# Contents

Preface ix

1 Introduction to economic growth 1

1.1 The field ........................................... 1
1.1.1 Economic growth theory ........................... 1
1.1.2 Some long-run data ............................... 3
1.2 Calculation of the average growth rate ................. 4
1.2.1 Discrete compounding ............................ 4
1.2.2 Continuous compounding ......................... 6
1.2.3 Doubling time .................................... 7
1.3 Some stylized facts of economic growth ................. 7
1.3.1 The Kuznets facts ............................... 7
1.3.2 Kaldor’s stylized facts ........................... 8
1.4 Concepts of income convergence ......................... 9
1.4.1 $\beta$ convergence vs. $\sigma$ convergence ........... 10
1.4.2 Measures of dispersion ........................... 11
1.4.3 Weighting by size of population .................. 13
1.4.4 Unconditional vs. conditional convergence ........ 14
1.4.5 A bird’s-eye view of the data .................... 14
1.4.6 Other convergence concepts ....................... 18
1.5 Literature ........................................... 19

2 Review of technology 23

2.1 The production technology ........................... 23
2.1.1 A neoclassical production function ............... 24
2.1.2 Returns to scale .................................. 27
2.1.3 Properties of the production function under CRS ... 32
2.2 Technological change ............................... 35
2.3 The concepts of a representative firm and an aggregate production function ......................... 39
2.4 Long-run vs. short-run production functions* .......... 42
9.5 Some empirics ............................................. 152
9.6 Literature ................................................. 152

10 Human capital and knowledge creation in a growing economy 157
10.1 The model ................................................. 157
10.2 Productivity growth along a BGP with R&D ................. 158
  10.2.1 Balanced growth with R&D ............................. 159
  10.2.2 A precondition for sustained productivity growth when
       $g_h = 0$: population growth ............................... 161
  10.2.3 The concept of endogenous growth ....................... 163
10.3 Permanent level effects .................................... 163
10.4 The case of no R&D ....................................... 164
10.5 Outlook ................................................... 165
  10.5.1 The case $n = 0$ ......................................... 165
  10.5.2 The case of rising life expectancy ....................... 166
10.6 Concluding remarks ....................................... 168
10.7 References ................................................. 169

11 AK and reduced-form AK models. Consumption taxation. 171
11.1 General equilibrium dynamics in the simple AK model .... 171
11.2 Reduced-form AK models ................................... 174
11.3 On consumption taxation ................................... 174

12 Learning by investing: two versions 179
12.1 The common framework .................................... 180
  12.1.1 The individual firm ..................................... 181
  12.1.2 The individual household ............................... 182
  12.1.3 Equilibrium in factor markets ......................... 182
12.2 The arrow case: $\lambda < 1$ ................................ 183
  12.2.1 Dynamics ............................................... 183
  12.2.2 Two types of endogenous growth ....................... 188
12.3 Romer’s limiting case: $\lambda = 1$, $n = 0$ ................. 189
  12.3.1 Dynamics ............................................... 190
  12.3.2 Economic policy in the Romer case .................... 193
12.4 Appendix: The golden-rule capital intensity in the Arrow case 197

13 Perspectives on learning by doing and learning by investing 201
13.1 Learning by doing* ....................................... 202
  13.1.1 The case: $\lambda < 1$ in (13.3) ........................... 204
  13.1.2 The case $\lambda = 1$ in (13.3) ........................... 206
## CONTENTS

13.2 Disembodied learning by investing* .............................................. 207
  13.2.1 The Arrow case: $\lambda < 1$ and $n \geq 0$ ............................ 208
  13.2.2 The Romer case: $\lambda = 1$ and $n = 0$ ............................... 208
  13.2.3 The size of the learning parameter ................................. 209
13.3 Disembodied vs. embodied technical change* .................................. 212
  13.3.1 Disembodied technical change ........................................... 213
  13.3.2 Embodied technical change .............................................. 213
  13.3.3 Embodied technical change and learning by investing .......... 215
13.4 Static comparative advantage vs. dynamics of learning by doing* 218
  13.4.1 A simple two-sector learning-by-doing model .................... 219
  13.4.2 A more robust specification .......................................... 221
  13.4.3 Resource curse? .......................................................... 222
13.5 Robustness issues and scale effects ........................................ 222
  13.5.1 On terminology ......................................................... 223
  13.5.2 Robustness of simple endogenous growth models .............. 225
  13.5.3 Weak and strong scale effects ...................................... 227
  13.5.4 Discussion .............................................................. 229
13.6 Appendix ................................................................. 231
13.7 References ............................................................... 234

14 The lab-equipment model 239
  14.1 Overview of the economy ................................................... 240
    14.1.1 The sectorial production functions ............................... 240
    14.1.2 National income accounting ....................................... 242
    14.1.3 The potential for sustained productivity growth ............ 244
  14.2 Households and the labor market ......................................... 244
  14.3 Firms’ behavior ............................................................ 245
    14.3.1 The competitive producers of basic goods ...................... 245
    14.3.2 The monopolist suppliers of intermediate goods .......... 246
    14.3.3 R&D firms ............................................................ 248
  14.4 General equilibrium of an economy satisfying (A1) .................. 254
    14.4.1 The balanced growth path ......................................... 254
    14.4.2 Comparative analysis ............................................... 255

15 Stochastic erosion of innovator’s monopoly power 257
  15.1 The three production sectors ............................................. 258
  15.2 Temporary monopoly ....................................................... 259
  15.3 The reduced-form aggregate production function ................... 261
  15.4 The no-arbitrage condition under uncertainty ...................... 262
  15.5 The equilibrium rate of return when R&D is active .............. 264
  15.6 Transitional dynamics* .................................................. 266

## CONTENTS

15.7 Long-run growth .................................................. 267  
15.8 Economic policy .................................................. 269  
15.9 Appendix ......................................................... 270  
15.10 References ...................................................... 271  

16 Natural resources and economic growth 273  
16.1 Classification of means of production .......................... 273  
16.2 The notion of sustainable development ......................... 275  
16.3 Renewable resources ............................................. 277  
16.4 Non-renewable resources ........................................ 282  
  16.4.1 The DHSS model ............................................. 282  
  16.4.2 Endogenous technical progress ............................. 289  
16.5 Natural resources and the issue of limits to economic growth . 290  
16.6 Appendix: The CES function ................................... 291  
16.7 Literature ....................................................... 296  

17 Addendum to Chapter 2 299  
17.1 Skill-biased technical change in the sense of Hicks: An example 299  
17.2 Capital-skill complementarity .................................... 300  
17.3 Literature ....................................................... 301  

A Appendix: Errata 303  

Preface

This is a collection of earlier separate lecture notes in Economic Growth. The notes have been used in recent years in the course Economic Growth within the Master’s Program in Economics at the Department of Economics, University of Copenhagen.

Compared with the earlier versions of the lecture notes some chapters have been extended and in some cases divided into several chapters. In addition, discovered typos and similar have been corrected. In some of the chapters a terminal list of references is at present lacking.

The lecture notes are in no way intended as a substitute for the textbook: D. Acemoglu, *Introduction to Modern Economic Growth*, Princeton University Press, 2009. The lecture notes are meant to be read along with the textbook. Some parts of the lecture notes are alternative presentations of stuff also covered by the textbook, while many other parts are complementary in the sense of presenting additional material. Sections marked by an asterisk, *, are cursory reading.

For constructive criticism I thank Niklas Brønager, class instructor since 2012, and plenty of earlier students. No doubt, obscurities remain. Hence, I very much welcome comments and suggestions of any kind relating to these lecture notes.

February 2014

Christian Groth