therefore an oil refinery can instigate a long hedge, whereby if the price of crude oil goes up in the spot market, the price of crude oil futures will also rise and the profit from the futures position will offset the rise in the input costs of crude oil. However, if the spot price of crude oil falls, the benefit from this favourable movement will be offset by a loss on the futures position.
Consider the case of an oil refinery that anticipates purchasing 100,000 barrels of crude oil in December. Crude oil futures traded on the CME have a face value of 1,000 barrels. Therefore, the oil refinery would need to instigate a long hedge comprising of a long position in 100 December futures contracts.

In order to hedge this risk, the oil refinery purchases 100 December 2017 crude oil futures contracts at a price of $49.92 per barrel. The mechanics of the hedge is that any increased (decreased) costs incurred in buying the 100,000 barrels of oil at the spot price will be offset by a profit (loss) on the futures position. If we assume (i) that the futures trade and the spot purchase are two separate transactions and (ii) that the spot and futures prices are equal on the expiry of the option, then we arrive at the following outcomes.

<table>
<thead>
<tr>
<th>Exposure = 100,000 barrels</th>
<th>FV = 1,000 barrels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N = 100</strong></td>
<td><strong>F0 = $49.92</strong></td>
</tr>
<tr>
<td>Spot price $40.00</td>
<td>$45.00</td>
</tr>
<tr>
<td>Futures price $40.00</td>
<td>$45.00</td>
</tr>
<tr>
<td>Spot cost $4,000,000</td>
<td>$4,500,000</td>
</tr>
<tr>
<td>Futures P/L $992,000</td>
<td>$492,000</td>
</tr>
<tr>
<td>Net cost $4,992,000</td>
<td>$4,992,000</td>
</tr>
<tr>
<td>Net cost (per barrel) $49.92</td>
<td>$49.92</td>
</tr>
</tbody>
</table>

Thus, if the price of crude oil on the spot market is $60/bl at the delivery date, the refinery would pay $60/bl and make a profit of $10.08/bl by closing out the futures position, representing a total cost per barrel of $49.92 ($60 – $10.08). But if the price of crude oil is $40/bl, the refinery would pay $40/bl but would make a loss of $9.92 by closing out the futures position, representing a total cost per barrel of $49.92 ($40 + $9.92). Therefore, regardless of the spot price, the refinery pays $49.92/bl.

The spreadsheet for this exercise can be found [here](#). Please ensure you click on Section 8 and the 8.5a tab at the bottom of the spreadsheet.

**Example**

Consider the case of a wheat farmer who anticipates selling 50,000 bushels of wheat in March. The farmer’s worry is obviously that the price of wheat will continue to fall below its current level of 461 cents per bushel. With wheat futures listed on the CME, the farmer can minimise price risk by taking a short position in the March wheat futures contract. With the standard size
on wheat futures of 5,000 bushels, the farmer would need to go short in 10 March wheat futures contracts to hedge the March spot sale.

In order to hedge this risk, the farmer sells 10 March 2018 wheat futures contracts at a price of 461 cents per bushel. The mechanics of the hedge is that any reduced (increased) revenue incurred in selling the 50,000 bushels of wheat at the spot price will be offset by a profit (loss) on the futures position. If we assume (i) that the futures trade and the spot purchase are two separate transactions and (ii) that the spot and futures prices are equal on the expiry of the option, then we arrive at the following outcomes.

<table>
<thead>
<tr>
<th>Exposure = 50,000 bushels</th>
<th>FV = 5,000 bushels</th>
</tr>
</thead>
<tbody>
<tr>
<td>N = 10</td>
<td>F0 = 461 cents per bushel</td>
</tr>
<tr>
<td>Spot price</td>
<td>340</td>
</tr>
<tr>
<td>Futures price</td>
<td>340</td>
</tr>
<tr>
<td>Spot revenue</td>
<td>$170,000</td>
</tr>
<tr>
<td>Futures P/L</td>
<td>$60,500</td>
</tr>
<tr>
<td>Net revenue</td>
<td>$230,500</td>
</tr>
<tr>
<td>Net revenue (per bushel)</td>
<td>$4.61</td>
</tr>
</tbody>
</table>

The spreadsheet for this exercise can be found [here](#). Please ensure you click on Section 8 and the 8.5b tab at the bottom of the spreadsheet.

We can see then that if the farmer receives only $3.40/bu for each bushel, he or she realises a profit on the futures position of $1.21/bu, resulting in net receipts of $4.61/bu. When the farmer receives $5.80, the futures position realises a loss of $1.19/bu, resulting in net receipts of $4.61/bu. Thus, regardless of the spot price, the farmer receives $4.61 per bushel.

The long hedge and short hedge examples provided here are almost too good to be true, as there is a guaranteed cost, in the case of the long hedge, or a guaranteed revenue, in the case of the short hedge, regardless of the resultant spot price. In practice, hedges are less than perfect. Quantity risk results from the standardisation of futures contracts. For example, if the oil refinery needs to purchase 105,000 barrels of crude oil, then it would either need to purchase 100 contracts, thereby leaving 5,000 barrels unhedged, or purchase 101 contracts and be over-hedged. The preceding examples relied upon the spot and futures prices moving in perfect correlation. In reality this may not be the case. Each futures contract has clear stipulations on the specification of the asset that should be delivered if a futures position reaches delivery. For example, cotton futures traded on the International Commodity Exchange require cotton to be delivered that is “Strict Low Middling Staple Length: 1 2/32nd”.

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If a company was using this contract to hedge a change in the price of cotton and the cotton they were purchasing was of a different quality, there would be no guarantee that the spot and futures prices would move in perfect correlation. This is referred to as quality risk. In section 8.4 the concept of delivery was covered. The convergence of the spot and futures prices on the delivery date introduces basis (or timing) risk. The “scales” diagram introduced earlier supposes that an increase in costs (decrease in revenue) is offset by a profit on the futures position. In order for this to occur, the relative change in the spot and futures prices must be equal. For example, if the movements of spot and futures prices is as shown below, and you were hedging against a decline in price using futures, it is evident that the decline in revenue would be much greater than the profit on the future. Likewise, if the prices rose (and converged together), then the increased revenue would not be entirely cancelled out by the loss on the futures position.

8.6 Basis

If the spot asset is sold or purchased at a date that differs from the expiration date, then the price on the futures contract will not necessarily be equal to the spot price. The difference between the futures price and the spot price is called the basis:
basis = spot price – futures price

The basis tends to narrow as expiration nears, converging to zero at the delivery date.

Under normal conditions, the futures price is higher than the cash price. Why? The futures price should incorporate the costs that the seller would incur for buying the commodity and storing it until delivery. These costs are called costs-of-carry.

The fair price of a future is then cash price + cost of carry.

If futures are fairly priced the basis will be negative, a position known as contango.

In exceptional circumstances, the opposite situation might occur and the cash price would be higher than the futures price. For example, this could be due to temporary scarcity of a commodity in the spot market causing an increase in the spot price. This situation is known as backwardation.

Consider the situation where a company knows that an asset will be sold, in the spot market, at some future date, $t_1$. In order to mitigate the risk of a price fall, the company instigates a short futures position at the futures price, $F_0$. If the resultant selling price is $S_1$ and the corresponding futures prices is $F_1$ then the net revenue from selling this asset is:

$$S_1 + [– (F_1 – F_0)]$$

If we define the basis at time $t_1$ as:

$$b_1 = S_1 – F_1$$

then the net revenue can be expressed as:

$$S_1 + (F_0 – F_1) = F_0 + b_1$$

The initial futures, price, $F_0$, is known when the hedge is instigated, but $b_1$ is not. Herein lies the uncertainty surrounding hedging and the so-called basis risk.

**Example**

Returning to the data in the previous wheat example, assume that the initial spot and futures prices are not equal. Previously we assumed that both the spot and futures prices were 461 cents per bushel. Now we will assume that the spot price is lower than the futures price at 420 cents per bushel. The basis is then –41 cents per bushel and we are in a situation of contango. If the spot price falls to 340 cents per bushel and the futures price drops to 350 cents per bushel, then we have the following outcome:

- exposure = 50,000 bushels, face value = 5,000 bushels
- number of contracts = 10
- $S_0 = 420$ cents per bushel
F₀ = 461 cents per bushel
S₁ = 340 cents per bushel
F₁ = 350 cents per bushel
Therefore b₁ = –10 cents = –$0.1
Revenue from selling wheat at S₁:

\[ 50,000 \text{ bushels} \times 340 \text{ cents per bushel} = 170,000 \]
profit from futures position = \(-10 \times 5,000 \times [350 – 461]/100\) = $55,500
net revenue = $225,500

net revenue per bushel = $4.51 per bushel

Or F₀ + b₁ = $4.61 + (–$0.1) = $4.51.

### Exposure = 50,000 bushels

<table>
<thead>
<tr>
<th>N = 10</th>
<th>F₀ = 461 cents per bushel</th>
</tr>
</thead>
<tbody>
<tr>
<td>FV = 5,000 bushels</td>
<td>S₀ = 420 cents per bushel</td>
</tr>
<tr>
<td></td>
<td>b₀ = –41 cents per bushel</td>
</tr>
<tr>
<td></td>
<td>F₁ = 350 cents per bushel</td>
</tr>
<tr>
<td></td>
<td>S₁ = 340 cents per bushel</td>
</tr>
<tr>
<td></td>
<td>b₁ = –10 cents per bushel</td>
</tr>
</tbody>
</table>

| Spot revenue | $170,000 |
| Profit/Loss from futures position | $55,500 |
| Net revenue | $225,500 |
| Net revenue (per bushel) | $4.51 |
| Net revenue (per bushel) | $4.51 using formula |

The spreadsheet for this exercise can be found [here](#). Please ensure you click on Section 8 and the 8.6a tab at the bottom of the spreadsheet.

Note further that basis can lead to an improvement or worsening of a hedge. In our example it is worsened by 10 cents, but if the basis is reversed when the hedge is closed, and the market goes into backwardation, then the revenue would be increased.

Consider instead a situation where a company knows it will buy an asset at time t₁ and in order to avoid a rise in costs takes out a long futures position at time t₁. The price paid is S₁ and the profit on the futures position is then (F₁ – F₀).
The effective price obtained for the asset with hedging is therefore:

\[ S_2 - (F_1 - F_0) = F_0 + b_1 \] (note we subtract the profit on the futures position)

**Example**

Returning to the data in the oil refinery example, now assume that the initial spot and futures prices are not equal. Previously we assumed that both the spot and futures prices were $49.92 per barrel. Now we will assume that the spot price is lower than the futures price at $49.42 per barrel. The basis is then -$0.50 per barrel and we are in a situation of contango. If the futures price rises to $60 per barrel, and the spot price rises to $59.80 per barrel, then we have the following outcome:

- **exposure = 100,000 barrels, face value = 1,000 barrels**
- **number of contracts = 100**
- **\( S_0 = 49.42 \) $ per barrel**
- **\( F_0 = 49.92 \) $ per barrel**
- **\( S_1 = 59.80 \) $ per barrel**
- **\( F_1 = 60 \) per barrel**

Therefore \( b_1 = -0.3 \) per barrel

Cost of buying crude oil at \( S_1 \):

- \( 100,000 \) barrels \( \times \) \$59.80 per barrel = \$5,980,000
- profit from futures position = \( +100 \times 1,000 \times [60 - 49.92] = \$1,008,000 \)
- net cost = \$4,972,000
- net cost per barrel = \$49.72

Or \( F_0 + b_1 = 49.92 + (-0.2) = 49.72 \).

<table>
<thead>
<tr>
<th>Exposure = 100,000 barrels</th>
</tr>
</thead>
<tbody>
<tr>
<td>( N = 100 )</td>
</tr>
<tr>
<td>( FV = 1,000 ) barrels</td>
</tr>
<tr>
<td>( b_0 = -0.5 ) per barrel</td>
</tr>
<tr>
<td>( S_1 = 59.80 ) per barrel</td>
</tr>
<tr>
<td>Spot cost</td>
</tr>
<tr>
<td>Profit/Loss from futures position</td>
</tr>
</tbody>
</table>
Net cost $4,972,000
Net cost (per barrel) $49.72
Net cost (per barrel) $49.72 using formula

The spreadsheet for this exercise can be found [here](#). Please ensure you click on Section 8 and the 8.6b tab at the bottom of the spreadsheet.

### 8.7 Hedge efficiency

In the previous two examples we have considered minimising net cost or maximising net revenue as the aim of the hedge. An alternative outlook is to consider the hedge efficiency:

\[
Hedge\ Efficiency = \left| \frac{\text{Gain or Loss on futures position}}{\text{Loss or Gain on spot position}} \right|
\]

It is usual to refer to the efficiency of a hedge as a percentage. The vertical lines indicate absolute values. Effectively we are measuring how much we were able to balance the scales shown earlier.

In the earlier wheat example, the initial spot price was 420 cents per bushel but the actual spot price was 340 cents per bushel. Had we been able to sell the wheat at 420 cents we would have realised revenue of $210,000, whereas we actually realised $170,000. In addition, the profit on our futures position was $55,500. It follows that the hedge efficiency is:

\[
Hedge\ Efficiency = \left| \frac{+$55,500}{$210,000 - $170,000} \right| = \frac{$55,500}{-$40,000} = 138.75\%
\]

Here the spot price fell from 420 cents per bushel to 340 cents per bushel, a fall of 80 cents, but the futures price fell from 461 cents per bushel to 350 cents per bushel, a fall of 111 cents. It is evident that the fall in the spot price was less than the fall in the futures price, which explains why the hedge efficiency is greater than 100%.

Using our earlier notation, the hedge efficiency can also be found by the following equation:

\[
1 + \frac{(b_0 - b_1)}{(S_1 - S_0)} = 1 + \frac{(-41 - (-10))}{(340 - 420)} = 1 + \frac{-31}{-80} = 138.75\%
\]
Example

Consider the case of a wheat farmer who anticipates selling 50,000 bushels of wheat in March. The face value of wheat futures contracts traded on the CME is 5,000 bushels. What is the hedge efficiency using the following data?

- initial futures price = 420 cents per bushel
- initial basis = +15 cents per bushel
- final futures price = 350 cents per bushel
- final basis = 0 cents per bushel

\[
F_0 = 420, \quad S_0 = b_0 + F_0 = 15 + 420 = 435 \\
F_1 = 350, \quad S_1 = b_1 + F_0 = 350 + 0 = 350 \\
\text{hedge efficiency} = 1 + \frac{(15-0)}{(350 - 435)} = 1 + \frac{15}{-85} = 82.35\%
\]

Alternatively:

- expected revenue = $217,500
- actual revenue = $175,000
- change in revenue = –$42,500
- profit on futures position = $35,000
- hedge efficiency = $35,000/$42,500 = 82.35%

Activity 8.1

A food producer, Ohlin plc, expects to purchase 200,000 bushels of wheat in early September 2013. It wishes to hedge against the price risk by using wheat futures contracts traded on the CME, each with a face value of 5,000 bushels. The current price of September 2013 wheat futures traded on the CME is 872 cents per bushel and the current spot price is 862 cents per bushel. Evaluate this hedge in September 2013 assuming the following spot values (cents per bushel):

<table>
<thead>
<tr>
<th>Spot price (cents per bushel)</th>
<th>820</th>
<th>840</th>
<th>860</th>
<th>880</th>
<th>900</th>
<th>920</th>
<th>940</th>
</tr>
</thead>
</table>

You may assume that the basis narrows to zero. What are the implications for the hedge efficiency if the basis remained constant?
8.8 Airlines hedging price risk

Consider an airline with a requirement to buy 100,000 metric tonnes of jet kerosene in February 2017 (assume it is now 29 July 2016). 100,000 metric tonnes is the equivalent of 793,000 barrels of oil. With 42 gallons in each barrel that is 33,306,000 gallons, and since a Boeing 777 jet burns fuel at 1,672 gallons an hour, this represents approximately 20,000 hours of flying time. Jet kerosene is produced in the process of refining crude oil. Therefore, as the price of crude oil goes up, the price of jet kerosene also rises. The chart below shows the rise (and fall) in prices of jet kerosene and crude oil during 2016 until 29 July. Note that the kerosene figure is scaled by a dividend of 7.93.

![Chart showing the relationship between jet kerosene and crude oil prices]

It is evident from the above that there exists a positive relationship between the two sets of data. This relationship is even more evident when we examine the relationship between the daily percentage changes in both prices.
The r-squared value of 0.688 indicates how good a “fit” the trendline is. It is apparent that the majority of circles are in the north-east and south-west quadrants. If we take the square root of the r-squared figure we obtain the correlation between the two series as 0.829, which indicates strong positive correlation. It follows that to hedge the price risk of a rise in the price of jet kerosene, an airline could buy crude oil futures. Then, as the price of crude oil goes up, it will profit on its futures contracts and this will offset the associated increase in the price of jet kerosene.

On 29 July 2016, the price of a Brent crude oil futures contract expiring in September 2017 (it actually expired in July 2017) was $48.17/bl. The price of jet kerosene was $400 per metric tonne. Each crude oil futures contract is worth 1,000 barrels of oil. An airline would therefore need to buy 793 contracts (i.e. 793,000/1,000).

If the price of crude oil is higher in July 2017, then the airline will gain on the futures contracts. However, the price of jet kerosene will also have risen. Ideally, the increased cost of jet kerosene will be offset by a profit on the futures position. Alternatively, if the price of crude oil is lower in July 2017, then the airline will suffer a loss on the futures contracts. However, this will be cancelled out by a gain in buying the jet kerosene at a lower price. If crude oil and jet kerosene move in a 1-for-1 manner, then the increased (reduced) costs will be exactly cancelled out by a gain (loss) on the futures contracts.

On 31 July when the 2017 contract expired, the price of jet kerosene was $529 per metric tonne and the price of the crude oil future was $52.65 per barrel.
The outcome can then be evaluated as follows:

**Exposure = 100,000 metric tonnes/793,000 barrels**

**FV = 1,000 barrels**

<table>
<thead>
<tr>
<th>N = 793</th>
<th>793</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected cost (as of 29 July 2016)</td>
<td>$40,000,000</td>
</tr>
<tr>
<td>Actual cost (as of 31 July 2017)</td>
<td>$52,900,000</td>
</tr>
<tr>
<td>Change in cost</td>
<td>$12,900,000</td>
</tr>
<tr>
<td>P/L on future</td>
<td>$3,552,640</td>
</tr>
<tr>
<td>Hedge efficiency</td>
<td>27.54%</td>
</tr>
<tr>
<td>Effective cost</td>
<td>$49,347,360</td>
</tr>
<tr>
<td>Effective cost (per barrel)</td>
<td>$62.23</td>
</tr>
</tbody>
</table>

To use the basis analysis requires more work, as the spot price is in $ per metric tonne but the future is in $ per barrel. But if you divide the spot price by 7.93 then you can verify the effective price ($ per bl) as \( F_0 + b_1 \) and the hedge efficiency as \( 1 + \frac{(b_0 - b_1)}{(S_1 - S_0)} \)

\[
S_0 = $50.44 \text{ per barrel} \\
F_0 = $48.17 \text{ per barrel} \\
b_0 = $2.27 \text{ per barrel} \\
S_1 = $66.71 \text{ per barrel} \\
F_1 = $52.65 \text{ per barrel} \\
b_1 = $14.06 \text{ per barrel} \\
\text{Effective cost} = F_0 + b_1 = $62.23 \text{ per barrel} \\
\text{Hedge efficiency} = 1 = \frac{(b_0 - b_1)}{(S_1 - S_0)} = 27.54\% 
\]

This example illustrates that hedging in the real world is much more complicated than our stylised wheat and crude oil examples presented earlier. The undoing of the jet kerosene hedge was that rather than narrowing, the basis widened to $14.06 per barrel.

The spreadsheet for this exercise can be found [here](#). Please ensure you click on Section 8 and the 8.8 tab at the bottom of the spreadsheet.