Derivatives
Essentials

An Introduction to Forwards, Futures, Options, and Swaps

ARON GOTTESMAN

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WILEY

*For my wife Ronit and our children
Libby, Yakov, Raphi, Tzipora, and Kayla*

Contents

Preface

This book provides an in-depth introduction to derivative securities. A derivative security is an agreement between two counterparties whose payoff depends on the value of an underlying asset. There is extensive interest in derivative securities due to their usefulness as tools through which investors can monetize views and transform exposures. Yet many that pursue an understanding of derivative securities can be frustrated with educational material that assumes the learner has sophisticated quantitative skills. Further, those with sophisticated quantitative skills can be frustrated with educational material that derives equations with little insight into the economic nature of derivative securities products and strategies.

This book focuses on helping you develop a meaningful understanding of derivative securities products and strategies and how to communicate your understanding both conceptually as well as through equations. You will learn about each product and strategy and the reasons for investing in them. You will learn about quantitative pricing and valuation models and will develop a deep understanding as to *why* the models represent price and value. You will learn of the great importance of the sensitivity measures known as the "Greeks" and learn how to use them to understand and characterize products and strategies.

Quantitative modeling is an important element of derivative securities, and this book will present quantitative models. However, this book does not assume that you have sophisticated quantitative or finance skills beyond the ability to add, subtract, multiply, divide, raise to a power, and rudimentary familiarity with time value of money concepts. Any other quantitative concept that is required to understand the material in this book will be introduced before it is required. Further, this book does not intend to provide comprehensive mathematical derivations nor provide quantitative overviews of each of the myriad of derivative securities variations in existence. Instead, the quantitative analysis in this book focuses on several key products through which we will explore conceptual and quantitative insights that are broadly applicable to other products and, most importantly, enable you to verbally communicate a deep understanding of products and strategies.

There are five parts to this book:

- Part One: Introduction to Forwards, Futures, and Options (Chapters 1–3)
- Part Two: Pricing and Valuation (Chapters 4–7)
- Part Three: The Greeks (Chapters 8–10)
- Part Four: Trading Strategies (Chapters 11–13)
- Part Five: Swaps (Chapters 14–15)

Part One introduces forwards, futures, and options. Forwards and futures are agreements that obligate counterparties to transact in the future. Options are agreements that provide one of the counterparties a right, and not an obligation, to transact in the future. In Part One you will learn about the key characteristics of forwards, futures, and options and each position's cash flows, payoffs, and P&L (profit and loss). You will also learn why forwards, futures, and options are described as zero-sum games and the concepts of moneyness and counterparty credit risk.

Part Two explores pricing and valuation of forwards and options. In Part Two you will learn to distinguish between price and value and explore models of price and value for each position, including the Black-Scholes and binomial option pricing models. You will also learn about the assumptions that these models make, risk-neutral valuation, and why the models represent price and value. You will also be introduced to the concepts of implied volatility and volatility surfaces.

Part Three explores the "Greeks," which are measures of product and strategy sensitivity to change in the determinants of their value. In Part Three you will learn how to define, calculate, and interpret the Greeks and why they can be inaccurate. You will also develop a deep understanding of how the Greeks can be used to understand and describe sensitivity; why a given Greek will be positive, negative, or zero; and why its magnitude can change.

Part Four explores trading strategies. In Part Four you will learn how to describe and implement price and volatility trading strategies, create synthetic positions, and implement protective, yield enhancing, and spread trading strategies. The trading strategies that will be explored in Part Four include straddles, strangles, protective puts, covered calls, collars, bull spreads, bear spreads, risk reversals, butterfly spreads, and condor spreads, among others. You will also learn advanced concepts related to moneyness and put-call parity.

Part Five introduces swaps. A swap is an exchange of cash flows between two counterparties over a number of periods of time. In an interest rate swap the counterparties exchange fixed and floating interest rates. In a credit default swap periodic payments of spread are exchanged for a payment contingent on a credit event. In a cross-currency swap the counterparties

exchange interest payments in different currencies. In Part Five you will learn about the key characteristics of these swaps, their sensitivities and cash flows, and how they can be used to transform exposures.

Most of the chapters in this book build on the material in previous chapters. It is therefore important that you truly understand each chapter before advancing to the next. To allow you to test your understanding, there are more than 650 *Knowledge check* questions throughout the book, the solutions to which are provided in the appendix. The *Knowledge check* questions can be used to ensure absorption of the material both when you learn the material for the first time and also when you review.

I hope this book provides you with a deep understanding of derivative securities and an enjoyable and valuable learning experience!

Acknowledgments

About the Author

Aron Gottesman is Professor of Finance and the Chair of the Department of Finance and Economics at the Lubin School of Business at Pace University in Manhattan. He holds a PhD in Finance, an MBA in Finance, and a BA in Psychology, all from York University. He has published articles in academic journals including the *Journal of Financial Intermediation, Journal of Banking and Finance, Journal of Empirical Finance*, and the *Journal of Financial Markets*, among others, and has coauthored several books. Aron Gottesman's research has been cited in newspapers and popular magazines, including *The Wall Street Journal, The New York Times, Forbes Magazine,* and *Business Week*. He teaches courses on derivative securities, financial markets, and asset management. Aron Gottesman also presents workshops to financial institutions. His website can be accessed at www.arongottesman.com.

Derivatives Essentials

Introduction to Forwards, Futures, and Options

Forwards and Futures

INTRODUCTION

A derivative security is an agreement between two counterparties whose payoff depends on the value of an underlying asset. In this chapter we will explore agreements that obligate counterparties to transact in the future, known as forward contracts and futures contracts.

After you read this chapter you will be able to

- Describe the key characteristics of a forward.
- Define and contrast the concepts of payoff and P&L.
- Describe a forward's cash flows, payoff, and P&L.
- Understand how equations and P&L diagrams can be used to describe a forward's cash flows.
- Understand when forwards earn profits, suffer losses, and break even.
- Explain why forwards are zero-sum games.
- Define counterparty credit risk and understand mechanisms through which it is managed and minimized.
- Describe futures contracts.
- Compare and contrast forwards and futures.

1.1   FORWARD CONTRACT CHARACTERISTICS

A forward contract is an agreement between two counterparties that obligates them to transact in the future. The key characteristics of a forward are as follows:

- One of the counterparties is referred to as the "long position" or "long forward," and the other counterparty is referred to as the "short position" or "short forward."
- The long forward is obligated to purchase an asset from the short forward at a future point in time. The short forward is obligated to sell the asset.

- The asset is known as the "underlying asset." The underlying asset can be any asset. Common examples include stocks, bonds, currencies, and commodities.
- The future point in time when the transaction occurs is known as the "expiration date." For example, a forward may have an expiration date that is three months after initiation.
- The price at which the underlying asset is purchased is called the "forward price." The forward price is set at initiation though the transaction only takes place in the future. For example, at initiation two counterparties may agree to a forward price of $100 and an expiration date that is in three months. The long forward is obligated to purchase the asset from the short forward for $100 in three months.
- All details are specified at initiation, including:
    - The counterparties
    - The underlying asset
    - The forward price
    - The expiration date

Hence, a forward is very similar to any transaction where an individual buys an asset from another individual, with the interesting twist that while the purchase price is set at initiation the transaction itself takes place at a future point in time. Figure 1.1 illustrates a forward.

For example, consider the following scenario:

- Initiation = July 15
- Expiration = September 15
- Underlying asset = one share
- Forward price = $100

Figure 1.2 illustrates this example.
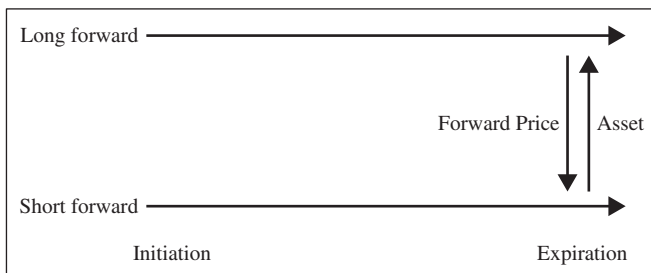
FIGURE 1.1   Forward contract cash flows
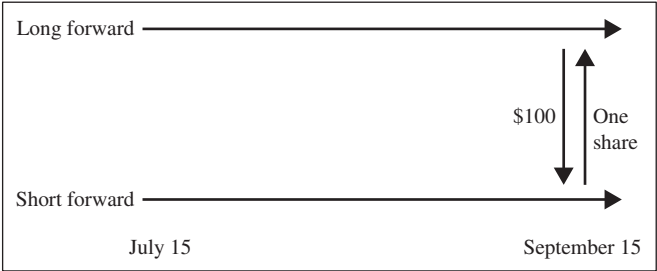
FIGURE 1.2   Forward contract cash flows example

Figure 1.2 shows that at initiation, July 15, no transaction takes place. Instead, on July 15 the long forward and short forward enter into an agreement that

- Obligates the long forward to purchase a single share from the short forward on September 15 for the forward price of $100. Hence, at expiration the long position pays $100 and receives one share in return.
- Obligates the short forward to sell a single share to the long forward on September 15 for the forward price of $100. Hence at expiration the short forward receives $100 and delivers one share in return.

Let's consider another example:

- Initiation = August 20
- Expiration = December 20
- Underlying asset = One ounce of gold
- Forward price = $1,250

Figure 1.3 illustrates this example.
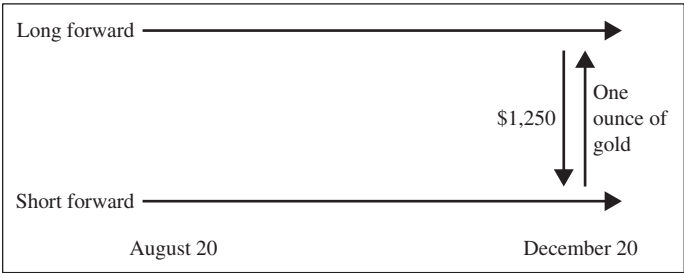
FIGURE 1.3   Forward contract cash flows example

Figure 1.3 shows that at initiation, August 20, no transaction takes place. However, on August 20 the long forward and short forward enter into an agreement that

- Obligates the long forward to purchase one ounce of gold from the short forward on December 20 for the forward price of $1,250. Hence, at expiration the long forward pays $1,250 and receives one ounce of gold in return.
- Obligates the short forward to sell one ounce of gold to the long forward on December 20 for the forward price of $1,250. Hence, at expiration the short forward receives $1,250 and delivers one ounce of gold in return.

Knowledge check

Q 1.1: What is a "forward contract"?
Q 1.2: What is the long forward position's obligation?
Q 1.3: What is the short forward position's obligation?
Q 1.4: What is the "expiration date"?
Q 1.5: What is the "forward price"?

1.2   LONG FORWARD PAYOFF

Payoff is the cash flow that occurs at expiration. A long forward is obligated to purchase the asset through paying the forward price at expiration. Hence, the long forward's payoff is the value of the underlying asset that it receives at expiration minus the forward price it pays. The value of the underlying asset at expiration is its market price at that time.

The long forward's payoff can be positive, negative, or zero:

- Positive payoff occurs when the price of the asset received is greater than the forward price paid.
- Negative payoff occurs when the price of the asset received is less than the forward price paid.
- Zero payoff occurs when the price of the asset received is equal to the forward price paid.

We can describe the long forward's payoff using an equation:

Long forward payoff = underlying asset price on the expiration date

– forward price
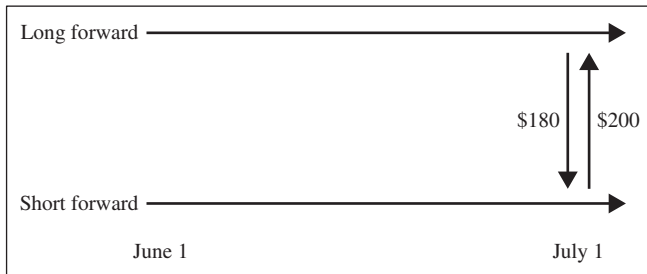
FIGURE 1.4 Long forward payoff example

This equation can be restated using notation rather than words. Let's define the following notation:

T = Expiration date
S_T = Underlying asset price at time T
F = Forward price

With this notation, we can rewrite the equation for the long forward's payoff:

$$Long\ forward\ payoff = S_T - F$$

For example, consider the following scenario:

- Initiation = June 1
- Expiration = July 1
- Forward price = $180
- Underlying asset price on July 1 = $200

This scenario is illustrated in Figure 1.4.
In this example, the long forward's payoff is:

$$Long\ forward\ payoff = S_T - F$$
$$= \$200 - \$180$$
$$= \$20$$

Knowledge check

Q 1.6: What is "payoff"?
Q 1.7: What is the long forward's payoff?
Q 1.8: When does the long forward have a positive payoff?
Q 1.9: When does the long forward have a negative payoff?
Q 1.10: When does the long forward have zero payoff?

1.3 LONG FORWARD P&L

P&L is profit and loss. The distinction between payoff and P&L is as follows:

- Payoff: The cash flow that occurs at expiration
- P&L: The difference between the cash flows at initiation and expiration

Hence, P&L takes into account any cash flow that is paid or received at initiation.

A long forward's payoff and P&L are identical. After all, the long forward does not pay nor receive a cash flow at initiation. The equation for a long forward's P&L is therefore identical to the equation for the long forward's payoff:

$$Long\ forward\ P\&L = Long\ forward\ payoff = S_T - F$$

The long forward may experience a profit, suffer a loss, or break even:

- Profit occurs when the price of the asset received is greater than the forward price paid.
- Loss occurs when the price of the asset received is less than the forward price paid.
- Breakeven occurs when the price of the asset received is equal to the forward price paid.

We can describe the long forward's breakeven point using an equation:

$$Long\ forward\ breakeven\ point : S_T = F$$
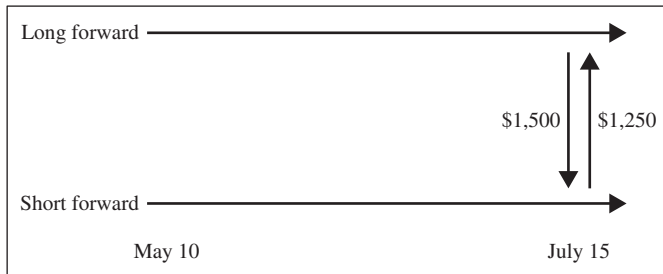
For example, consider the following scenario:

- Initiation = May 10
- Expiration = July 15
- Forward price = $1,500
- Underlying asset price on July 15 = $1,250

This scenario is illustrated in Figure 1.5.
In this example, the long forward's P&L is:

$$Long\ forward\ P\&L = S_T - F$$
$$= \$1,250 - \$1,500$$
$$= -\$250$$

FIGURE 1.5 Long forward P&L example

Q 1.11: What is "P&L"?
Q 1.12: What is the long forward's P&L?
Q 1.13: When does the long forward earn a profit?
Q 1.14: When does the long forward suffer a loss?
Q 1.15: When does the long forward break even?

1.4 SHORT FORWARD PAYOFF

A short forward is obligated to sell an asset at expiration in return for which it receives the forward price. Hence, the short forward's payoff at expiration is the forward price received minus the price of the asset it delivers. The short forward's payoff can be positive, negative, or zero:

- Positive payoff occurs when the forward price received is greater than the price of the asset delivered.
- Negative payoff occurs when the forward price received is less than the price of the asset delivered.
- Zero payoff occurs when the forward price received is equal to the price of the asset delivered.

The short forward's payoff can be expressed as:

$$Short\ forward\ payoff = F - S_T$$

For example, consider the following scenario:

- Initiation = October 3
- Expiration = February 1
- Forward price = $65
- Underlying asset price on February 1 = $82
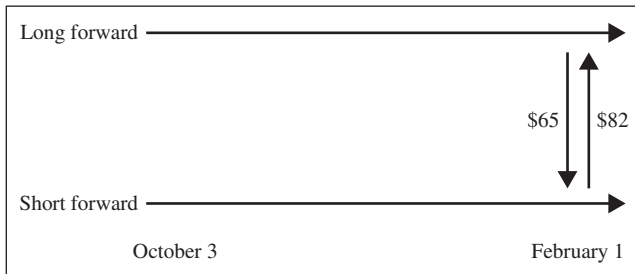
FIGURE 1.6 Short forward payoff example

This scenario is illustrated in Figure 1.6.
In this example, the short forward's payoff is:

$$Short\ forward\ payoff = F - S_T$$
$$= \$65 - \$82$$
$$= -\$17$$

Knowledge check

Q 1.16: What is the short forward's payoff?
Q 1.17: When does the short forward have a positive payoff?
Q 1.18: When does the short forward have a negative payoff?
Q 1.19: When does the short forward have zero payoff?

1.5   SHORT FORWARD P&L

P&L is the difference between the cash flows that occur at initiation and expiration. A short forward's P&L is equal to its payoff as the only cash flow associated with a short forward is the payoff that takes place at expiration. Therefore, the equation for the short forward's P&L is identical to the equation for the short forward's payoff:

$$Short\ forward\ P\&L = Short\ forward\ payoff = F - S_T$$

The short forward may experience a profit, suffer a loss, or break even:

- Profit occurs when the forward price received is greater than the price of the asset delivered.

FIGURE 1.7 Short forward P&L example
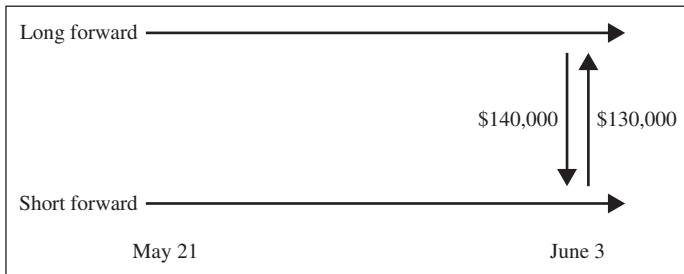
- Loss occurs when the forward price received is less than the price of the asset delivered.
- Breakeven occurs when the forward price received is equal to the price of the asset delivered.

We can describe the short forward's breakeven point using an equation:

$$Short\ forward\ breakeven\ point : S_T = F$$

The short forward's breakeven point is identical to the long forward's breakeven point.

For example, consider the following scenario:

- Initiation = May 21
- Expiration = June 3
- Forward price = $140,000
- Underlying asset price on June 3 = $130,000

This scenario is illustrated in Figure 1.7.
In this example, the short forward's P&L is:

$$Short\ Forward\ P\&L = F - S_T$$

$$= \$140,000 - \$130,000$$

$$= \$10,000$$

Knowledge check

Q 1.20: What is the short forward's P&L?
Q 1.21: When does the short forward earn a profit?
Q 1.22: When does the short forward suffer a loss?
Q 1.23: When does the short forward break even?