# Contents

List of Figures and Table xxi Preface xxvii

## 1 Introduction 1

- 1.1 The Nature and Evolution of Macroeconomics 2
  - 1.1.1 Pre-Keynesian Macroeconomics 2
  - 1.1.2 Classical and Keynesian Macroeconomics 4
  - 1.1.3 Microeconomic Foundations of Macroeconomics 6
  - 1.1.4 Deterministic and Stochastic Dynamic General Equilibrium Models 7
- 1.2 Key Facts about Long-Run Economic Growth 11
  - 1.2.1 Cross-Country Differences in Per Capita Output and Income 11
  - 1.2.2 Evolution of Per Capita Output and Income over Time 13
  - 1.2.3 Economic Growth and Convergence since 1820 14
- 1.3 Key Facts about Aggregate Fluctuations 18
  - 1.3.1 Frequency, Severity, and Duration of Recessions 18
  - 1.3.2 Unemployment in Booms and Recessions 20
  - 1.3.3 Trends and Fluctuations in the Price Level and Inflation 22
  - 1.3.4 Monetary Policy and Government Debt 26
  - 1.3.5 Monetary Policy and Inflation in the Postwar Period 31
- 1.4 Conclusion 32

## 2 The Intertemporal Approach 33

- 2.1 Models, Variables, and Functions 34
- 2.2 General Equilibrium in a One-Period Competitive Model 36
  - 2.2.1 Endowments, Preferences, and the Optimal Behavior of Households 36
  - 2.2.2 The Production Function and the Profit-Maximizing Behavior of Firms 38
  - 2.2.3 The Cobb-Douglas Production Function 40
  - 2.2.4 General Equilibrium in the One-Period Model 40
- 2.3 Savings and Investment in a Two-Period Competitive Model 42
  - 2.3.1 The Representative Household in a Two-Period Model 42
  - 2.3.2 Implications of the Euler Equation for Consumption 45
  - 2.3.3 The Case of a Constant Elasticity of Intertemporal Substitution 46
  - 2.3.4 Firms, Technology, and the Optimal Output Path 48

- 2.3.5 General Equilibrium in the Two-Period Model 49
- 2.3.6 Diagrammatic Exposition of the Intertemporal Equilibrium 53
- 2.3.7 Implications for Growth and Business Cycle Theory 55
- 2.4 Consumption and Labor Supply in a One-Period Competitive Model 56
  - 2.4.1 The Optimal Choice of Consumption and Labor Supply 56
  - 2.4.2 Income and Substitution Effects on Labor Supply 58
  - 2.4.3 The Frisch Elasticity of Labor Supply 60
  - 2.4.4 The Production Function and the Optimal Decisions of Firms 61
  - 2.4.5 General Equilibrium and the Determination of Output and Employment 61
- 2.5 Consumption and Labor Supply in a Two-Period Competitive Model 62
  - 2.5.1 Optimal Consumption and Labor Supply in a Two-Period Model 63
  - 2.5.2 Intertemporal Substitution in Consumption and Labor Supply 64
  - 2.5.3 Optimal Production Decisions of Firms 65
  - 2.5.4 General Equilibrium and the Determination of Output and Employment 66
  - 2.5.5 Implications for Business Cycle Theory 68
- 2.6 Money, Prices, and Inflation in a Two-Period Competitive Model 69
  - 2.6.1 The Representative Household and the Demand for Money 69
    - 2.6.2 The Classical Dichotomy and the Neutrality of Money 71
  - 2.6.3 The Two-Period Competitive Model and Classical Monetary Theory 74
- 2.7 Fiscal Policy in a Two-Period Competitive Model 74
  - 2.7.1 Government Expenditure and Taxes in a One-Period Economy 74
  - 2.7.2 Income Taxes and Labor Supply 76
  - 2.7.3 Government Expenditure, Taxes, and Debt in a Two-Period Economy 77
  - 2.7.4 Ricardian Equivalence between Tax and Debt Finance 78
  - 2.7.5 Income Taxation and Aggregate Savings and Investment 81
  - 2.7.6 Implications for Fiscal Policy and Government Debt 81
- 2.8 The Treatment of Time and the Intertemporal Approach 82
- 2.9 Conclusion 84

### 3 Savings, Investment, and Economic Growth 85

- 3.1 The Solow Growth Model 87
  - 3.1.1 The Neoclassical Production Function 87
  - 3.1.2 The Cobb-Douglas Production Function 89
  - 3.1.3 Population Growth and Technical Progress 90
  - 3.1.4 Savings, Capital Accumulation, and Economic Growth 90
  - 3.1.5 The Balanced Growth Path and the Convergence Process 92
  - 3.1.6 The Rate of Growth of Capital and Output 93
  - 3.1.7 Significance of the Inada Conditions 95
- 3.2 Competitive Markets, the Real Interest Rate, and Real Wages 96
- 3.3 The Savings Rate and the Golden Rule 97
  - 3.3.1 The Savings Rate and the Balanced Growth Path 98
  - 3.3.2 The Savings Rate, the Golden Rule, and Dynamic Inefficiency 99
  - 3.3.3 The Elasticity of Steady State Output with Respect to the Savings Rate 101

- 3.4 Total Factor Productivity and Population Growth 102
  - 3.4.1 Dynamic Effects of Total Factor Productivity in the Solow Model 103
  - 3.4.2 Dynamic Effects of Population Growth in the Solow Model 104
- 3.5 Speed of Convergence toward the Balanced Growth Path 104
- 3.6 The Process of Economic Growth and the Solow Model 106
  - 3.6.1 The Kaldor Stylized Facts of Economic Growth 107
  - 3.6.2 Differences in Per Capita Output and Income between Developed and Less Developed Economies 108
  - 3.6.3 Conditional Convergence 110
- 3.7 Convergence with a Cobb-Douglas Production Function 110
- 3.8 Dynamic Simulations of a Calibrated Solow Model 111
  - 3.8.1 The Solow Model in Discrete Time 112
  - 3.8.2 The Calibrated Solow Model 113
  - 3.8.3 Dynamic Simulations of the Model 114
- 3.9 Conclusion 117

## 4 The Representative Household Model of Optimal Growth 119

- 4.1 The Optimal Intertemporal Path of Consumption 121
- 4.2 The Ramsey Model of Economic Growth 124
  - 4.2.1 The Production Function 124
  - 4.2.2 The Utility Function of the Representative Household 125
  - 4.2.3 The Accumulation of Capital and the Optimality of the Decentralized Competitive Equilibrium 126
  - 4.2.4 Conditions for Utility Maximization by the Representative Household 128
  - 4.2.5 The Euler Equation for Consumption 129
  - 4.2.6 The Intertemporal Budget Constraint of the Representative Household 130
  - 4.2.7 The Transversality Condition with an Infinite Time Horizon 132
  - 4.2.8 The Consumption Function of the Representative Household with an Infinite Horizon 133
- 4.3 Dynamic Adjustment and the Balanced Growth Path 135
  - 4.3.1 Dynamic Adjustment toward the Balanced Growth Path 135
  - 4.3.2 The Balanced Growth Path and the Modified Golden Rule 138
  - 4.3.3 Effects of a Permanent Increase in the Pure Rate of Time Preference 139
  - 4.3.4 Effects of a Permanent Increase in Total Factor Productivity 141
  - 4.3.5 Effects of a Permanent Increase in the Rate of Growth of Population 142
- 4.4 Properties of the Adjustment Path and the Speed of Convergence 143
- 4.5 Dynamic Simulations of a Calibrated Ramsey Model 146
  - 4.5.1 The Ramsey Model in Discrete Time 146
  - 4.5.2 The Calibrated Ramsey Model 148
  - 4.5.3 Dynamic Simulations of the Model 149
- 4.6 Conclusion 152

## 5 Overlapping Generations Models of Growth 153

- 5.1 The Diamond Model 154
  - 5.1.1 Definitions 155
  - 5.1.2 The Production Function 155

- 5.1.3 The Intertemporal Utility Function of Households 155
- 5.1.4 Markets and the Behavior of Households 156
- 5.1.5 Capital Accumulation and the Dynamic Adjustment of the Economy 157
- 5.1.6 A Simplified Diamond Model with Logarithmic Preferences and Cobb-Douglas Technology 159
- 5.1.7 The Speed of Adjustment in the Simplified Diamond Model 163
- 5.1.8 Welfare Implications of the Diamond Model and the Possibility of Dynamic Inefficiency 164
- 5.1.9 Dynamic Simulations of a Calibrated Diamond Model 165
- 5.2 The Blanchard-Weil Model 169
  - 5.2.1 Definitions 169
  - 5.2.2 The Production Function 170
  - 5.2.3 The Intertemporal Utility Function of Households and Household Consumption 170
  - 5.2.4 Aggregation across Generations 172
  - 5.2.5 The Model in Terms of Efficiency Units of Labor 173
  - 5.2.6 The Balanced Growth Path and the Adjustment Path 173
- 5.3 Dynamic Simulations of a Calibrated Blanchard-Weil Model 177
  - 5.3.1 The Blanchard-Weil Model in Discrete Time 178
  - 5.3.2 Dynamic Simulations of the Model 178
- 5.4 Conclusion 182

# 6 Fiscal Policy and Economic Growth 183

- 6.1 The Government Budget Constraint 185
  - 6.1.1 Government Deficits, Debt, and Solvency 185
- 6.2 Ricardian Equivalence and the Ramsey Model 187
  - 6.2.1 Ricardian Equivalence between Government Debt and Taxes 187
  - 6.2.2 Government Expenditure, Taxes, and Debt in the Ramsey Model 188
- 6.3 Dynamic Effects of Fiscal Policy in the Blanchard-Weil Model 191
  - 6.3.1 The Blanchard-Weil Model with Government Expenditure and Debt 191
  - 6.3.2 Government Debt, Taxes, and Redistribution across Generations 192
  - 6.3.3 Dynamic Simulations of Fiscal Policy in a Calibrated Blanchard-Weil Model 194
- 6.4 Dynamic Effects of Distortionary Taxation 201
  - 6.4.1 Distortionary and Nondistortionary Taxes 201
  - 6.4.2 Dynamic Effects of Capital Income and Business Gross Profits Taxation 203
  - 6.4.3 Dynamic Simulations of Increases in Capital Income and Business Gross Profits Taxation 205
- 6.5 Conclusion 206

### 7 Money, Inflation, and Economic Growth 209

- 7.1 Private Consumption and Money Demand in a Representative Household Model 211
  - 7.1.1 Money in the Utility Function of Households 211
  - 7.1.2 Nominal and Real Interest Rates and the Opportunity Cost of Real Money Balances 212

- 7.1.3 First-Order Conditions for an Optimum 212
- 7.1.4 The Money Demand Function 213
- 7.1.5 Growth Rate of the Money Supply and Inflation 214
- 7.1.6 The Euler Equation for Consumption 215
- 7.2 Aggregate Capital Accumulation in a Ramsey Model with Money 216
  7.2.1 The Production Function, the Real Interest Rate, and the Real Wage
  - 7.2.2 The Inflation Tax and the Accumulation of Capital 216
- 7.3 Effects of the Growth Rate of the Money Supply in the Ramsey Monetary Model 218
  - 7.3.1 The Balanced Growth Path in the Ramsey Model with Money 219
  - 7.3.2 The Superneutrality of Money and Inflation 220
  - 7.3.3 The Welfare Costs of Inflation in a Ramsey Model 221
- 7.4 Effects of Monetary Growth in an OLG Model 222
  - 7.4.1 The Blanchard-Weil Model with Money 223
  - 7.4.2 Real Effects of the Growth Rate of the Money Supply 224
  - 7.4.3 A Dynamic Simulation of the Effects of a Rise in the Growth Rate of the Money Supply in a Calibrated Blanchard-Weil Model 227
- 7.5 Conclusion 229

## 8 Externalities, Human Capital, and Technical Progress 231

- 8.1 Externalities from Capital Accumulation and Economic Growth 232
  - 8.1.1 Definitions 233
  - 8.1.2 The Production Function 233
  - 8.1.3 Externalities from the Accumulation of Capital 234
  - 8.1.4 Determination of the Real Interest Rate and the Real Wage 237
  - 8.1.5 The Savings Rate and the Endogenous Growth Rate 238
  - 8.1.6 Externalities and Endogenous Growth in the Ramsey Model 239
  - 8.1.7 The Suboptimality of the Competitive Equilibrium with Externalities Due to Capital Accumulation 241
  - 8.1.8 Externalities and Endogenous Growth in the Blanchard-Weil Model 242
  - 8.1.9 Fiscal Policy and Endogenous Growth 245
  - 8.1.10 Convergence in Exogenous and Endogenous AK Growth Models 247
- 8.2 Investment in Human Capital and Economic Growth 248
  - 8.2.1 The Extended Solow Model and the Share of Spending on Education and Training 249
  - 8.2.2 The Balanced Growth Path in the Extended Solow Model 250
  - 8.2.3 Endogenous Growth in the Extended Solow Model 251
  - 8.2.4 The Jones Model of Human Capital Accumulation 252
  - 8.2.5 The Lucas Model of Human Capital Accumulation and Endogenous Growth 253
  - 8.2.6 A Detailed Analysis of the Lucas Model 254
- 8.3 Ideas, Innovations, and Technical Progress 258
  - 8.3.1 Key Features of Ideas and Innovations 258
  - 8.3.2 Key Elements of an Ideas-and-Innovations Growth Model 259
  - 8.3.3 Endogenous Determination of the Rate of Technical Progress 261
  - 8.3.4 The Balanced Growth Path with Endogenous Technical Progress 261
- 8.4 Unified Growth Theory and the Transition from Stagnation to Growth 262

216

- 8.5 Institutions and Long-Run Growth 263
- 8.6 The New Stylized Facts of Economic Growth 265
- 8.7 Conclusion 266

## 9 Dynamic Stochastic Models under Rational Expectations 269

- 9.1 A Stochastic Expectational Model of a Competitive Market 271
  - 9.1.1 Absence of Uncertainty and Perfect Foresight 272
  - 9.1.2 Uncertainty and Adaptive Expectations 273
  - 9.1.3 The Rational Expectations Hypothesis 275
- 9.2 Rational Expectations for Linear Autoregressive Processes 277
- 9.3 First-Order Linear Expectational Models 279
  - 9.3.1 The Method of Repeated Substitutions 279
  - 9.3.2 The Method of Factorization 281
  - 9.3.3 The Method of Undetermined Coefficients 282
  - 9.3.4 Two Additional Economic Examples 282
  - 9.3.5 Alternative Assumptions about the Evolution of Exogenous Variables 284
  - 9.3.6 The Expectational Competitive Market Model Revisited 286
- 9.4 Second-Order Linear Expectational Models 286
  - 9.4.1 The Method of Factorization 287
  - 9.4.2 The Method of Undetermined Coefficients 288
  - 9.4.3 An Economic Example of a Second-Order System 290
- 9.5 Multivariate Linear Models with Rational Expectations 291
  - 9.5.1 The Blanchard-Kahn Method 291
  - 9.5.2 Other Solution Methods 293
  - 9.5.3 A Second-Order Example of the Blanchard-Kahn Method 293
- 9.6 Rational Expectations and Learning 295
- 9.7 Conclusion 295

### 10 Consumption and Portfolio Choice under Uncertainty 297

- 10.1 Consumption and Portfolio Choice 298
  - 10.1.1 The Random Walk Model of Consumption 301
  - 10.1.2 The Consumption Capital Asset Pricing Model 302
- 10.2 Full Analysis of Consumption and Portfolio Choice 303
  - 10.2.1 The Case of Logarithmic Preferences 303
    - 10.2.2 Quadratic Preferences and Certainty Equivalence 305
  - 10.2.3 The Permanent-Income Hypothesis with Quadratic Preferences 306
  - 10.2.4 The Consumption CAPM with Quadratic Preferences 307
  - 10.2.5 The Efficient Markets Hypothesis 308
- 10.3 Precautionary Savings and Borrowing Constraints 310
- 10.4 Conclusion 311

## 11 Investment and the Cost of Capital 313

- 11.1 Optimal Investment with Convex Adjustment Costs 315
  - 11.1.1 The Choice of Optimal Investment 315
  - 11.1.2 The Case of Zero Adjustment Costs 317

- 11.1.3 The Investment Function with Convex Adjustment Costs 317
- 11.1.4 The Determinants of *q* 317
- 11.1.5 Dynamic Adjustment of *q* and the Capital Stock *K* 318
- 11.2 Optimal Investment under Uncertainty 320
  - 11.2.1 The Value of a Firm under Uncertainty 321
  - 11.2.2 The Lucas-Prescott Model of Investment under Uncertainty 323
  - 11.2.3 Rational Expectations Equilibrium and Aggregate Investment
  - in the Lucas-Prescott Model 325
- 11.3 Conclusion 327

## 12 Money, Interest, and Prices 329

- 12.1 The Functions of Money 331
- 12.2 The Supply of Money and Central Banks 332
  - 12.2.1 Central Banks and Their Functions 332
    - 12.2.2 Central Banks and the Money Supply 333
- 12.3 The Demand for Money 336
- 12.4 Nominal Interest Rates and Short-Run Equilibrium in the Money Market 339
- 12.5 The Long-Run Neutrality of Money 343
  - 12.5.1 Monetary Growth, Inflation, and Nominal Interest Rates in the Long Run 345
  - 12.5.2 The Welfare Cost of Inflation 346
  - 12.5.3 The Long-Run Neutrality of Money and Monetary Reforms 346
- 12.6 Money and the Price Level in Dynamic General Equilibrium Models 347
  - 12.6.1 The Samuelson OLG Model 347
    - 12.6.2 Money in the Utility Function of a Representative Household 351
    - 12.6.3 Cash in Advance in a Representative Household Model 353
    - 12.6.4 Cash in Advance in an OLG Model 355
- 12.7 Nominal and Real Interest Rates and the Money Supply 357
  - 12.7.1 Money in the Utility Function of a Representative Household 357
  - 12.7.2 Cash in Advance in a Representative Household Model 359
  - 12.7.3 Cash in Advance in an OLG Model 359
  - 12.7.4 The Liquidity Effect in Representative Household Models 360
- 12.8 Interest Rate Pegging and Price Level Indeterminacy 361
  - 12.8.1 Interest Rate Pegging and Price Level Indeterminacy in Representative Household Models 361
  - 12.8.2 The Wicksell Solution to the Problem of Price Level Indeterminacy 362
  - 12.8.3 The Fiscal Theory of the Price Level 363
  - 12.8.4 The Pigou Effect and Price Level Determinacy in OLG Models 364
- 12.9 Money Growth, Seigniorage, and Inflation 364
  - 12.9.1 Relations between Monetary Growth, Seigniorage, and Inflation 365
  - 12.9.2 The Seigniorage Laffer Curve 367
  - 12.9.3 The Demand for Seigniorage and Equilibrium with High Inflation 368
  - 12.9.4 The Transition to Hyperinflation 368
  - 12.9.5 How Can High Inflation and Hyperinflation Be Tackled? 371
- 12.10 Conclusion 372

# 13 The Stochastic Growth Model of Aggregate Fluctuations 375

- 13.1 The Stochastic Growth Model 376
  - 13.1.1 Extending the Ramsey Model to Account for Aggregate Fluctuations 377
  - 13.1.2 The Representative Firm 377
  - 13.1.3 The Representative Household 378
  - 13.1.4 Exogenous Population Growth, Efficiency of Labor, and Government Expenditure 378
  - 13.1.5 Labor Supply of the Representative Household 380
  - 13.1.6 Intertemporal Substitution in Labor Supply 381
  - 13.1.7 Uncertainty and the Behavior of the Representative Household 382
- 13.2 A Simplified Version of the Stochastic Growth Model 383
  - 13.2.1 Fluctuations of Output in the Simplified Stochastic Growth Model 384
  - 13.2.2 The Simplified Stochastic Growth Model and the Evidence on Aggregate Fluctuations 385
- 13.3 A Log-Linear Approximation to the General Stochastic Growth Model 386
  - 13.3.1 The Steady State 387
  - 13.3.2 Log-Linearizing the Model around the Steady State 388
- 13.4 Solving the Log-Linear Stochastic Growth Model 390
  - 13.4.1 Aggregate Fluctuations around the Steady State 391
  - 13.4.2 A Dynamic Simulation of the Log-Linear Stochastic Growth Model 391
- 13.5 Conclusion 393

## 14 Perfectly Competitive Models with Flexible Prices 395

- 14.1 A Perfectly Competitive Model without Capital 396
  - 14.1.1 The Representative Household 396
  - 14.1.2 The Representative Firm 397
  - 14.1.3 General Equilibrium 398
- 14.2 Monetary Factors in a Perfectly Competitive Model 400
  - 14.2.1 An Exogenous Path for the Money Supply 400
  - 14.2.2 An Exogenous Path for the Nominal Interest Rate 401
  - 14.2.3 An Inflation-Based Nominal Interest Rate Rule 401
  - 14.2.4 Optimal Monetary Policy 402
- 14.3 Imperfect Information and the Nonneutrality of Money 403
  - 14.3.1 Competitive Equilibrium under Imperfect Information about the Price Level 403
  - 14.3.2 The Determination of Output and Employment 406
  - 14.3.3 The Real Effects of Monetary Shocks in a Rational Expectations Equilibrium 407
  - 14.3.4 Optimal Monetary Policy in the Lucas Model 410
  - 14.3.5 The New Classical Model and the Great Depression 410
  - 14.3.6 Models of Informational Frictions and Rational Inattention 411
- 14.4 Conclusion 411

# 15 Keynesian Models and the Phillips Curve 413

- 15.1 The Original Keynesian Models 415
  - 15.1.1 The Keynesian Cross 416
  - 15.1.2 The IS-LM Model 419
  - 15.1.3 The AD-AS Model 422
  - 15.1.4 The Impact of Aggregate Demand Policies 424
- 15.2 The Samuelson Multiplier Accelerator Model 427
- 15.3 The Theory of Discretionary Monetary and Fiscal Policy 429
  - 15.3.1 The Tinbergen-Theil Theory of Discretionary Aggregate Demand Policies 431
  - 15.3.2 Monetary and Fiscal Policy with a Full Employment Target 431
  - 15.3.3 Monetary and Fiscal Policy with a Full Employment Target and a Price Level Target 432
- 15.4 The Phillips Curve and Inflationary Expectations 435
  - 15.4.1 The Phillips Curve and the Trade-off between Inflation and Unemployment 435
  - 15.4.2 Instability of the Phillips Curve and Inflationary Expectations 437
- 15.5 The Natural Rate of Unemployment and Aggregate Demand Policies 439
  - 15.5.1 The Path of Inflation and Unemployment under Adaptive Expectations 440
  - 15.5.2 Rules versus Discretion in Aggregate Demand Policy 444
  - 15.5.3 Inflation and Unemployment under Rational Expectations 446
- 15.6 Conclusion 447

# 16 A Model of Imperfect Competition and Staggered Pricing 449

- 16.1 An Imperfectly Competitive Model of Aggregate Fluctuations 451
  - 16.1.1 The Representative Household 452
  - 16.1.2 The Representative Firm and Optimal Pricing 454
  - 16.1.3 Full Price Flexibility and the Natural Rate 455
  - 16.1.4 Inefficiency of the Natural Rate 456
- 16.2 Staggered Price Adjustment and Aggregate Fluctuations 457
  - 16.2.1 Optimal Pricing with Staggered Price Adjustment 459
  - 16.2.2 Equilibrium in the Market for Goods
    - and Services and the New Keynesian IS curve 461
  - 16.2.3 Labor Market Equilibrium and the New Keynesian Phillips Curve 462
  - 16.2.4 The Imperfectly Competitive Model with Staggered Pricing and the Taylor Rule 463
  - 16.2.5 Real and Monetary Shocks and Aggregate Fluctuations 464
  - 16.2.6 The Divine Coincidence and Optimal Monetary Policy in the New Keynesian Model with Staggered Pricing 468
  - 16.2.7 A Dynamic Simulation of the Model 469
- 16.3 The Rotemberg Model of Convex Costs of Price Adjustment 470
- 16.4 Conclusion 473

# 17 A Model of Unemployment and Nominal Wage Contracts 475

- 17.1 Alternative Views of the Labor Market and Equilibrium Unemployment 477
- 17.2 Households and Optimal Consumption and Money Demand 478

- 17.3 Firms and Optimal Pricing and Production 481
- 17.4 Wage Setting and Employment in a Model with Insiders and Outsiders 483
  - 17.4.1 Wage Determination, Unemployment Persistence, and the Phillips Curve 485
  - 17.4.2 The Relation between Output and Unemployment Persistence 487
  - 17.4.3 The Phillips Curve in Terms of Deviations of Output from Its Natural Rate 488
- 17.5 The Implications of Staggered Pricing 489
  - 17.5.1 Optimal Pricing with Staggered Price Adjustment 490
  - 17.5.2 Inflation and Unit Labor Costs under Staggered Pricing 491
- 17.6 An Extended New Keynesian Phillips Curve: Combining Staggered Pricing with Periodic Nominal Wage Contracts 492
- 17.7 Inflation and Aggregate Fluctuations under a Taylor Rule 494
  - 17.7.1 New Neoclassical Synthesis IS-LM Functions 494
  - 17.7.2 The Natural and Equilibrium Real Interest Rate 494
  - 17.7.3 Equilibrium Fluctuations with Exogenous Preference and Productivity Shocks 495
  - 17.7.4 Does Staggered Pricing Matter for Inflation Persistence? 500
  - 17.7.5 Inflation Stabilization and the Divine Coincidence 501
- 17.8 The Optimal Taylor Rule 502
  - 17.8.1 Optimal Inflation Policy 502
- 17.9 A Dynamic Simulation of the Effects of Monetary and Real Shocks 504
- 17.10 Conclusion 506

## 18 Matching Frictions and Equilibrium Unemployment 509

- 18.1 The Matching Function 510
  - 18.1.1 The Probability of Filling a Vacancy and Labor Market Tightness 511
  - 18.1.2 The Probability of the Unemployed Finding a Job 511
- 18.2 Flows into and out of Employment, Equilibrium Unemployment, and the Beveridge Curve 512
- 18.3 Firms and the Creation of Vacancies 513
  - 18.3.1 The Present Value of Net Expected Profits from an Existing Job 514
  - 18.3.2 The Present Value of Net Expected Profits from a Vacancy and the Creation of Vacancies 515
  - 18.3.3 Free Entry and the Job Creation Condition 516
- 18.4 The Behavior of Unemployed Job Seekers 517
  - 18.4.1 The Permanent Income of an Unemployed Job Seeker 518
  - 18.4.2 The Permanent Income of an Employed Worker 518
  - 18.4.3 Comparing the Permanent Income of the Employed and the Unemployed 518
- 18.5 Wage Bargaining and the Wage Equation 519
- 18.6 Wage Determination and Equilibrium Unemployment 521
- 18.7 Determinants of Equilibrium Unemployment, Real Wages, and Labor Market Tightness 523
  - 18.7.1 An Increase in Labor Productivity 523
  - 18.7.2 An Increase in Unemployment Benefits 525

- 18.7.3 An Increase in the Real Interest Rate 527
- 18.7.4 An Increase in the Probability of Job Destruction 527
- 18.8 Dynamic Adjustment to the Steady State
  - 18.8.1 The Dynamic Adjustment of Unemployment and Vacancies 530

527

- 18.8.2 Numerical Simulations of the Model 532
- 18.9 Matching Models and Nominal Rigidities 534
- 18.10 Conclusion 535

# 19 The Macroeconomic Implications of Financial Frictions 539

- 19.1 The Role of Finance and Financial Markets 539
  - 19.1.1 Financial Frictions and Financial Intermediation 541
  - 19.1.2 The Risks of Financial Intermediation, Leverage, and the External Finance Premium 542
  - 19.1.3 The Links between the Financial Sector and Real Activity in the Presence of Frictions 543
- 19.2 Financial Frictions in a New Keynesian Model with Staggered Pricing 544
- 19.3 Financial Frictions in a Model with Unemployment Persistence and Nominal Wage Contracts 546
- 19.4 Conclusion 548

# 20 The Role of Monetary Policy 551

- 20.1 Rules versus Discretion in Monetary Policy 552
- 20.2 Rules, Discretion, and Credibility in a New Keynesian Model 554
  - 20.2.1 The Social Welfare Loss from Inflation and Unemployment 555
  - 20.2.2 Monetary Policy under Discretion: The Problem of Credibility 556
  - 20.2.3 Monetary Policy under a Fixed Inflation Rule 559
  - 20.2.4 Central Bank Constitutions 559
  - 20.2.5 Reputation as a Solution to the Problem of Inflationary Bias 560
- 20.3 Optimal Monetary Policy in the Presence of Stochastic Shocks 562
- 20.4 The Mechanics of Monetary Policy 564
  - 20.4.1 Financial Markets and Open Market Operations 565
  - 20.4.2 The Term Structure of Interest Rates 566
- 20.5 Optimal Monetary Policy and the Taylor Rule 567
- 20.6 Monetary Policy Shocks and the Optimal Policy Rule 569
- 20.7 Monetary Policy, Financial Frictions, and the Zero Lower Bound on Interest Rates 571
  - 20.7.1 The Liquidity Trap 572
  - 20.7.2 Monetary Policy at the Zero Lower Bound 573
  - 20.7.3 The Zero Lower Bound and Unconventional Monetary Policy 574
- 20.8 Conclusion 576

# 21 Fiscal Policy and Government Debt 579

- 21.1 Tax Smoothing and Government Debt Accumulation 581
  - 21.1.1 The Barro Tax-Smoothing Model 581
  - 21.1.2 Steady State Implications of Tax Smoothing 583
- 21.2 Keynesian Stabilization Policy, Automatic Stabilizers, and Fiscal Implications of the Zero Lower Bound 585

- 21.3 Optimal Dynamic Ramsey Taxation 586
- 21.4 Fiscal Policy and Politics 589
  - 21.4.1 Distributional Considerations and Politics 589
  - 21.4.2 Electoral Eactors and Partisan Differences 590
- 21.5 The Burden of High Government Deficits and Debt 592
- 21.6 A Model of Government Debt Crises 593
  - 21.6.1 The Calvo Model 593
  - 21.6.2 Multiple Equilibria and Self-Fulfilling Prophecies 598
- 21.7 Conclusion 600

#### 22 Bubbles, Multiple Equilibria, and Sunspots 601

- 22.1 Bubbles in Linear Rational Expectations Models 602
  - 22.1.1 Bubbles versus Fundamentals 603
  - 22.1.2 Deterministic versus Stochastic Bubbles 604
  - 22.1.3 Bubbles as Self-Fulfilling Prophecies in Inherently Unstable Models 605
  - 22.1.4 Higher-Order Linear Models 607
- 22.2 Bubbles in Models of Stock and Money Markets 607
  - 22.2.1 Stock Market Bubbles 607
    - 22.2.2 Money Market Bubbles, the Price Level, and Inflation 609
- 22.3 Ruling Out Unstable Bubbles 611
- 22.4 Indeterminacy, Self-Fulfilling Prophecies, and Sunspots 612
  - 22.4.1 The Samuelson OLG Model with Money, Revisited 614
  - 22.4.2 Other Models of Indeterminacy and Sunspots in Macroeconomics 619
- 22.5 Conclusion 620

#### 23 The Interaction of Events and Ideas in Dynamic Macroeconomics 623

- 23.1 The Financial Crisis and Recent Developments in Dynamic Macroeconomics 624
- 23.2 The Interaction of Events and Ideas and the Role of Empirical Macroeconomics 626
- 23.3 Policy Evaluation and DSGE Models 628
- 23.4 Conclusion 629

### Appendixes 631

#### Α Variables, Functions, and Optimization 633

- Models, Variables, and Functions A 1 633
  - A.1.1 Functions 634
  - A.1.2 Derivatives and Partial Derivatives of Functions 635
  - A.1.3 Maxima and Minima of Functions 642
- A.2 Mathematical Optimization under Constraints 644
  - A.2.1 Constrained Optimization in the Case of a Function of One Variable 644
  - A.2.2 Optimal Consumption under an Income Constraint 645
  - A.2.3 The Lagrange Method 647
- A.3 Some Useful Functional Forms 651
  - A.3.1 The Two-Factor CES Production Function and the Elasticity of Substitution 652

- A.3.2 Special Cases of the CES Production Function 653
- A.3.3 The CES Production Function and the Solow Model of Economic Growth 653
- A.3.4 The CES Utility Function 655
- A.3.5 Additively Separable Utility and the CEIS Utility Function 655

# B Linear Models and Linear Algebra 659

- B.1 Linear Models 659
- B.2 Elements of Linear Algebra 660
  - B.2.1 Matrix Addition, Subtraction, and Multiplication 661
  - B.2.2 The Inverse of a Square Matrix 661
- B.3 An Example with Two Endogenous Variables 663
  - B.3.1 Cramer's Rule 664
  - B.3.2 The Augmented Matrix and Gauss-Jordan Elimination 664
  - B.3.3 Diagonalization, Eigenvalues, and Eigenvectors 665
  - B.3.4 Solving a System with Two Endogenous and Two Exogenous Variables 665

# C Ordinary Differential Equations 667

- C.1 Definitions 667
- C.2 First-Order Linear Differential Equations 669
  - C.2.1 Constant Coefficients 669
  - C.2.2 Variable Right-Hand Side 670
  - C.2.3 Variable Coefficients 671
  - C.2.4 Homogeneous and Nonhomogeneous Differential Equations 671
  - C.2.5 Convergence and Stability of First-Order Differential Equations 672
- C.3 Second-Order Linear Differential Equations 673
  - C.3.1 Homogeneous Equations with Constant Coefficients 673
  - C.3.2 Nonhomogeneous Equations with Constant Coefficients 674
- C.4 A Pair of First-Order Linear Differential Equations 675
  - C.4.1 The Method of Substitution 675
  - C.4.2 The Method of Eigenvalues 676
- C.5 A System of *n* First-Order Linear Differential Equations 678
  - C.5.1 Eigenvalues and Eigenvectors 679
  - C.5.2 Solving the *n*th-Order System of Linear Differential Equations 679

# D Difference Equations 683

- D.1 Lag Operators and Difference Equations 683
- D.2 First-Order Linear Difference Equations 686
- D.3 Second-Order Linear Difference Equations 687
- D.4 A Pair of First-Order Linear Difference Equations 689
- D.5 A System of *n* First-Order Linear Difference Equations 690

# E Methods of Intertemporal Optimization 693

- E.1 The Form of Dynamic Optimization Problems 693
- E.2 The Method of Optimal Control 694
- E.3 The Optimal Control Method in Continuous Time 696

- E.4 Dynamic Programming and the Bellman Equation 697
- E.5 An Example Based on Optimal Savings in Continuous Time 700

# F Random Variables and Stochastic Processes 703

- F.1 Probability 703
- F.2 Random Variables and Probability Distributions 704
  - F.2.1 Discrete Probability Distributions 704
  - F.2.2 Continuous Probability Distributions 705
  - F.2.3 Mathematical Expectation, Variance, and Higher Moments 706
  - F.2.4 Some Useful Probability Distributions 707
  - F.2.5 Convergence of Random Variables 712
  - F.2.6 The Law of Large Numbers 713
  - F.2.7 The Central Limit Theorem 714
  - F.2.8 Joint Probability Distributions 714
- F.3 Stochastic Processes 715
- F.4 Univariate Linear Stochastic Processes in Discrete Time 716
  - F.4.1 The White Noise Process 717
  - F.4.2 Moving Average Stochastic Processes 717
  - F.4.3 Autoregressive Stochastic Processes 718
  - F.4.4 Autoregressive Moving Average Stochastic Processes 720
- F.5 Vector Stochastic Processes and Vector Autoregressions 720

References 723

Index 743