

Introduction to Computational Economics Using Fortran

Hans Fehr

Fabian Kindermann

OXFORD
UNIVERSITY PRESS

■ CONTENTS

PART I AN INTRODUCTION TO FORTRAN 90 AND NUMERICAL METHODS

1 Fortran 90: A simple programming language	3
1.1 About Fortran in general	3
1.1.1 The history of Fortran	3
1.1.2 Why Fortran?	4
1.1.3 The workings of high-level programming languages	5
1.1.4 Fortran compilers for Windows, Mac, and Linux	6
1.2 Imperative Fortran programs	6
1.2.1 The general structure of Fortran programs	7
1.2.2 The declaration of variables	7
1.2.3 The basics of imperative programming	8
1.2.4 Control flow statements	11
1.2.5 The concept of arrays	16
1.3 Subroutines and functions	19
1.4 Modules and global variables	23
1.4.1 Storing code in a module	23
1.4.2 The concept of global variables	25
1.5 Installing the toolbox	27
1.6 Plotting graphs with the toolbox and GNUPlot	28
1.6.1 Two-dimensional plotting	28
1.6.2 Three-dimensional plotting	31
1.7 Further reading	34
1.8 Exercises	35
2 Numerical solution methods	39
2.1 Matrices, vectors, and linear equation systems	39
2.1.1 Matrices and vectors in Fortran	39
2.1.2 Solving linear equation systems	40
2.2 Nonlinear equations and equation systems	47
2.2.1 Bisection search in one dimension	48
2.2.2 Newton's method in one dimension	51
2.2.3 Fixed-point iteration methods	54
2.2.4 Multidimensional nonlinear equation systems	56
2.3 Function minimization	60
2.3.1 The Golden-Search method	61
2.3.2 Brent's and Powell's algorithms	63
2.3.3 The problem of local and global minima	67

x CONTENTS

2.4 Numerical integration	68
2.4.1 Summed Newton-Cotes methods	69
2.4.2 Gaussian quadrature	72
2.5 Random variables, distributions, and simulation	77
2.5.1 Random variables and their distribution	77
2.5.2 Simulating realizations of random variables	81
2.6 Function approximation and interpolation	85
2.6.1 Polynominal interpolation	88
2.6.2 Piecewise polynomial interpolation	91
2.6.3 A two-dimensional interpolation example	95
2.7 Linear programming	100
2.7.1 Graphical solution to linear programs in standard form	102
2.7.2 The simplex algorithm	103
2.8 Further reading	105
2.9 Exercises	106

PART II COMPUTATIONAL ECONOMICS FOR BEGINNERS

3 The static general equilibrium model	113
3.1 The basic economy model	113
3.1.1 The command optimum	113
3.1.2 The market solution	115
3.1.3 Variable labour supply	119
3.1.4 Public sector and tax incidence analysis	120
3.2 Extensions of the basic model	123
3.2.1 Imperfect labour markets and unemployment policy	123
3.2.2 Intermediate goods in production	126
3.2.3 Open economies and international trade	130
3.3 Further reading	134
3.4 Exercises	134
4 Topics in finance and risk management	139
4.1 Mean-variance portfolio theory	139
4.1.1 Portfolio choice with risky assets	139
4.1.2 Introducing risk-free assets	143
4.1.3 Short-selling constraints	146
4.1.4 Monte Carlo minimization	149
4.2 Option pricing theory	151
4.2.1 The binomial approach by Cox-Ross-Rubinstein	152
4.2.2 The Black-Scholes formula	155
4.2.3 Numerical implementation of both approaches	158
4.2.4 Option pricing with Monte Carlo simulation	161

4.3	Managing credit risk with corporate bonds	164
4.3.1	Modelling credit risk with a single corporate bond	164
4.3.2	Credit risk in a bond portfolio	173
4.4	Mortality risk management	184
4.4.1	Modelling longevity risk	184
4.4.2	Pricing and risk analysis of insurance products	189
4.4.3	Optimization of a mortality portfolio	196
4.5	Appendix	198
4.6	Further reading	200
4.7	Exercises	201
5	The life-cycle model and intertemporal choice	205
5.1	Why do people save?	205
5.1.1	Optimal savings in a certain world	205
5.1.2	Uncertain labour income and precautionary savings	207
5.1.3	Uncertain capital and labour income	212
5.2	Where do people save and invest?	214
5.2.1	Uncertain capital income and portfolio choice	214
5.2.2	Uncertain lifespan and annuity choice	218
5.3	Further reading	221
5.4	Exercises	222
6	The overlapping generations model	225
6.1	General structure and long-run equilibrium	225
6.1.1	Demographics, behaviour and markets	225
6.1.2	Computation of the long-run equilibrium	229
6.1.3	Long-run analysis of policy reforms	232
6.2	Transitional dynamics and welfare analysis	234
6.2.1	Computation of transitional dynamics	235
6.2.2	Generational welfare and aggregate efficiency	240
6.2.3	Comprehensive analysis of policy reforms	245
6.3	Further reading	250
6.4	Exercises	250
7	Extending the OLG model	253
7.1	Accounting for variable labour supply	253
7.1.1	The household decision problem	254
7.1.2	Functional forms and numerical implementation	255
7.1.3	Simulation results and economic interpretations	258
7.1.4	A note on labour-augmenting technological progress	261
7.2	Human capital and the growth process	263
7.2.1	Education investment and externalities	264
7.2.2	Numerical implementation and simulation	266

xii CONTENTS

7.2.3 Human-capital spillovers and endogenous growth	270
7.2.4 Numerical implementation and simulation	271
7.3 Longevity risk and annuitization	274
7.3.1 The households' problem without annuity markets	274
7.3.2 Numerical implementation and simulation	277
7.3.3 Introducing private annuity markets	279
7.4 Further reading	282
7.5 Exercises	282

PART III ADVANCED COMPUTATIONAL ECONOMICS

8 Introduction to dynamic programming	289
8.1 Motivation: The cake-eating problem	289
8.1.1 The all-in-one solution	290
8.1.2 The dynamic programming approach	291
8.1.3 An analytical solution	295
8.2 Numerical solution by value function iteration	298
8.2.1 Grid search	301
8.2.2 Optimization and interpolation	306
8.3 Numerical solution by policy function iteration	313
8.3.1 Root-finding and interpolation	314
8.3.2 The method of endogenous gridpoints	316
8.4 Further reading	320
8.5 Exercises	321
9 Dynamic macro I: Infinite horizon models	323
9.1 The basic neoclassical growth model	323
9.1.1 The model economy	324
9.1.2 Numerical implementation	329
9.1.3 A model with a public sector	334
9.2 The stochastic growth model	341
9.2.1 Modelling aggregate uncertainty	341
9.2.2 A numerical implementation using discretized shocks	344
9.2.3 Simulating time paths	350
9.2.4 Speeding up the computational process	352
9.3 The real business-cycle model	354
9.3.1 A dynamic program with endogenous labour supply	354
9.3.2 Numerical implementation with policy function iteration	356
9.3.3 Comparing model results to the data	358
9.3.4 The welfare costs of business-cycle fluctuations	363
9.3.5 Procyclical vs. constant government expenditure	369

9.4	The heterogeneous agent model	374
9.4.1	The basic setup	374
9.4.2	Solving for market-clearing prices	377
9.4.3	Determining household policy functions	380
9.4.4	Aggregation of individual decisions	385
9.4.5	Model parametrization and simulation	390
9.4.6	The optimum quantity of debt	394
9.5	Further reading	401
9.6	Exercises	401
10	Life-cycle choices and risk	406
10.1	Labour supply, savings, and risky earnings	406
10.1.1	The baseline model	407
10.1.2	The role of variable labour supply	422
10.1.3	Female labour-force participation	429
10.2	Portfolio choice and retirement savings	444
10.2.1	A model with stocks and bonds	444
10.2.2	The choice to buy annuities	469
10.2.3	Retirement savings in tax-favoured savings vehicles	478
10.3	Further reading	492
10.4	Exercises	493
11	Dynamic macro II: The stochastic OLG model	505
11.1	General structure and long-run equilibrium	505
11.1.1	Demographics, behaviour, and markets	506
11.1.2	Numerical implementation of steady-state equilibrium	512
11.1.3	Model parametrization and calibration	516
11.1.4	The initial equilibrium	521
11.1.5	Long-run analysis of policy reforms	523
11.2	Transitional dynamics and welfare analysis	525
11.2.1	Computation of transitional dynamics	525
11.2.2	Generational welfare and aggregate efficiency	527
11.3	Comprehensive analysis of policy reforms	539
11.3.1	The optimal size of the pension system	539
11.3.2	The optimal progressivity of the labour-income tax	544
11.3.3	Should capital income be taxed?	550
11.4	Further reading	556
11.5	Exercises	558
	BIBLIOGRAPHY	561
	INDEX	567