

# Agricultural Production Economics

## SECOND EDITION

### Table of Contents

|                                                                         |               |
|-------------------------------------------------------------------------|---------------|
| <b>Chapter 1. Introduction</b>                                          | <b>1</b>      |
| 1.1 Economics Defined                                                   | 2             |
| 1.2 The Logic of Economic Theory                                        | 2             |
| 1.3 Economic Theory as Abstraction                                      | 3             |
| 1.4 Economic Theory Versus Economic Model                               | 3             |
| 1.5 Representing Economic Relationships                                 | 4             |
| 1.6 Consumption Versus Production Economics                             | 4             |
| 1.7 Microeconomics Versus Macroeconomics                                | 5             |
| 1.8 Statics Versus Dynamics                                             | 6             |
| 1.9 Economics Versus Agricultural Economics                             | 7             |
| 1.10 Agricultural Production Economics                                  | 7             |
| 1.11 The Assumptions of Pure Competition                                | 8             |
| 1.12 Why Retain the Purely Competitive Model                            | 10            |
| 1.13 Concluding Comments                                                | 10            |
| Questions for Thought and Class Discussion                              | 12            |
| References                                                              | 12            |
| <br><b>Chapter 2. Production With One Variable Input</b>                | <br><b>13</b> |
| 2.1 What Is a Production Function                                       | 14            |
| 2.2 Fixed Versus Variable Inputs and the Length of Run                  | 17            |
| 2.3 The Law of Diminishing Returns                                      | 19            |
| 2.4 Marginal and Average Physical Product                               | 21            |
| 2.5 <i>MPP</i> and the Marginal Product Function                        | 22            |
| 2.6 A Neoclassical Production Function                                  | 26            |
| 2.7 <i>MPP</i> and <i>APP</i> for the Neoclassical Function             | 28            |
| 2.8 Sign, Slope and Curvature                                           | 29            |
| 2.9 A Single-Input Production Elasticity                                | 33            |
| 2.10 Elasticities of Production for a Neoclassical Production Function  | 35            |
| 2.11 Further Topics on the Elasticity of Production                     | 36            |
| 2.12 Concluding Comments                                                | 37            |
| Problems and Exercises                                                  | 37            |
| <br><b>Chapter 3. Profit Maximization with One Input and One Output</b> | <br><b>39</b> |
| 3.1 Total Physical Product Versus Total Value of the Product            | 40            |
| 3.2 Total Factor or Resource Cost                                       | 41            |

|                   |                                                                                     |            |
|-------------------|-------------------------------------------------------------------------------------|------------|
| 3.3               | Value of the Marginal Product and Marginal Factor Cost . . . . .                    | 41         |
| 3.4               | Equating $VMP$ and $MFC$ . . . . .                                                  | 43         |
| 3.5               | Calculating the Exact Level of Input Use<br>to Maximize Output or Profits . . . . . | 45         |
| 3.6               | General Conditions for Profit Maximization . . . . .                                | 51         |
| 3.7               | Necessary and Sufficient Conditions . . . . .                                       | 52         |
| 3.8               | The Three Stages of the Neoclassical Production Function . . . . .                  | 52         |
| 3.9               | Further Topics on States of Production . . . . .                                    | 56         |
| 3.10              | The Imputed Value of an Additional Unit of an Input . . . . .                       | 56         |
| 3.11              | Concluding Comments . . . . .                                                       | 59         |
|                   | Problems and Exercises . . . . .                                                    | 59         |
| <b>Chapter 4.</b> | <b>Costs, Returns and Profits on the Output Side . . . . .</b>                      | <b>61</b>  |
| 4.1               | Some Basic Definitions . . . . .                                                    | 62         |
| 4.2               | Simple Profit Maximization from the Output Side . . . . .                           | 68         |
| 4.3               | The Duality of Cost and Production . . . . .                                        | 71         |
| 4.4               | The Inverse of a Production Function . . . . .                                      | 74         |
| 4.5               | Linkages between Cost and Production Functions . . . . .                            | 76         |
| 4.6               | The Supply Function for the Firm . . . . .                                          | 77         |
| 4.7               | Concluding Comments . . . . .                                                       | 79         |
|                   | Problems and Exercises . . . . .                                                    | 79         |
| <b>Chapter 5.</b> | <b>Production with Two Inputs . . . . .</b>                                         | <b>81</b>  |
| 5.1               | Introduction . . . . .                                                              | 82         |
| 5.2               | An Isoquant and the Marginal Rate of Substitution . . . . .                         | 86         |
| 5.3               | Isoquants and Ridge Lines . . . . .                                                 | 93         |
| 5.4               | $MRS$ and the Marginal Product . . . . .                                            | 95         |
| 5.5               | Partial and Total Derivatives and the Marginal Rate of Substitution . . . . .       | 96         |
| 5.6               | Concluding Comments . . . . .                                                       | 99         |
|                   | Problems and Exercises . . . . .                                                    | 100        |
| <b>Chapter 6.</b> | <b>Maximization in the Two-Input Case . . . . .</b>                                 | <b>102</b> |
| 6.1               | Introduction to Maximization . . . . .                                              | 103        |
| 6.2               | The Maximum of a Function . . . . .                                                 | 104        |
| 6.3               | Some Illustrative Examples . . . . .                                                | 105        |
| 6.4               | Some Matrix Algebra Principles . . . . .                                            | 110        |
| 6.5               | A Further Illustration . . . . .                                                    | 111        |
| 6.6               | Maximizing a Profit Function with Two Inputs . . . . .                              | 112        |
| 6.7               | A Comparison with Output- or Yield-Maximization Criteria . . . . .                  | 115        |
| 6.8               | Concluding Comments . . . . .                                                       | 116        |
|                   | Problems and Exercises . . . . .                                                    | 117        |

|                                                                |     |
|----------------------------------------------------------------|-----|
| <b>Chapter 7. Maximization Subject to Budget Constraints</b>   | 118 |
| 7.1 Introduction                                               | 119 |
| 7.2 The Budget Constraint                                      | 119 |
| 7.3 The Budget Constraint and the Isoquant Map                 | 121 |
| 7.4 Isoclines and the Expansion Path                           | 123 |
| 7.5 General Expansion Path Conditions                          | 124 |
| 7.6 The Production Function for the Bundle                     | 126 |
| 7.7 Pseudo-Scale Lines                                         | 128 |
| 7.8 Summary of Marginal Conditions and Concluding Comments     | 131 |
| Problems and Exercises                                         | 134 |
| <br><b>Chapter 8. Further Topics in Constrained</b>            |     |
| <b>Maximization and Minimization</b>                           | 135 |
| 8.1 Simple Mathematics of Global Profit Maximization           | 136 |
| 8.2 Constrained Revue Maximization                             | 138 |
| 8.3 Second Order Conditions                                    | 142 |
| 8.4 Interpretation of the Lagrangean Multiplier                | 143 |
| 8.5 Constrained Output Maximization                            | 145 |
| 8.6 Cost-Minimization Subject to a Revenue Constraint          | 147 |
| 8.7 Application in the Design of a Lease                       | 148 |
| 8.7.1 Cash Rent                                                | 148 |
| 8.7.2 Shared Rental Arrangements                               | 149 |
| 8.8 An Application to an Acreage Allotment Problem             | 151 |
| 8.9 Concluding Comments                                        | 154 |
| Problems and Exercises                                         | 155 |
| Reference                                                      | 156 |
| <br><b>Chapter 9. Returns to Scale, Homogeneous Functions,</b> |     |
| <b>and Euler's Theorem</b>                                     | 157 |
| 9.1 Economies and Diseconomies of Size                         | 158 |
| 9.2 Economies and Diseconomies of Scale                        | 159 |
| 9.3 Homogeneous Production Functions                           | 161 |
| 9.4 Returns to Scale and Individual Production Elasticities    | 162 |
| 9.5 Duality of Production and Cost for the Input Bundle        | 164 |
| 9.6 Euler's Theorem                                            | 167 |
| 9.7 Concluding Comments                                        | 168 |
| Problems and Exercises                                         | 169 |
| <br><b>Chapter 10. The Cobb-Douglas Production Function</b>    | 171 |
| 10.1 Introduction                                              | 172 |
| 10.2 The Original Cobb-Douglas Function                        | 172 |

|                                                                        |                                                                       |            |
|------------------------------------------------------------------------|-----------------------------------------------------------------------|------------|
| 10.3                                                                   | Early Generalizations .....                                           | 173        |
| 10.4                                                                   | Some Characteristics of the Cobb-Douglas Type of Function .....       | 174        |
| 10.5                                                                   | Isoquants for the Cobb-Douglas Type of Function .....                 | 175        |
| 10.6                                                                   | The Production Surface for the Cobb-Douglas Production Function ..... | 177        |
| 10.7                                                                   | Profit Maximization with the Cobb-Douglas Production Function ..      | 180        |
| 10.8                                                                   | Duality and the Cobb-Douglas Production Function .....                | 181        |
| 10.9                                                                   | Constrained Output or Revenue Maximization .....                      | 184        |
| 10.10                                                                  | Concluding Comments .....                                             | 185        |
|                                                                        | Problems and Exercises .....                                          | 185        |
|                                                                        | Reference .....                                                       | 186        |
| <b>Chapter 11. Other Agricultural Production Functions .....</b>       |                                                                       | <b>187</b> |
| 11.1                                                                   | Introduction .....                                                    | 188        |
| 11.2                                                                   | The Spillman .....                                                    | 188        |
| 11.3                                                                   | The Transcendental Production Function .....                          | 189        |
| 11.4                                                                   | The Two-Input Transcendental .....                                    | 190        |
| 11.5                                                                   | Illustrations and Applications of the Transcendental .....            | 193        |
| 11.6                                                                   | Cobb-Douglas with Variable Input Elasticities .....                   | 196        |
| 11.7                                                                   | de Janvry Modifications .....                                         | 196        |
| 11.8                                                                   | Polynomial Forms .....                                                | 197        |
| 11.9                                                                   | Concluding Comments .....                                             | 198        |
|                                                                        | Problems and Exercises .....                                          | 198        |
|                                                                        | References .....                                                      | 199        |
| <b>Chapter 12. The Elasticity of Substitution .....</b>                |                                                                       | <b>200</b> |
| 12.1                                                                   | An Introduction to the Concept .....                                  | 201        |
| 12.2                                                                   | Elasticities of Substitution and the Cobb Douglas Function .....      | 204        |
| 12.3                                                                   | Policy Applications of the Elasticity of Substitution .....           | 205        |
| 12.4                                                                   | The CES Production Function .....                                     | 207        |
| 12.5                                                                   | Concluding Comments .....                                             | 212        |
|                                                                        | Problems and Exercises .....                                          | 213        |
|                                                                        | References .....                                                      | 213        |
| <b>Chapter 13. The Demand for Inputs to the Production Process ...</b> |                                                                       | <b>215</b> |
| 13.1                                                                   | Introduction .....                                                    | 216        |
| 13.2                                                                   | A Single-Input Setting .....                                          | 216        |
| 13.3                                                                   | The Elasticity of Input Demand .....                                  | 218        |
| 13.4                                                                   | Technical Complements, Competitiveness and Independence .....         | 221        |
| 13.5                                                                   | Input Demand Functions in a Two-Input Setting .....                   | 222        |
| 13.6                                                                   | Input Demand Functions Under Constrained Maximization .....           | 225        |
| 13.7                                                                   | Comparative Statics and Input Demand Elasticities .....               | 227        |
| 13.8                                                                   | Concluding Comments .....                                             | 230        |

|                                                                           |     |
|---------------------------------------------------------------------------|-----|
| Problems and Exercises .....                                              | 231 |
| Reference .....                                                           | 231 |
| <br><b>Chapter 14. Variable Product and Input Prices</b> .....            | 232 |
| 14.1 Relaxing the Assumptions of Pure Competition .....                   | 233 |
| 14.2 Variation in Output Prices from the Output Side .....                | 233 |
| 14.3 Variation in Output Prices from the Input Side .....                 | 236 |
| 14.4 Variable Input Prices .....                                          | 239 |
| 14.5 A General Profit Maximization Statement .....                        | 239 |
| 14.6 Concluding Comments .....                                            | 241 |
| Problems and Exercises .....                                              | 242 |
| <br><b>Chapter 15. Production of More Than One Product</b> .....          | 243 |
| 15.1 Production Possibilities for a Society .....                         | 244 |
| 15.2 Production Possibilities at the Farm Level .....                     | 245 |
| 15.3 General Relationships .....                                          | 247 |
| 15.4 Competitive, Supplementary, Complementary and Joint Products ...     | 249 |
| 15.5 Product Transformations from Single-Input Production Functions ..    | 250 |
| 15.6 Product Transformation and the Output Elasticity of Substitution ... | 254 |
| 15.7 Concluding Comments .....                                            | 257 |
| Problems and Exercises .....                                              | 258 |
| References .....                                                          | 258 |
| <br><b>Chapter 16. Maximization in a Two-Output Setting</b> .....         | 259 |
| 16.1 The Family of Product Transformation Functions .....                 | 260 |
| 16.2 Maximization of Output .....                                         | 260 |
| 16.3 The Isorevenue Line .....                                            | 261 |
| 16.4 Constrained Revenue Maximization .....                               | 262 |
| 16.5 Simple Mathematics of Constrained Revenue Maximization .....         | 265 |
| 16.6 Second-Order Conditions .....                                        | 268 |
| 16.7 An Additional Example .....                                          | 270 |
| 16.8 Minimization Subject to a Revenue Constraint .....                   | 273 |
| 16.9 An Output Restriction Application .....                              | 275 |
| 16.10 Concluding Comments .....                                           | 277 |
| Problems and Exercises .....                                              | 277 |
| <br><b>Chapter 17. Two Outputs and Two Inputs</b> .....                   | 279 |
| 17.1 Introduction .....                                                   | 280 |
| 17.2 Two Inputs and Two Outputs: A Basic Presentation .....               | 280 |
| 17.3 Some General Principles .....                                        | 282 |

|                                                                                            |                                                                 |     |
|--------------------------------------------------------------------------------------------|-----------------------------------------------------------------|-----|
| 17.4                                                                                       | The Constrained Maximization Problem .....                      | 284 |
| 17.5                                                                                       | An Intermediate Product Model .....                             | 285 |
| 17.6                                                                                       | Concluding Comments .....                                       | 289 |
|                                                                                            | Problems and Exercises .....                                    | 290 |
| <br><b>Chapter 18. General Multiple-Product and Multiple-Input Conditions</b> .....        |                                                                 |     |
| 18.1                                                                                       | Introduction .....                                              | 292 |
| 18.2                                                                                       | Multiple Inputs and a Single Output .....                       | 292 |
| 18.3                                                                                       | Many Outputs and a Single Input .....                           | 295 |
| 18.4                                                                                       | Many Inputs and Many Outputs .....                              | 296 |
| 18.5                                                                                       | Concluding Comments .....                                       | 299 |
|                                                                                            | Problems and Exercises .....                                    | 300 |
| <br><b>Chapter 19. Enterprise Budgeting and Marginal Analysis</b> .....                    |                                                                 |     |
| 19.1                                                                                       | The Development of an Enterprise Budget .....                   | 302 |
| 19.2                                                                                       | The Level of Output to be Produced .....                        | 304 |
| 19.3                                                                                       | The Variable Input Levels .....                                 | 305 |
| 19.4                                                                                       | The Fixed Input Allocation .....                                | 306 |
| 19.5                                                                                       | The Economies of Size and Farm Budgets .....                    | 307 |
| 19.6                                                                                       | Price and Output Uncertainty .....                              | 307 |
| 19.7                                                                                       | Concluding Comments .....                                       | 308 |
|                                                                                            | Problems and Exercises .....                                    | 308 |
| <br><b>Chapter 20. Decision Making in an Environment<br/>of Risk And Uncertainty</b> ..... |                                                                 |     |
| 20.1                                                                                       | Risk and Uncertainty Defined .....                              | 309 |
| 20.2                                                                                       | Farmer Attitudes Toward Risk and Uncertainty .....              | 310 |
| 20.3                                                                                       | Actions, States of Nature, Probabilities and Consequences ..... | 312 |
| 20.4                                                                                       | Risk Preference and Utility .....                               | 314 |
| 20.5                                                                                       | Risk, Uncertainty and Marginal Analysis .....                   | 316 |
| 20.6                                                                                       | Strategies for Dealing with Risk and Uncertainty .....          | 318 |
|                                                                                            | 20.6.1 Insure Against Risk .....                                | 318 |
|                                                                                            | 20.6.2 Contracts .....                                          | 319 |
|                                                                                            | 20.6.3 Flexible Facilities and Equipment .....                  | 319 |
|                                                                                            | 20.6.4 Diversification .....                                    | 320 |
|                                                                                            | 20.6.5 Government Programs .....                                | 321 |
| 20.7                                                                                       | Concluding Comments .....                                       | 322 |
|                                                                                            | Problems and Exercises .....                                    | 322 |
|                                                                                            | Reference .....                                                 | 323 |
| <br><b>Chapter 21.1 Time and Agricultural Production Processes</b> .....                   |                                                                 |     |
|                                                                                            |                                                                 | 324 |

|                    |                                                                      |            |
|--------------------|----------------------------------------------------------------------|------------|
| 21.1               | Introduction .....                                                   | 325        |
| 21.2               | Alternative Goals of a Farm Manager over Many Seasons .....          | 325        |
| 21.2.1             | Long-Run Profit Maximization .....                                   | 325        |
| 21.2.2             | Accumulation of Wealth .....                                         | 326        |
| 21.2.3             | Other Goals .....                                                    | 326        |
| 21.3               | Time as an Input to the Production Process .....                     | 327        |
| 21.4               | Time, Inflation, Interest Rates and Net Worth .....                  | 328        |
| 21.5               | Discounting Future Revenues and Costs .....                          | 329        |
| 21.5.1             | The Present Value of a Dollar .....                                  | 329        |
| 21.5.2             | Discounting Revenues with the Present Value Formula ....             | 330        |
| 21.5.3             | Compounding Revenues and Costs .....                                 | 331        |
| 21.6               | Polyperiod Production and Marginal Analysis .....                    | 332        |
| 21.7               | Concluding Comments .....                                            | 335        |
|                    | Problems and Exercises .....                                         | 336        |
| <b>Chapter 22.</b> | <b>Linear Programming and Marginal Analysis .....</b>                | <b>337</b> |
| 22.1               | Introduction .....                                                   | 338        |
| 22.2               | Classical Optimization and Linear Programming .....                  | 338        |
| 22.3               | Assumptions of Linear Programming .....                              | 339        |
| 22.4               | Technical Requirements and Fixed-Proportion Production Functions     | 340        |
| 22.5               | A Simple Constrained Maximization Problem .....                      | 340        |
| 22.6               | Other Approaches for Solving Linear Programming Models .....         | 343        |
| 22.7               | The Simplex Method .....                                             | 344        |
| 22.8               | Duality .....                                                        | 348        |
| 22.9               | An Application .....                                                 | 350        |
| 22.10              | Concluding Comments .....                                            | 353        |
|                    | Problems and Exercises .....                                         | 354        |
| <b>Chapter 23.</b> | <b>Frontiers in Agricultural Production Economics Research .....</b> | <b>355</b> |
| 23.1               | Management and Agricultural Production Functions .....               | 356        |
| 23.1.1             | Alternative Approaches to Management .....                           | 356        |
| 23.1.2             | Management and Profit Maximization .....                             | 357        |
| 23.2               | New Technology and the Agricultural Production Function .....        | 358        |
| 23.2.1             | Some Examples .....                                                  | 360        |
| 23.2.2             | Time and Technology .....                                            | 361        |
| 23.3               | Conceptual Issues in Estimating Agricultural Production Functions .  | 362        |
| 23.4               | Concluding Comments .....                                            | 364        |
|                    | Problems and Exercises .....                                         | 364        |
|                    | Reference .....                                                      | 365        |

|                                                                                         |                |
|-----------------------------------------------------------------------------------------|----------------|
| <b>Chapter 24. Contemporary Production Theory: The Factor Side</b>                      | <b>366</b>     |
| 24.1 Introduction                                                                       | 367            |
| 24.2 Fundamentals of Duality                                                            | 367            |
| 24.3 Duality Theorems                                                                   | 373            |
| 24.4 The Envelope Theorem                                                               | 374            |
| 24.5 Shephard's Lemma                                                                   | 374            |
| 24.6 Hotelling's Lemma                                                                  | 376            |
| 24.7 Alternative Elasticity of Substitution Measures                                    | 378            |
| 24.8 Elasticities of Substitution and the Cobb-Douglas Specification                    | 383            |
| 24.9 The CES, or Constant Elasticity of Substitution Specification                      | 384            |
| 24.10 The Transcendental Production Function and $\mathbf{F}$                           | 385            |
| 24.11 Linear in the Parameters Functional Forms<br>And the Translog Production Function | 386            |
| 24.12 Restrictions and Other Estimation Problems                                        | 389            |
| 24.13 Elasticities of Substitution for U.S. Agriculture                                 | 389            |
| 24.14 An Empirical Illustration                                                         | 390            |
| 24.15 Theoretical Derivation                                                            | 390            |
| 24.16 Empirical Results                                                                 | 392            |
| 24.17 Concluding Comments                                                               | 395            |
| References                                                                              | 395            |
| <br><b>Chapter 25. Contemporary Production Theory: The Product Side</b>                 | <br><b>398</b> |
| 25.1 Introduction                                                                       | 399            |
| 25.2 Duality in Product Space                                                           | 399            |
| 25.3 Cobb-Douglas-Like Product Space                                                    | 401            |
| 25.4 CES-Like Functions in Product Space                                                | 402            |
| 25.5 Alternative Elasticity of Substitution Measures in Product Space                   | 403            |
| 25.6 Translog-Like Functions in Product Space                                           | 408            |
| 25.7 Translog Revenue Functions                                                         | 408            |
| 25.8 Empirical Applications                                                             | 410            |
| References                                                                              | 411            |