QUANTITATIVE INVESTMENT ANALYSIS WORKBOOK

Second Edition

Richard A. DeFusco, CFA
Dennis W. McLeavey, CFA
Jerald E. Pinto, CFA
David E. Runkle, CFA

John Wiley & Sons, Inc.
QUANTITATIVE INVESTMENT ANALYSIS WORKBOOK
CFA Institute is the premier association for investment professionals around the world, with over 85,000 members in 129 countries. Since 1963 the organization has developed and administered the renowned Chartered Financial Analyst® Program. With a rich history of leading the investment profession, CFA Institute has set the highest standards in ethics, education, and professional excellence within the global investment community, and is the foremost authority on investment profession conduct and practice.

Each book in the CFA Institute Investment Series is geared toward industry practitioners along with graduate-level finance students and covers the most important topics in the industry. The authors of these cutting-edge books are themselves industry professionals and academics and bring their wealth of knowledge and expertise to this series.
# CONTENTS

## PART 1

Learning Outcomes, Summary Overview, and Problems

### CHAPTER 1

The Time Value of Money 3

- Learning Outcomes 3
- Summary Overview 3
- Problems 4

### CHAPTER 2

Discounted Cash Flow Applications 7

- Learning Outcomes 7
- Summary Overview 7
- Problems 8

### CHAPTER 3

Statistical Concepts and Market Returns 11

- Learning Outcomes 11
- Summary Overview 11
- Problems 13

### CHAPTER 4

Probability Concepts 21

- Learning Outcomes 21
- Summary Overview 21
- Problems 23

### CHAPTER 5

Common Probability Distributions 29

- Learning Outcomes 29
- Summary Overview 30
- Problems 31
## Contents

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>CHAPTER 6</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Sampling and Estimation</strong></td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>Learning Outcomes</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>Summary Overview</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>Problems</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td><strong>CHAPTER 7</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Hypothesis Testing</strong></td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Learning Outcomes</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Summary Overview</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>Problems</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td><strong>CHAPTER 8</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Correlation and Regression</strong></td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>Learning Outcomes</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>Summary Overview</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>Problems</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td><strong>CHAPTER 9</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Multiple Regression and Issues in Regression Analysis</strong></td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>Learning Outcomes</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>Summary Overview</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>Problems</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td><strong>CHAPTER 10</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Time-Series Analysis</strong></td>
<td>83</td>
</tr>
<tr>
<td></td>
<td>Learning Outcomes</td>
<td>83</td>
</tr>
<tr>
<td></td>
<td>Summary Overview</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>Problems</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td><strong>CHAPTER 11</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Portfolio Concepts</strong></td>
<td>97</td>
</tr>
<tr>
<td></td>
<td>Learning Outcomes</td>
<td>97</td>
</tr>
<tr>
<td></td>
<td>Summary Overview</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>Problems</td>
<td>102</td>
</tr>
<tr>
<td></td>
<td><strong>PART 2</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Solutions</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>CHAPTER 1</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>The Time Value of Money</strong></td>
<td>111</td>
</tr>
<tr>
<td></td>
<td>Solutions</td>
<td>111</td>
</tr>
</tbody>
</table>
Contents

CHAPTER 2
Discounted Cash Flow Applications 129
Solutions 129

CHAPTER 3
Statistical Concepts and Market Returns 135
Solutions 135

CHAPTER 4
Probability Concepts 149
Solutions 149

CHAPTER 5
Common Probability Distributions 155
Solutions 155

CHAPTER 6
Sampling and Estimation 161
Solutions 161

CHAPTER 7
Hypothesis Testing 167
Solutions 167

CHAPTER 8
Correlation and Regression 175
Solutions 175

CHAPTER 9
Multiple Regression and Issues in Regression Analysis 185
Solutions 185

CHAPTER 10
Time-Series Analysis 193
Solutions 193

CHAPTER 11
Portfolio Concepts 199
Solutions 199

About the CFA Program 205
PART I

LEARNING OUTCOMES, SUMMARY OVERVIEW, AND PROBLEMS
CHAPTER 1

THE TIME VALUE OF MONEY

LEARNING OUTCOMES

After reading chapter 1, you should be able to do the following:

• Explain an interest rate as the sum of a real risk-free rate and premiums that compensate investors for distinct types of risk.
• Calculate the future value (FV) or present value (PV) of a single sum of money.
• Distinguish between the stated annual interest rate and the effective annual rate.
• Calculate the effective annual rate, given the stated annual interest rate and the frequency of compounding.
• Solve time value of money problems when compounding periods are other than annual.
• Calculate the FV or PV of an ordinary annuity and an annuity due.
• Calculate the PV of a perpetuity.
• Calculate an unknown variable, given the other relevant variables, in time value of money problems.
• Calculate the FV or the PV of a series of uneven cash flows.
• Draw a time line, specify a time index, and solve problems involving the time value of money as applied, for example, to mortgages and savings for college tuition or retirement.
• Explain the cash flow additivity principle in time value of money applications.

SUMMARY OVERVIEW

In chapter 1, we have explored a foundation topic in investment mathematics, the time value of money. We have developed and reviewed the following concepts for use in financial applications:

• The interest rate, \( r \), is the required rate of return; \( r \) is also called the discount rate or opportunity cost.
• An interest rate can be viewed as the sum of the real risk-free interest rate and a set of premiums that compensate lenders for risk: an inflation premium, a default risk premium, a liquidity premium, and a maturity premium.
• The future value, FV, is the present value, PV, times the future value factor, \( (1 + r)^N \).
• The interest rate, \( r \), makes current and future currency amounts equivalent based on their time value.
• The stated annual interest rate is a quoted interest rate that does not account for compounding within the year.
• The periodic rate is the quoted interest rate per period; it equals the stated annual interest rate divided by the number of compounding periods per year.
• The effective annual rate is the amount by which a unit of currency will grow in a year with interest on interest included.
• An annuity is a finite set of level sequential cash flows.
• There are two types of annuities, the annuity due and the ordinary annuity. The annuity due has a first cash flow that occurs immediately; the ordinary annuity has a first cash flow that occurs one period from the present (indexed at \( t = 1 \)).
• On a time line, we can index the present as 0 and then display equally spaced hash marks to represent a number of periods into the future. This representation allows us to index how many periods away each cash flow will be paid.
• Annuities may be handled in a similar fashion as single payments if we use annuity factors instead of single-payment factors.
• The present value, PV, is the future value, FV, times the present value factor, \((1 + r)^{-N}\).
• The present value of a perpetuity is \(A/r\), where \(A\) is the periodic payment to be received forever.
• It is possible to calculate an unknown variable, given the other relevant variables in time value of money problems.
• The cash flow additivity principle can be used to solve problems with uneven cash flows by combining single payments and annuities.

PROBLEMS

1. The table below gives current information on the interest rates for two two-year and two eight-year maturity investments. The table also gives the maturity, liquidity, and default risk characteristics of a new investment possibility (Investment 3). All investments promise only a single payment (a payment at maturity). Assume that premiums relating to inflation, liquidity, and default risk are constant across all time horizons.

<table>
<thead>
<tr>
<th>Investment</th>
<th>Maturity (in years)</th>
<th>Liquidity</th>
<th>Default Risk</th>
<th>Interest Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>High</td>
<td>Low</td>
<td>2.0</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Low</td>
<td>Low</td>
<td>2.5</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>Low</td>
<td>Low</td>
<td>(r_3)</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>High</td>
<td>Low</td>
<td>4.0</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>Low</td>
<td>High</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Based on the information in the above table, address the following:

A. Explain the difference between the interest rates on Investment 1 and Investment 2.
B. Estimate the default risk premium.
C. Calculate upper and lower limits for the interest rate on Investment 3, \(r_3\).
2. A client has a $5 million portfolio and invests 5 percent of it in a money market fund projected to earn 3 percent annually. Estimate the value of this portion of his portfolio after seven years.

3. A client invests $500,000 in a bond fund projected to earn 7 percent annually. Estimate the value of her investment after 10 years.

4. For liquidity purposes, a client keeps $100,000 in a bank account. The bank quotes a stated annual interest rate of 7 percent. The bank’s service representative explains that the stated rate is the rate one would earn if one were to cash out rather than invest the interest payments. How much will your client have in his account at the end of one year, assuming no additions or withdrawals, using the following types of compounding?

   A. Quarterly
   B. Monthly
   C. Continuous

5. A bank quotes a rate of 5.89 percent with an effective annual rate of 6.05 percent. Does the bank use annual, quarterly, or monthly compounding?

6. A bank pays a stated annual interest rate of 8 percent. What is the effective annual rate using the following types of compounding?

   A. Quarterly
   B. Monthly
   C. Continuous

7. A couple plans to set aside $20,000 per year in a conservative portfolio projected to earn 7 percent a year. If they make their first savings contribution one year from now, how much will they have at the end of 20 years?

8. Two years from now, a client will receive the first of three annual payments of $20,000 from a small business project. If she can earn 9 percent annually on her investments and plans to retire in six years, how much will the three business project payments be worth at the time of her retirement?

9. To cover the first year’s total college tuition payments for his two children, a father will make a $75,000 payment five years from now. How much will he need to invest today to meet his first tuition goal if the investment earns 6 percent annually?

10. A client has agreed to invest $100,000 one year from now in a business planning to expand, and she has decided to set aside the funds today in a bank account that pays 7 percent compounded quarterly. How much does she need to set aside?

11. A client can choose between receiving 10 annual $100,000 retirement payments, starting one year from today, or receiving a lump sum today. Knowing that he can invest at a rate of 5 percent annually, he has decided to take the lump sum. What lump sum today will be equivalent to the future annual payments?

12. A perpetual preferred stock position pays quarterly dividends of $1,000 indefinitely (forever). If an investor has a required rate of return of 12 percent per year on this type of investment, how much should he be willing to pay for this dividend stream?

13. At retirement, a client has two payment options: a 20-year annuity at €50,000 per year starting after one year or a lump sum of €500,000 today. If the client’s required rate of return on retirement fund investments is 6 percent per year, which plan has the higher present value and by how much?