

Financial Mathematics

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¹Based on Robert L. McDonald's *Derivatives Markets*, 3rd Ed, Pearson, 2013.

Chapter 2. An Introduction to Forwards and Options

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§ 2.1 Forward contracts

§ 2.2 Call options

§ 2.3 Put options

§ 2.4 Options are insurance

§ 2.5 Summary of forward and option positions

§ 2.6 Problems

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Definition 2.1-1 **Forward contract** is a binding agreement (obligation) to buy or sell an underlying asset in the future, at a price set today. The time at which the contract settles is called the **expiration date**. A forward contract specifies

- ▶ The features and quantity of the asset to be delivered.
- ▶ The delivery logistics, such as time, date, and place.
- ▶ The price the buyer will pay at the time of delivery.

Remark 2.1-1

1. **Futures contracts** are the same as forwards in principle except for some institutional and pricing differences. We will study future contracts in Chapter 5.
2. A forward contract requires no initial payment or **premium**.

Long = buy short = sell

Definition 2.1-2 Payoff for a contract is its value at expiration. In particular, for forward contracts,

Payoff for Long forward = Spot price at expiration – Forward price

Payoff for Short forward = Forward price – Spot price at expiration

Remark 2.1-2 Payoff and profit (net payoff) are the same for forward contracts because there is no initial payment – premium.

Example 2.1-1 S&R (special and rich) index:

Today: Spot price = \$1,000

6-month forward price = \$1,020

In six months at contract expiration: Spot price = \$1,050.

What are the payoff of long/short forward?

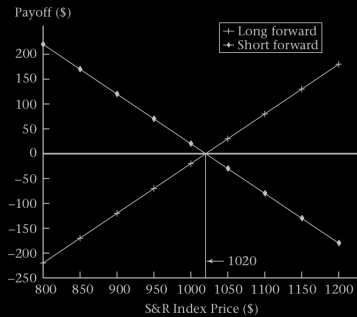
Solution.

Long position payoff = $\$1,050 - \$1,020 = \$30$,

Short position payoff = $\$1,020 - \$1,050 = (\$30)$.



Payoff diagram for a forward price = \$1,020



Forward versus outright purchase

We will see this through the following example:

Example 2.1-2 S&R 6-month forward contract with a zero-coupon bond (e.g., Treasury bills). The 6-month interest rate is 2%. Spot price today = \$1,000.

\$1,000 today is worth $\$1,000 \times 1.02 = \$1,020$ in 6 months.

Outright purchase² is equivalent to forward + bond³

because

$$\begin{aligned}\text{Payoff of forward+bond} &= \underbrace{\text{Spot price at expiration} - \$1,020}_{\text{Forward payoff}} + \underbrace{\$1,020}_{\text{Bond payoff}} \\ &= \text{Spot price at expiration} \\ &= \text{Payoff of outright purchase}\end{aligned}$$

²It is also called long physical index.

³Invest \$1,000 to bond for 6 month and enter long position of forward contract at the same time.

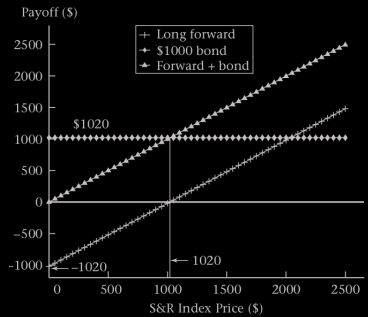
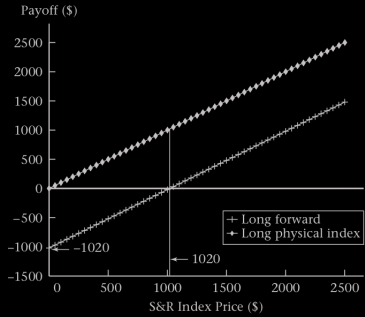
\$1,000 today is worth $\$1,000 \times 1.02 = \$1,020$ in 6 months.

Long forward is equivalent to borrow-to-buy⁴

because

$$\begin{aligned} \text{Payoff of borrow-to-buy} &= \underbrace{\text{Spot price at expiration}}_{\text{Payoff for outright buy}} - \underbrace{\$1,020}_{\text{Return borrowed money}} \\ &= \text{Payoff of long forward.} \end{aligned}$$

⁴Borrow money (\$1,000) to outright buy physical index and at expiration pay back the money (\$1,020).



Cash settlement versus physical delivery

– Type of settlement

- ▶ Cash settlement: less costly and more practical
- ▶ Physical delivery: often avoided due to significant costs

Example 2.1-3 Consider the S&R index with the forward price \$1,020.

- ▶ Suppose that the S&R index at expiration is \$1,040.
- ▶ The long position has a payoff of \$20.
- ▶ Similarly, the short position loses \$20.

With **cash settlement**, the short simply pays \$20 to the long, with **no transfer of the physical asset**, and hence **no transaction costs**. It is as if the long paid \$1,020, acquired the index worth \$1,040, and then immediately sold it with no transaction costs.

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- ▶ Suppose that the S&R index price at expiration had instead been \$960.
 - ▶ The long position would have a payoff of $-\$60$.
 - ▶ The short would have a payoff of \$60.

Cash settlement in this case entails the long paying \$60 to the short.

Credit risk

All derivatives contracts have **credit risk**, which is the possibility that the counterparty who owes money fails to make a payment.

- ▶ Major issue for **over-the-counter (OTC) contracts**

Credit check

Credit **protections** such as collateral and bank letter of credit

- ▶ Less severe for **exchange-traded contracts**

Exchange guarantees transactions, requires collateral