Institut für Landwirtschaftliche Betriebslehre der Universität Hohenheim
Fachgebiet Produktionstheorie und Ressourcenökonomik im Agrarbereich
Prof. Dr. Stephan Dabbert

Calibrating Regional Production Models Using Positive Mathematical Programming

An Agro-environmental Policy Analysis in Southwest Germany

Dissertation zur Erlangung des Grades eines Doktors der
Agrarwissenschaften der Fakultät IV – Agrarwissenschaften II

von

Johannes Umstätter

aus Mainz

1999

Vorliegende Arbeit wurde am 24. Juni 1999 von der Fakultät IV – Agrarwissenschaften II – der Universität Hohenheim als „Dissertation zur Erlangung des Grades eines Doktors der Agrarwissenschaften“ angenommen.

Tag der mündlichen Prüfung:	23. Juli 1999
Dekan:	Prof. Dr. Thomas Jungbluth
Berichterstatter, 1. Prüfer:	Prof. Dr. Stephan Dabbert
Mitberichterstatter, 2. Prüfer:	Prof. Dr. Arno Henze
3. Prüfer:	Prof. Dr. Werner Doppler

Studien zur Agrar- und Umweltpolitik

Herausgegeben von
Prof. Dr. W. Henrichsmeyer

Johannes Umstätter

Calibrating Regional Production Models Using Positive Mathematical Programming

An Agro-environmental Policy Analysis in Southwest Germany

D 100 (Diss. Universität Hohenheim)

Shaker Verlag
Aachen 1999

Die Deutsche Bibliothek - CIP-Einheitsaufnahme

Umstätter, Johannes:
Calibrating Regional Production Models Using Positive Mathematical Programming : An Agro-environmental Policy Analysis in Southwest Germany / Johannes Umstätter.
- Als Ms. gedr. - Aachen : Shaker, 1999
(Studien zur Agrar- und Umweltpolitik)
Zugl.: Hohenheim, Univ., Diss., 1999
ISBN 3-8265-6674-2

Copyright Shaker Verlag 1999
All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission of the publishers.

Printed in Germany.

ISBN 3-8265-6674-2
ISSN 0945-4675

Shaker Verlag GmbH • P.O. Box 1290 • D-52013 Aachen
Telefon: 0049/2407/9596 - 0 • Telefax: 0049/2407/9596 - 9
Internet: www.shaker.de • eMail: info@shaker.de

Acknowledgements

It is a pleasure to thank my advisor, Prof. Dr. Stephan Dabbert, for his support, encouragement and guidance during my doctoral studies. I would also like to extend my gratitude to the members of my committee, Prof. Dr. Arno Henze and Prof. Dr. Werner Doppler, for their time and interest in my research project.

My particular thanks go to Prof. Richard Howitt and Prof. Quirino Paris at the Department of Agricultural and Resource Economics at the University of California Davis (UC Davis). Their generous and patient assistance with my efforts to study PMP was of immeasurable value for the successful completion of this thesis. I would also like to acknowledge the invitation to stay as a visiting scholar at UC Davis which was extended to me by Prof. Richard Sexton.

This research has also benefited greatly from discussions with my colleagues in the department of Farm Economics at the University of Hohenheim. Special thanks go to the secretaries of the same department whose caring assistance was outstanding.

This research was generously supported with funds from the Volkswagenstiftung. I would also like to acknowledge the support from the German Academic Exchange Service (DAAD) whose generous scholarship enabled me to stay as a visiting scholar at UC Davis.

Johannes Umstätter

Stuttgart
July 23, 1999

Table of contents

page

Table of contents I

List of tables III

List of figures IV

List of abbreviations and units V

1 Introduction 1

2 Positive mathematical programming 5

2.1 The role of calibration in programming models 5

2.1.1 Calibrating with calibration constraints 7

2.1.2 Calibrating with nonlinear objective functions 12

2.1.3 Calibrating with PMP 14

2.2 Methodology of PMP 15

2.2.1 Original PMP version according to Howitt 17

2.2.2 Extended PMP version on the basis of increasing marginal costs 30

2.2.3 Extended PMP version on the basis of decreasing marginal yields 46

2.2.4 PMP version according to Paris 64

2.2.5 Scenario runs with PMP models 72

2.3 Overview of previous PMP applications and developments 87

2.3.1 Original PMP version according to Howitt 88

2.3.2 Original PMP version with extended Leontieff technology 89

2.3.3 Extended PMP version on the basis of increasing marginal costs 90

2.3.4 PMP version according to Paris 90

2.3.5 Specification of complex production functions using PMP 91

2.3.6 Maximum entropy 91

2.4 Selection of the PMP version to be used in the regional optimization model 92

3 The regional optimization model ROMEO 94

3.1 Spatial resolution of ROMEO 94

3.2 Temporal resolution of ROMEO 96

3.3 Production activities covered in ROMEO 96

3.4 Mathematical structure of ROMEO 97

page
3.5 Data used in ROMEO 100
3.5.1 Economic data 100
3.5.1.1 Crop yield 100
3.5.1.2 Output prices and government subsidies 102
3.5.1.3 Input prices, variable costs and factor endowments 103
3.5.1.4 Land use and livestock holdings 106
3.5.1.5 Calculation of gross margins 106
3.5.2 Ecological data 108
3.5.2.1 Nitrate concentration in the infiltration water 108
3.5.2.2 Soil erosion 109

4 ROMEO model results 110
4.1 Base period 112
4.2 Nitrogen tax scenario 120
4.2.1 Background 120
4.2.2 Model adaptation 123
4.2.3 Results and discussion 126
4.3 Mandatory mulch drilling scenario 133
4.3.1 Background 133
4.3.2 Model adaptation 134
4.3.3 Results and discussion 135
4.4 Mandatory land retirement scenario 145
4.4.1 Background 145
4.4.2 Model adaptation 146
4.4.3 Results and discussion 148

5 Conclusions 157

Summary 162
Zusammenfassung 167
References 172
Appendix A 181
Appendix B 185
Appendix C 189
Appendix D 193

List of tables

page

Table 2.1: Characteristics of linear, traditional nonlinear and positive mathematical programming 15
Table 2.2: Economic characteristics of the production activities in the example model 18
Table 2.3: Average and marginal revenues, costs and gross margins in problem (I) 22
Table 2.4: Specification of PMP models according to the corresponding PMP version 73
Table 2.5: Base run and scenario run results for LP and PMP models 80
Table 3.1: Yields of selected crops in the Kraichgau region and Baden-Württemberg 101
Table 3.2: Prices of selected agricultural products in 1995 102
Table 3.3: Selected EU- and MEKA-payments in 1995 103
Table 4.1: Base period and base run cropping activities 113
Table 4.2: Land distribution in the Kraichgau region 114
Table 4.3: Base period and base run livestock activities 114
Table 4.4: Base run gross margins 115
Table 4.5: Base run crop yields and nitrogen fertilization 116
Table 4.6: Base run nitrate concentration levels 117
Table 4.7: Base period and base run tillage variants for arable crops 119
Table 4.8: Base run soil erosion levels 120
Table 4.9: Cropping activities in the nitrogen tax scenario 126
Table 4.10: Livestock activities in the nitrogen tax scenario 127
Table 4.11: Gross margins in the nitrogen tax scenario 128
Table 4.12: Crop yields and nitrogen fertilization in the nitrogen tax scenario 129
Table 4.13: Nitrate concentration levels in the nitrogen tax scenario 131
Table 4.14: Cropping activities in the mandatory mulch drilling scenario 136
Table 4.15: Livestock activities in the mandatory mulch drilling scenario 137
Table 4.16: Gross margins in the mandatory mulch drilling scenario 138
Table 4.17: Tillage variants for arable crops in the mandatory mulch drilling scenario 139
Table 4.18: Soil erosion levels in the mandatory mulch drilling scenario 141
Table 4.19: Cropping activities in the mandatory land retirement scenario 149
Table 4.20: Livestock activities in the mandatory land retirement scenario 150
Table 4.21: Farmland reduction in the mandatory land retirement scenario 151
Table 4.22: Gross margins in the mandatory land retirement scenario 152

page

Table 4.23: Nitrate concentration levels in the mandatory land retirement scenario 154
Table 4.24: Soil erosion levels in the mandatory land retirement scenario..... 155

List of figures

Figure 2.1: Optimal solution of model M1 (excluding calibration constraint) 9
Figure 2.2: Optimal solution of model M2 (including calibration constraint)..... 11
Figure 2.3: Optimal solution of model M3 (quadratic objective function)..... 13
Figure 2.4: Graphical presentation of the notion of PMP 16
Figure 2.5a: LP optimal solution of problem (I) - revenues and variable costs..... 20
Figure 2.5b: LP optimal solution of problem (I) - gross margins..... 21
Figure 2.6a: PMP optimal solution of problem (II) - revenues and variable costs 23
Figure 2.6b: PMP optimal solution of problem (II) - gross margins 23
Figure 2.7a: PMP optimal solution of problem (III) - revenues and variable costs..... 31
Figure 2.7b: PMP optimal solution of problem (III) - gross margins..... 32
Figure 2.8: Model behavior with linear versus nonlinear marginal crop specification..... 36
Figure 2.9a: PMP optimal solution of problem (III') - revenues and variable costs..... 43
Figure 2.9b: PMP optimal solution of problem (III') - gross margins 44
Figure 2.10a: PMP optimal solution of problem (IV) - revenues and variable costs..... 47
Figure 2.10b: PMP optimal solution of problem (IV) - gross margins..... 47
Figure 2.11: Determination of the marginal yield function of the marginal crop..... 56
Figure 2.12a: PMP optimal solution of problem (IV') - revenues and variable costs 61
Figure 2.12b: PMP optimal solution of problem (IV') - gross margins 62
Figure 2.13a: PMP optimal solution of problem (V) - revenues and variable costs..... 70
Figure 2.13b: PMP optimal solution of problem (V) - gross margins..... 72
Figure 2.14: Behavior of different PMP models in the presence of a price increase 84
Figure 4.1: Response of the quadratic yield function to a nitrogen tax 125
Figure 4.2a: Suggested modified PMP version - revenue and variable costs..... 143
Figure 4.2b: Suggested modified PMP version - gross margin..... 144

List of abbreviations and units

AC ..... average costs
AGM ..... average gross margin
AR ..... average revenue
AY ..... average yield
CAP ..... Common Agricultural Policy
DM ..... Deutsche Mark
dt ..... decimal ton
EU ..... European Union
ha ..... hectare
kg ..... kilogram
km ..... kilometer
l ..... liter
LP ..... Linear Programming
LSU ..... livestock units
MC ..... marginal costs
MEKA ..... Marktentlastungs- und Kulturlandschaftsausgleich
mg ..... milligram
MGM ..... marginal gross margin
Mill. ..... million
MR ..... marginal revenue
MRS ..... marginal rate of substitution
MY ..... marginal yield
NLP ..... Nonlinear Programming
PMP ..... Positive Mathematical Programming
t ..... metric ton
TC ..... total costs
TGM ..... total gross margin
TR ..... total revenue
VMP ..... value marginal product