RICE PRODUCTION STRUCTURE AND POLICY EFFECTS IN JAPAN

Quantitative Investigations

Yoshimi Kuroda

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Softcover reprint of the hardcover 1st edition 2016 978-1-137-57314-8

First published in Japanese as *Beisaku-Nogyo no Seisaku Kouka Bunseki* in 2015 by Keio University Press Inc.

English-language edition first published 2016 by
PALGRAVE MACMILLAN

Palgrave Macmillan in the UK is an imprint of Macmillan Publishers Limited, registered in England, company number 785998, of Houndmills, Basingstoke, Hampshire RG21 6XS.

Palgrave Macmillan in the US is a division of St Martin's Press LLC, 175 Fifth Avenue, New York, NY 10010.

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ISBN 978-1-349-57152-9 ISBN 978-1-137-57315-5 (eBook)
DOI 10.1007/978-1-137-57315-5

This book is printed on paper suitable for recycling and made from fully managed and sustained forest sources. Logging, pulping and manufacturing processes are expected to conform to the environmental regulations of the country of origin.

A catalogue record for this book is available from the British Library.

A catalog record for this book is available from the Library of Congress.

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Foreword by Keijiro Otsuka

In its influential book *East Asian Miracle* the World Bank (1993) concluded that there is no unique pattern of economic development among high-performing East Asian countries. However, it has become increasingly and overwhelmingly clear that this is incorrect. Without exception, high-performing East Asian countries have followed the flying-geese pattern of economic development, beginning with the development of light industries and proceeding to that of the heavy and chemical industries and further to high-tech industries. Japan has always been a forerunner of this economic transformation process. Technology transfer, initially from Europe and the US to Japan and gradually from Japan to other East Asian countries, has supported such common development patterns. As a result, wage rates have been increasing in East Asia, initially in Japan then subsequently in Taiwan, South Korea, and Singapore as well as Malaysia, Thailand, and China in more recent years.

This pattern of industrial development commonly poses major challenges for agriculture in East Asia, which is characterized by the dominance of small-scale, family-based farming. By its very nature, small-scale farming is labor intensive. In the face of rising wages, however, production costs need to be reduced by means of labor-saving technology, including large-scale mechanization on large-scale farms. Thus, farm size expansion through the consolidation of small farms and large-scale mechanization needs to take place in East Asia for it not to lose comparative advantage in agriculture. This is coupled with the shift towards livestock products, which require larger amounts of feed grain, which means that East Asia is likely to become a major importer of food grains. A case in point is China, where the average farm size is as small as 0.6 hectares, wage rates are rising sharply, and the imports of soybean are sky-rocketing. If East Asia imports a lot of grain from international markets, the world will starve as food prices shoot up throughout the world (Otsuka 2013).

In order to avoid a potentially tragic outcome "the structural transformation of the agricultural sector from the low-productive, small-scale farming to high-productive, large-scale farming", as expressed by Professor Kuroda, is necessary. Indeed, according to my own study using pooled cross-section and time-series country data (Otsuka et al. 2013), there is clearly an increasing disadvantage of small farms vis-à-vis large farms in Asian agriculture. Yet, the average farm size in most countries in Asia is not only small but has also been shrinking significantly. To my knowledge, major exceptions include the Punjab in India, the Central Plain in Thailand, and the Mekong Delta in Vietnam, where farm size has been relatively large and its structure conducive to expansion. This is similar to the Tohoku area in Japan. Since Japan was the first high-income country in Asia, it was also the first to face the challenge of expansion in farm size, large-scale mechanization, and introduction of labor saving methods. Gradually, other countries in Asia will face the same challenges.

It is therefore very clear that other Asian countries should learn from the experience of post-war Japanese agriculture. To what extent did economies of scale arise in Japanese agriculture in the course of post-war economic development? How important was mechanization in saving labor? How effectively did land markets work to transfer land from less-efficient small farms to more-efficient large farms? What were the effects of the rice price support policy, the set-aside program of paddy fields, and input subsidy programs on the structural transformation of Japanese agriculture? These are some of the central issues that Professor Kuroda's new book addresses, while paying special attention to rice farming in the Tohoku area, which is one of the most promising rice-growing areas in Japan.

Undoubtedly this book is a great boon for those who are interested in the transformation of agriculture not only in Japan but also in other Asian countries, including China and India, the two most populous countries in the world. Fortunately, major findings and their policy implications are clearly stated in this book for those who are not familiar with economics and econometrics, even though sophisticated econometrics tools are used for the accuracy of the quantitative analyses.

As readers can see from this book, Professor Kuroda's assessment of Japanese agricultural policies is negative. I am completely supportive of his assessment, as it is highly evidence-based. Moreover, the book is full of useful information about the structure of Japanese agriculture, its transformation, and obstacles to achieving that transformation. That is why I strongly recommend policymakers, governmental agricultural officers, agricultural specialists, and agricultural economists, including graduate students, to read this book, learn lessons from the Japanese experience, and draw socially and globally useful policy implications.

Keijiro Otsuka
Professor, National Graduate Institute for Policy Studies

Foreword by Masayoshi Honma

Japanese agriculture needs to change its structure. This is necessary not only because of external pressure from negotiations for international trade agreements, such as the TPP (Trans-Pacific Partnership), but also because of the need to revitalize Japanese agriculture itself. Because agricultural revival is largely dependent on structural reform, detailed and comprehensive analyses that show the correct direction of reform are required. The author of this book, Professor Yoshimi Kuroda, has contributed to the study of Japan's agricultural structure and published many academic papers and articles in academic journals, mainly in English.

Dr. Kuroda has synthesized his major works into a book entitled *Production Structure and Productivity of Japanese Agriculture* in two volumes (published by Palgrave Macmillan in 2013). Whereas many people are interested in Japanese agriculture around the world, not much information is available in English. Most researchers are Japanese among whom few are writing papers in English. Dr. Kuroda is one of the exceptions. These volumes are very useful for understanding Japanese agriculture and agricultural structure as a whole and have been well received for this reason. The present book is a companion piece to these earlier volumes but focuses on the rice sector and its historical policies. Needless to say, rice is the most important product in Japanese agriculture and the agricultural problem is almost synonymous with the rice sector problem.

In general, policy discussions and debates should be based on facts and empirical analyses that are theoretically sound. Dr. Kuroda's book provides exactly this kind of material for discussion and Japanese policymakers can also learn from the research results presented in it.

As Prime Minister Abe argues, agricultural reform is one of the keys to Japan's economic growth strategy, making agricultural policy a very hot topic in Japan. Indeed, many economists and scientists are involved in discussions. However, in most cases the discussions tend to be ideological and so it is necessary to share the reality of agriculture in Japan. Without a common recognition of this reality, it will be hard to find desirable policies. Dr. Kuroda's book also deserves to be read from this point of view.

I expect this book will be read by many people, although understanding all the details may be difficult. Unlike books that reveal only the essence of a problem, this book is an authentic research publication and clearly explains the theoretical background and appropriate methodology. Dr. Kuroda's approach to economic research is to develop empirical analyses grounded in economic theory. Hence the results of his analyses are robust and the implications are clear-cut. His approach to Japanese agriculture in the quantitative study utilizes production functions and duality theory from which cost or profit functions are derived. His research is also characterized by the introduction of index theory to elucidate technological progress in agricultural production. These techniques generate excellent policy evaluations based on empirical data.

This book is a must-read for researchers, especially young researchers, seeking to understand diverse aspects of and approaches to the study of Japanese agricultural structure, particularly in the rice sector. It demonstrates how to make empirical studies consistent with economic theories. It also reminds readers of the importance of microeconomics to the study of agricultural economics.

Masayoshi Honma
Professor, Department of Agricultural and Resource Economics
The University of Tokyo

Preface

The present book is a companion to the two-volume set *Production Structure and Productivity of Japanese Agriculture* (*Volume 1: Quantitative Investigations on Production Structure; Volume 2: Impacts of Policy Measures,* 2013, Palgrave Macmillan). These books provided an econometric analysis of the production structure and policy impacts of Japanese agriculture as a whole over the period 1957–1997.

This book, by contrast, seeks to shed light on the production structure and policy impacts for the rice sector. Rice remains the most important agricultural commodity in Japan, not only because it is a basic staple food but also because of the historic role it has played in Japanese culture over two millennia. This volume employs a very similar methodology to the previous two, although the latter's methodologies are much more comprehensive.

It has been critical for Japanese agriculture to seriously try to change attitudes within the sector from defensive to offensive and promote positive management through modernizing and industrializing the traditional structure of family farming by taking advantage of joining the TPP (Trans-Pacific Partnership).

There are already many farm-firms with highly motivated and strong incentives for modernizing the management of their agricultural production all over Japan who have even been trying to launch out into the world. Unfortunately, however, the number of such farms with strong venture-minded farmers has been very limited thus far.

The major objectives of this book are twofold.

First, it investigates quantitatively the production structure of the rice sector of post-war Japanese agriculture for, roughly speaking, the second half of the 20th century (1956–1997). Utilizing extensively the newly developed methods of production economics, such as, the *duality* theorem, flexible functional forms, and index number theory – the translog variable cost function (VC), rather than the total cost (TC in short hereafter) function and the variable profit (VP in short hereafter), with labor and land being the quasi-fixed factor inputs – will be estimated in order to quantitatively capture the basic and comprehensive picture of the production structure of the rice sector. More specifically, based on the estimated parameters of the translog VC and VP functions, various not important and intriguing, economic indicators will be estimated and evaluated. For this objective, we quantitatively investigate the following critical economic indicators: the output (rice) supply and factor input demand and substitution elasticities; the rates and biases of technological change; the degrees of returns to scale; and the shadow value of land as a quasi-fixed input.

Second, the book quantitatively estimates and evaluates the impacts of various agricultural policy measures: such as (1) the output (rice) price-supports; (2) the set-asides; (3) the factor input subsidies; and (4) the R&D and extension (R&E in short hereafter) programs on various important economic indicators, such as, (i) the supply of rice, (ii) the demands for variable factor inputs, (iii) the amount of variable profits, (iv) the magnitudes of returns to scale, and (v) the shadow value of paddy land. Based on such quantitative investigations, we evaluate whether each of these agricultural policy measures has made a positive or negative impact on the transfer of paddy lands from small- to large-scale farms, and led to more efficient and productive rice farming on much larger-scale farms roughly for the four decades of the 20th century, 1956–1997.

In short, the present book quantitatively investigates how the various above-mentioned agricultural policy instruments, which have basically strong characteristics of protecting almost all rice producing farms with whichever scale of paddy lands and levels of efficiency, played significantly negative roles in constructing more efficient and productive rice farming on much larger-scale paddy lands by highly motivated rice farmers during roughly the second half of the 20th century. For this objective, I employ newly developed analytical methods – such as, *duality* theorem, flexible functional forms, in particular, the translog functions, and index number theories – which have been extensively utilized all over the world from the late-1960s until recently. Based on the extensive applications of these analytical tools, I offer quantitatively comprehensive, consistent, robust, and reliable analytical results for the production structure of rice farming during the second half of the 20th century and derive useful information both for farmers and for policymakers.

In this sense, I would like to claim that the present book may be the first trial for a comprehensive and consistent quantitative analysis of the structure and the policy impacts on Japanese rice production in the second half of the 20th century. I do hope that the empirical results of this sort of analysis provide useful and helpful information, especially for those countries whose economies have started growing fairly fast, in particular, in Asia and Africa. Needless to say, however, the analysis employed in this book is not limited to rice farming but may be applicable to other agricultural commodities.

At this point, it may be helpful for the reader to understand roughly the status of the present book within the history of empirical production economics from around the mid-1940s until recently. Needless to say, from the 1950s to the 1960s, not only in Japan but also in many other countries, the most popular methods for empirical analysis of production structures were the Cobb–Douglas (C–D in short hereafter) and constant elasticity of substitution (CES in short hereafter) production functions. As is well known, however, behind these functions very strict assumptions are implicitly incorporated from the beginning. In the case of the C–D type production functions, the well-known assumptions are: (1) the elasticity of production of each factor input is the same for all observations; (2) technological change is Hicks neutral and constant for the entire estimation period; (3) the elasticity of substitution between any pair of factor inputs is unity; and (4) the original C–D function was characterized by constant returns to scale (CRTS in short hereafter).

On the other hand, the CES function was invented (and published in 1961) by Arrow, Chenery, Minhas, and Solow in order to relax the assumption of unitary elasticity of substitution between the two factor inputs, labor and capital. In this case, however, quite strict assumptions are introduced, as follows: (1) though the elasticity of substitution can take any value other than unity (which is also included as an extreme case), its value is constant, i.e., 0.1, 1.5, 3.0, for the entire sample period; (2) the technological change is Hicks neutral, as in the case of the C–D production function; (3) returns to scale is unity (this assumption was relaxed by Murray Brown in 1967); (4) the firm is at equilibrium with respect to the levels of use of labor and capital, implying the marginal productivities of the two factor inputs are equal to the respective market prices. Although the CES type production functions were globally utilized during the 1960s through to the early 1970s, the life of the CES functions was rather short, due mainly to the explosive evolution of the *duality* theorem, flexible functional forms, and index number theories from the late-1960s and the early-1970s through to the recent years of the 21st century.

In a little more detail, however, the *duality* theorem had already been developed as early as 1951 by Shephard, who derived the cost function as a *dual* of the *primal* production function. But we had to wait until the late 1960s and the early 1970s for the explosive developments of the *duality* theorems, flexible functional forms, and index number theories. For empirical applications of these theories, the translog function has been most popular, especially in econometrical applications to the production economics, and in consumption economics, either for general economics or specifically for agricultural economics. Accordingly, tremendous amounts of useful and helpful information have been accumulating for policymakers in wide economic arenas in many countries.

As already mentioned at the beginning of this Preface, I would like to claim this book as a companion volume to my books, *Production Structure and Productivity of Japanese Agriculture Volumes 1 and 2*, published by Palgrave Macmillan in 2013. In these books, I employed and estimated a slightly more sophisticated two-output Stevenson–Greene (S–G in short hereafter) type translog TC, VC, and VP functions to quantitatively investigate the production structure, productivity and impact of various policy measures on the important economic indicators for the Japanese agricultural sector. This was for the period 1957–97. For the details of the empirical results, I would like the reader to refer to those volumes, which offer comprehensive, consistent, robust, and reliable quantitative information on Japanese agriculture as a whole for the second half of the 20th century. On the other hand, the present book presents sharper results, specifically for the rice sector, than those obtained in the above-mentioned one; though, of course, the two support each other.

At this point, I must mention a difficulty when reading this book – especially for those readers whose mathematical and statistical backgrounds are rather rusty. I have tried to avoid mathematical expressions as much as possible while developing the methodologies for Chapters 2 through 7, and have put them in the appendices in those chapters. To be honest, however, it was almost impossible to employ such a procedure in order to logically present the methodology for each chapter without mathematical expressions. Thus, I admit that I have had to use mathematical developments to clarify the logic of the methodology as much as possible for all chapters, except Chapter 1. Accordingly, I would strongly suggest that readers with poor or rusty mathematical backgrounds totally skip, or just briefly glance at, them to capture the idea of what is going to be executed in each chapter. Instead, I would strongly recommend such readers to concentrate on grabbing the rich information and ideas by reading carefully the interpretations and evaluations of the econometrically estimated results expressed in the many tables and figures in each chapter.

For the reader to read and understand smoothly the theoretical methods and their empirical applications, it is required that they have at least an intermediate knowledge of microeconomics and econometrics. In that sense, this book may be relevant as a textbook or reference book for advanced (junior and senior) undergraduate courses or for graduate (Master's level) courses. Although the main analytical subject is the production structure of rice and policy impacts, I would ask the reader not to regard this book as only a textbook or reference book for students of agricultural economics. Instead, I am confident in stressing that it will be useful, helpful, and informative as a textbook or reference book for students of general economics, and for economists who are interested in the applications of the *duality* theorem and flexible functional forms.

This book may also be useful for readers with minimal mathematics but a keen interest in the economic issues of agriculture. I would strongly urge them to concentrate on Chapters 1, 4, 5, 6, 7, and 8, while skipping Chapters 2 and 3. I am sure that such readers will understand the basic issues of how the skewed introduction of agricultural policy measures has negatively contributed to the modernizing of Japanese agriculture; particularly to rice production in the second half of the 20th century. To say it more strongly, those policy instruments played an important negative role in constructing modernized rice farming characterized by much more efficient, productive, and profitable production on much larger paddy lands by farm businesses with strong motivation and incentives for agricultural production management.

As for the data used for empirical analysis, I chose the Tohoku agricultural district (Tohoku in short hereafter). This was mainly because, in my experience from previous studies, Tohoku is one of the two most representative rice production districts in Japan and has offered the most consistent, stable, reliable, and robust estimates of the parameters of the functions used and various economic indicators based on the estimated parameters. Furthermore, I have to mention that the Hokuriku agricultural district (Hokuriku in short hereafter) has also given me equally reliable, though slightly different, results. Because of such features of the data of them, I first planned to analyze both districts independently to examine how different the rice production structures were between the two districts during the second half of the 20th century. But, if I had done so, the tables and figures would have been too numerous and taken up too much space. Another possible procedure would have been to pool the data of the two districts for the same analyses. In this case, however, the tables and figures have been unnecessarily numerous, again taking up too much space. Recall here, however, that basic econometrics teaches us that econometrical estimations of any functions should ideally be as homogeneous as possible. Following this lesson, therefore, I decided to obtain the samples from a single homogeneous agricultural district, Tohoku.

It is already four years since the monster earthquake and tsunami hit north-eastern Japan on March 11, 2011. It caused terrific damage in Tohoku, not only to human life but also to economic activity, including agriculture in Tohoku. Though terribly tough, this destruction of farmland provided a significant opportunity to farmers with a strong incentive and motivation to reconstruct Tohoku agriculture. This may be characterized as a modern pilot for the farming of rice, as well as other crops and livestock. I would expect those venturesome farmers to unite their strong wills and strength and yield real farm businesses as soon as possible. I myself would like to sincerely support and pray for them, not only as an agricultural economist but also as a human being.

Acknowledgements

This book is an English version of *Beisaku-Nogyo no Seisaku Kouka Bunseki,* published by Keio University in June 2015.

Looking back on the summer of 2013 following two major events in my life – retiring from Kyushu Sangyo (Industrial) University in March, and my first book in English, *Production Structure and Productivity of Japanese Agriculture: Volumes 1 and 2*, in June – I see that I had lost the passion and motivation to do something active, such as, research, sport, reading – even gardening. I decided to let it go on like this for a while until I felt the need to engage in something passionately. While I was spending a very "lazy" life without doing anything solid, I was thinking deeply day and night. Perhaps doing some research, instead of just reading history books, might give me much more joy and fun because I could enjoy the feeling of creating, attaining, and producing something original. After a couple of months of the "lazy" life, I made up my mind to continue research which would follow upon the first book, *Production Structure and Productivity of Japanese Agriculture* published by Palgrave Macmillan. But this time in Japanese, my mother language.

One day I called up one of my good younger friends, Professor Masayoshi Honma at the University of Tokyo, and told him that I would like to write a book as a follow-up to the first I published with Palgrave Macmillan, but this time in Japanese. He agreed with my plan with pleasure and introduced me to Mr. Tetsuya Kiuch of the Keio University, a publisher who had been a section chief, with a strong interest in quality academic books. I told him about my desire to write a book on rice production and policy effects with quantitative investigations. Luckily, Mr. Kiuchi agreed with my idea and encouraged me strongly. I strongly appreciate the friendly and strong support of Professor Honma and Mr. Kiuchi for my ambition to write that follow-up 2013 book. The temporary title of the book in Japanese was going to be *Nihon Beisaku no Seisan-Kozo to Nogyo-Seisaku no Koka* [*Japanese Rice Production Structure and Effects of Agricultural Policies*]. So, I was ready to take on a new challenge with verve and gusto.

While writing this book in Japanese, I strongly wanted to write the same book in English, as a "sister" to my previous 2013 publication. Again, I discussed this with Mr. Kiuchi, who agreed completely. So, I started immediately on finishing the Japanese version of this book. This was around the end of November, 2014. Then, until late April, 2015, I concentrated on writing the English version, entitled *Rice Production Structure and Policy Effects in Japan: Quantitative Investigations*, spending almost 350 hours on it. Again, Mr. Kiuchi was a great help in arranging with Keio University Publications for me to write the English version through a freelance contract with Palgrave Macmillan. I am very grateful to Keio University Publishing for such generous permission.

At this point, I would now like to acknowledge the warm support of many friends, both in Japan and abroad, who have contributed, from the late 1960s up until May this year (2015). I have already listed the names of those people in the above-mentioned previous book, published by Palgrave Macmillan in 2013. So, I will limit the names in this "sister book" to a select few.

First of all, the most influential and important person for my research was been the late Professor Shujiro Sawada at the Graduate School of Agricultural Economics of Kyushu University, Fukuoka, Japan. He guided me in studying agricultural economics as one of the fields of general economics. Professor Sawada also told me that agriculture is the most important industry for any country at the start of its economic growth, with more than 90% of its people engaged in agriculture. This is why agricultural economics has been intimately related to the arena of development economics. Much more than this, Professor Sawada used to tell me that rice-producing agriculture is the basis of Japanese culture; the English word agri-"culture" shows it. I was deeply impressed by his teachings and had a strong interest and even love for studying agricultural economics.

While I was studying hard as a graduate student at Kyushu University, the late Professor Sawada recommended that I study at the Food Research Institute of Stanford University. Consequently, I submitted my application to Stanford in November 1969. To my great surprise and pleasure, on April 1, 1970 I received an acceptance letter. The news was too good for it to be an "April Fool's" joke! The year 1970 turned out to be a great turning point in my life, so I would like to dedicate this book to the memory of the late Professor Sawada.

Professor Takeshi Amemiya, of the Economics Department of Stanford University, has also always encouraged and helped me in many aspects of my research and daily life, from the initial hard work of a graduate student at Stanford until now. Playing regular games of tennis with him was most enjoyable and relaxing, with no thought of research. He also invited me and other Japanese friends, senior or junior, to very enjoyable open house parties.

Professor Pan A. Yotopoulos, the advisor for my Ph.D. dissertation, always encouraged me by offering useful, constructive and positive, though sometimes severe, comments, not only on my Ph.D. dissertation but also on the many other papers I have written thus far. Like Professor Amemiya, his family often invited me and other students under his research directions and guidance.

Professors Lawrence J. Lau and Dale W. Jorgenson were always very encouraging and helpful by giving me appropriate, and sometimes severe, advice on the theory, mathematical and econometric techniques associated with empirical investigation of agricultural household behavior, both on the production and consumption sides. In particular, the profit function approach, as a dual of the production function, provided me with a fresh and big surprise. The profit function turned out to be the core of the methodology of my Ph.D. dissertation and has ever since been key to my research work. In this sense, Professors Jorgenson and Lau have always been the great guides of my research life. I would like to say: "Thank you very much for everything you both have given me."

Next, I sincerely appreciate the following financial grants which have helped me greatly:

Grants to the National Bureau of Economic Research (NBER) from Sumitomo Fund for Policy Research Studies, the Bank of America, and Dillingham Corporation.

The Ford Foundation Grant No. 720-0432.

The US National Science Foundation Grant No. 73-05675 A01.

A Senior Research Grant from the Japan-United States Educational Commission (Fulbright).

A Grant-in-Aid for Scientific Research (C) No. 12660197 from the Ministry of Education, Science, Sports and Culture of Japan.

A Grant-in-Aid for Scientific Research (C) No. 06041074 from the Ministry of Education, Science, Sports and Culture of Japan.

A Grant-in-Aid for International Scientific Research No. 06660273 from the Ministry of Education, Science, Sports and Culture of Japan.

A Research Fund from the Statistical Data Bank Project of the Ministry of Education, Science, Sports and Culture of Japan.

A Grant from the Nomura Foundation for Social Sciences.

A Grant from the Japan Securities Scholarship Foundation.

A Grant from the Murata Science Foundation.

A Research Project Fund from the Industrial Management Institute (2007 Academic Year), Kyushu Sangyo University (Fukuoka, Japan).

A Research Project Fund from the Industrial Management Institute (2009 Academic Year), Kyushu Sangyo University (Fukuoka, Japan).

A Research Project Fund for Kyushu Agriculture from the International Centre for Study of East Asian Development (now the Asian Growth Institute) Kitakyushu (Japan).

Furthermore, I sincerely appreciate the commissioning editor Rachel Sangster and the assistant editors for their warm and persistent encouragement and help. I also thank other editorial and production staff.

In addition, Professors Otsuka and Honma, who have been very good friends since we were in our twenties, have written excellent forewords to this book from which the reader can fully catch what my book aims at. I deeply appreciate their warm friendship, as ever.

Finally, I am deeply grateful to my late parents, who always supported my research life both emotionally and financially. In addition, I am sincerely grateful to my wife Junko for her support in many aspects of my research life; in particular, her loving support while I was in and out of hospital for two operations in 2014, during which time I continued to write this book wearing a corset. Without the persistent and heartfelt support of my family, this book could not have been completed. I would sincerely like to dedicate this book to the memory of the late Professor Shujiro Sawada, my parents and to Junko.

List of Abbreviations

AC	average cost
AES	Allen partial elasticity of substitution
BC	bio-chemical
C–D	Cobb–Douglas
CCD	Caves, Christensen, and Diewert
CCS	Caves, Christensen, and Swanson
CES	constant elasticity of substitution
CRTS	constant returns to scale
DRTS	decreasing returns to scale
E	extension
FHE	farm household economy (survey report)
FIML	full information maximum likelihood
IRTS	increasing returns to scale
ISUR	iterated seemingly uncorrelated regression
M	mechanization
MC	marginal cost
MEOS	minimum efficient output scale
MES	Morishima elasticity of substitution
n.a.	not applicable
OOES	one-factor-one-price elasticity of substitution
P	probability
PCRWB	production costs of rice, wheat, and barley
PWRV	prices and wages in rural villages (survey report)
R&D	research and development
R&E	research and extension
RTS	returns to scale
S–G	Stevenson–Greene
S.E.R.	standard error of regression
SES	shadow elasticity of substitution
TC	total cost
TOES	two-factor-one-price elasticity of substitution
TPP	trans-pacific partnership
TTES	two-factor-two-price elasticity of substitution
VC	variable cost
VP	variable profit

Introduction

It is typical for an academic book to mention in its introduction: motivation; the construction of the book; its analytical methodology; the sources of data used and the time periods considered; the target readership; how to read the book effectively; the book's conclusions; the political implications of its findings, both at home and worldwide.

However, I have already mentioned most of these subjects, except for the book's construction, its conclusions and its implications. The latter two subjects are discussed comprehensively in Chapter 8. So, here I would like to concentrate on the first: the book's construction.

This book is comprised of two parts: *The Production Structure of the Rice Sector of Japanese Agriculture during the Second Half of the 20th Century*, and *The Impact of Agricultural Policies and Structural Transformation of the Rice Sector*.

Part I contains: Chapter 1 (*Changes in Post-war Japanese Agriculture, Problems Setting Up, and the Analytical Framework*); Chapter 2 (*Technology Structure of the Rice Sector of Japanese Agriculture: (I) A Translog Variable Cost (VC) Function Approach*); and Chapter 3 (*Technology Structure of the Rice Sector of Japanese Agriculture: (II) A Translog Variable Profit Function Approach*).

Part II consists of: Chapter 4 (*The Impacts of the Rice Price-Support Programs on the Structural Transformation of the Rice Sector*); Chapter 5 (*Impact of the Set-Aside Programs on the Agricultural Structural Transformation of the Rice Sector*); Chapter 6 (*The Impacts of Factor Inputs-Subsidies on the Agricultural Structural Transformation of the Rice Sector*); Chapter 7 (*The Impacts of Public Agricultural R&D and Extension (R&E) Programs on the Agricultural Structural Transformation of the Rice Sector*); and Chapter 8 (*Summary and Conclusions*).

Each chapter fully describes its objectives, methodology, and empirical results and the estimated results are carefully and comprehensively evaluated. I encourage the reader to read them carefully to appreciate what has been done in each chapter.

Roughly speaking, Part I focuses on capturing the technology production of Japanese rice farming based on the translog VC and VP function models. While Part II sheds special light on the impact of various policy measures – the rice price-support, set-aside, the factor input subsidy, and various R&E programs. These measures aimed to transform Japanese rice production from a small-scale, less-efficient, and low-productive nature to efficient, productive, and profitable organizations, run by highly motivated rice farmers.

This book is the product of almost half a century of research. I recommend it to anyone who is interested in a "cool-head-but-warm-heart" quantitative analysis of late 20th century Japanese rice agriculture. To be more specific, I believe that graduate students in the field of agricultural economics – not only in Japan but particularly in Asian and African countries – will find it useful for their dissertations when applying the basic theories of production economics and econometric tools.

Part I

Production Structure of the Rice Sector of Japanese Agriculture during the Second Half of the 20th Century

The Objectives of Part I

Part I is composed of three chapters. They are, Chapter 1: Changes in Postwar Japanese Agriculture, Problems Setting up, and the Analytical Framework; Chapter 2: Technology Structure of the Rice Sector of Japanese Agriculture: (I) A Translog Variable Cost Function Approach; and, Chapter 3: Technology Structure of the Rice Sector of Japanese Agriculture: (II) A Translog Variable Profit Function Approach.

The major objectives of Part I are twofold.

First, Chapter I will statistically investigate from the macroscopic point of view how the production structure of Japanese agriculture has changed during the postwar years, in particular, from around the mid-1950s when the Japanese economy as a whole started growing rather sharply to the early 2000s. It will try to find economic issues emerged in this process of drastic changes in the Japanese economy as a whole.

Second, Chapters 2 and 3 will expose briefly what methodology is most appropriate to quantitatively capture how such issues occurred during the period of drastic economic growth in Japan in the second half of the 20th century. To be more specific, throwing away the traditional analytical tools such as the C-D and CES production functions, these two chapters will introduce respectively the *dual* VC and the *dual* variable profit (VP in short hereafter) functions of the *primal* production function, based on the theory of the firm. They will analyze econometrically the over-time changes of the rice production structure of the Tohoku agricultural district (Tohoku in short hereafter. This name will apply to all agricultural regions),[1] chosen as a representative rice-producing district. Using the parameter estimates of the translog-specified VC and VP functions, we quantitatively analyze the basic economic indicators of Tohoku. Chapters 2 and 3 quantitatively investigate elasticities of output (rice) supply and variable factor demands, the three sets of elasticities of factor substitutions – the Allen, Morishima, and McFadden elasticities (AES, MES, and SES), the rates and biases of technological change, the degrees of returns to scale, and the shadow values of paddy lands. The details of the methodologies will be given.

1

Changes in Post-war Japanese Agriculture Changes, Problems Setting Up, and the Analytical Framework

1.1 Introduction

The major objective of this chapter is to overview statistically how agricultural structure has changed and what sorts of problems Japanese agriculture faced from 1956 through to the early 2000s. More specifically, this chapter will try to clarify major problems by statistically investigating changes in: crops and livestock, transfers of farmland, the definitions and numbers of farm households, the budgets for agriculture as a whole, and changes in the budgets for agricultural research and extension activities. During this investigation the statistics of the rice sector of Tohoku will be observed in parallel to those for Japan, using the translog VC (Chapter 2) and VP (Chapter 3) function frameworks, respectively.

1.2 Statistical observations of post-war Japanese agriculture

1.2.1 Post-war agricultural production in Japan as a whole

First of all, we will look into changes in the indexes of aggregate agricultural outputs in real terms for Japan as a whole (see Figure 1.1). According to Figure 1.1, the real total agricultural output has been stagnant since the late-1970s and even decreasing since around the mid-1980s. Behind such movements in the real total output, production of livestock and vegetables sharply increased from the early-1960s through to around the mid-1980s; in the case of fruit, however, production reached its peak around the late-1970s. The sharp increases in these products may have been due to the encouragement of the "Selective

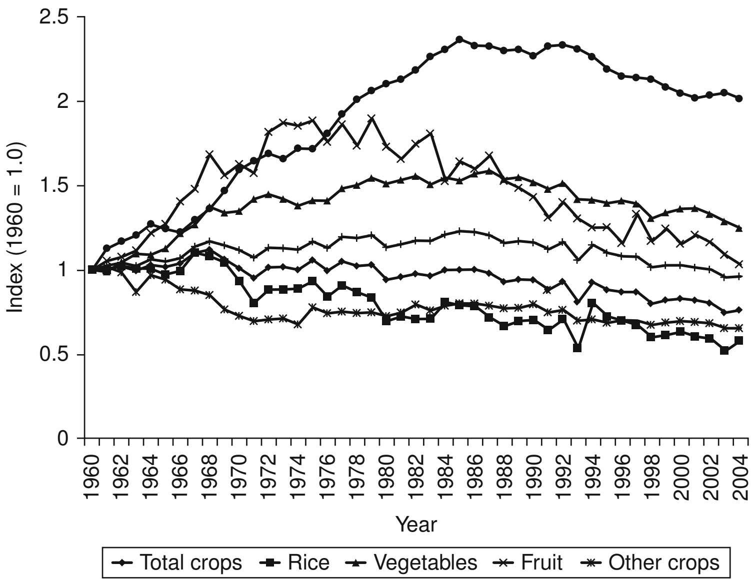

Figure 1.1 Changes in the indexes of total output, total crops, rice, vegetables, fruit, other crops, and livestock for 1960–2004 at 2000 prices: all Japan

Source: The statistical Department. The MAFF, *The Nogyo · Shokuryo Kanrensangyo no Keizai Keisan (The Social Account for Agriculture and Food-Related Industries). 2006.*

Expansion Production Programs" of the Basic Agricultural Act inaugurated by the government in 1961. In addition, as shown in Figure 1.2, the price movements of these products were considerably favorable; i.e, the price indexes of vegetables, fruit, and livestock had fairly sharp increasing trends during the late-1950s through to the early-1980s.

However, since around the mid-1980s, production of these three selective categories of products started declining consistently like the other products such as rice and other crops, which may have contributed to the declining trend of the amount of total agricultural output from the mid-1980s on. In particular, the output index of rice seems to have had the worst declining trend among all products presented in Figure 1.1. Behind the unfavorable movements of rice and livestock, we observe in Figure 1.2 that the price indexes of these products were stagnant or declining from around the early-1980s. This may have been caused by the government policies of reducing the producer prices of rice and

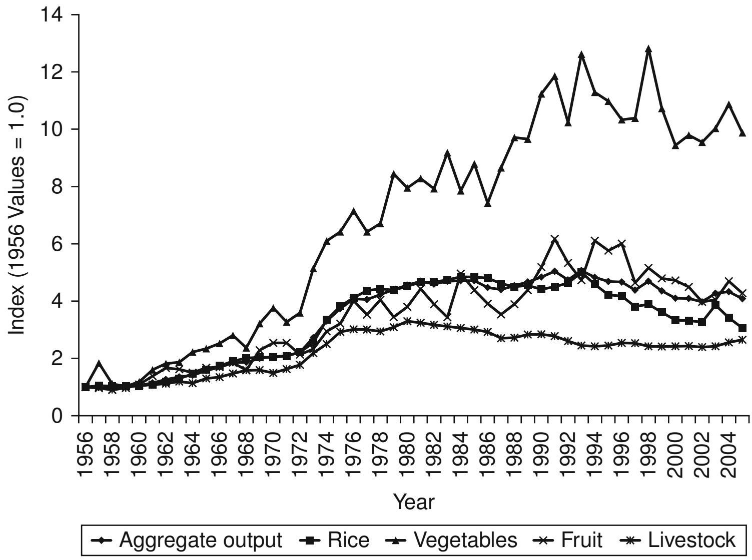

Figure 1.2 Price indexes of major agricultural products for 1956–2005 at 2000 prices: all Japan

Source: The same as in Figure 1.1.

livestock products, in particular, since around the mid-1980s towards the late-1990s.

On the contrary, however, the price indexes of vegetables and fruit had increasing trends even after the early-1980s until around the mid-1990s against an opposite trend in production for these products (see Figure 1.1). This may imply an excess demand for vegetables and fruit from the early-1980s through to the mid-1990s. However, since then we observe decreasing prices for these two products, though with some volatility. As a result, production of vegetables and fruit began to decrease, which may indicate an excess of supply.

Figure 1.3 shows a decline in the share of livestock and vegetables in total agricultural output, which increased consistently over time. Although the share of fruit increased after 1960, it declined consistently between 1982 and the late 1990s. On the other hand, the share of rice consistently decreased over time from around 38 percent in 1960 to around 23 percent in 2004. As a matter of fact, the share of rice became smaller than that of livestock for the period 1982–2004; the share of

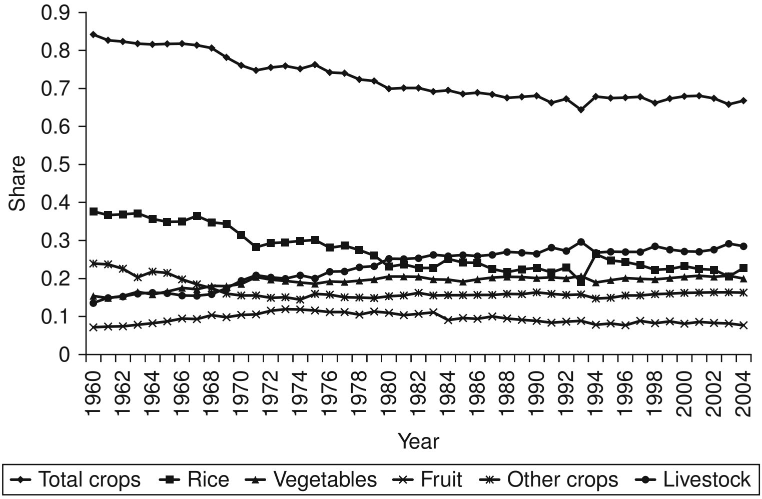

Figure 1.3 Changes in the shares of total crops, rice, vegetables, fruit, other crops, and livestock in the total amount of agricultural output for 1960–2004 at 2000 prices: all Japan

Source: The same as in Figure 1.1.

livestock in 2004 was around 29 rather larger than that of rice, around 23 percent.

1.2.2 Post-war transfers of farmland in Tofuken and Tohoku

One of the primary concerns in Japanese agriculture since the Basic Agricultural Act was enacted in 1961 has been the implementation of more efficient and productive farming on larger-scale farmlands. This concern has received even greater attention because of persistent pressure from foreign countries for Japanese commodities markets to liberalize, including the most important agricultural product in Japan, i.e., rice. The transition from small- to large-scale farming has thus been heavily promoted, and various policy measures have been introduced by the government; revisions of the Farmland Act in 1970 and 1980, launching of the Farmland Utilization Promotion Project in 1975, and passage of the Farmland Utilization Promotion Act in 1980.

To assess the effects of these policies on shifts to more efficient and productive larger-scale farming, Table 1.1 offers general information on farmland transfers in Tofuken and Tohoku. As mentioned earlier,

Table 1.1 Transfers of rights on agricultural land for cultivation (1000 ha), Tofuken and Tohoku: 1960–2004

Selected years	Transfers of rights for land holdings (1)	Transfers of rights for lease (2)	Total (3) =(1)+(2)	Total cultivated area (4)	Ratio of transferred to cultivated areas (5)=(3)/(4) (%)
Tofuken					
1960	67.4	4.4	71.8	5,186.4	1.4
1970	127.9	6.7	134.6	4,808.9	2.8
1980	68.3	105.5	173.8	4,321.0	4.0
1990	40.9	101.2	142.1	4,034.0	3.5
2000	221.1	103.9	325.0	3,649.0	8.9
2004	220.0	95.5	315.5	3,505.5	9.0
Tohoku					
1960	15.0	0.6	15.6	1,050.0	1.5
1970	24.9	7.5	32.4	1,029.6	3.1
1980	23.3	16.7	40.0	998.5	4.0
1990	11.5	21.9	33.4	973.9	3.4
2000	7.6	30.0	37.6	907.6	4.1
2004	7.7	26.1	33.8	887.6	3.8

Source: The Statistics Department, Ministry of Agriculture, Forestry, and Fisheries (MAFF in short hereafter). *Norin Suisan-sho Tokei-hyo* [*Statistical Yearbook of Ministry of Agriculture, Forestry, and Fisheries*], Statistical Bureau of the MAFF: Tokyo, various issues.

Notes:

(1) The transfers of cultivated land area due to transfers of rights for land holdings consist of (i) transfer of ownership of owner-farmer's agricultural land with compensation, (ii) transfer of ownership of owner-farmer's agricultural land without compensation, and (iii) transfer of ownership of tenant-farmers' agricultural land to tenant-farmers.

(2) The transfers of rights for lease are composed of (i) creations of rights for lease, (ii) transfers of rights for lease, and (iii) creations and transfers of rights by loans for use.

(3) The total areas of transfers of cultivated land after 1980 are composed of (i) transfers of rights on agricultural land for cultivation and (ii) creations on rights for use to "Improvements of Agricultural Land Use" under the "Law of Improvement of Agricultural Land Use" launched in 1980.

Tohoku is the northernmost agricultural district of Tofuken where rice may be considered as the most important agricultural product.

Table 1.1 reports areas of land transfers by (i) transfers of rights to lease. These are reported for selected years from 1960 to 2004, both for Tofuken and Tohoku. First, according to this table, the renting-out area increased from 1980 both in Tofuken and in Tohoku when the Agricultural Management Reinforcement Law was inaugurated. On the other hand, land transfers by transfers of rights for land holdings increased from 2000 in Tofuken but those in Tohoku decreased since 1990. Due mainly to the latter movement, the ratios of total transferred land area to total cultivated area increased fairly sharply for the period 1970–2004 in Tofuken; from around 2.8% in 1970 to around 9% in 2004. On the contrary, however, the corresponding ratios in Tohoku were stagnant for the same period; only from around 3.1% in 1970 to around 4.8%.

How can we interpret these findings, high or low? We argue that they are still low; in particular, this has been the case in Tohoku.

1.2.3 Post-war transfers of the numbers of farm households in Tofuken and Tohoku

Furthermore, Table 1.2 presents the numbers of farm households by size of cultivated land area in Tofuken and Tohoku for the period 1960–2005. According to the 1990 Agricultural Census, the term "farm household" refers to a household that operates farming with 10 ares (a, in short hereafter) or more of cultivated land or a household whose agricultural product sales amount to 150,000 yen and over in a year, even with cultivated land being below 10 a. In addition, since the 1990 Census, the "farm household" is further divided into two categories: "commercial farm household" whose main products are for sales; and "noncommercial farm household" whose main products such as rice are for own use. Several points are noteworthy from Table 1.2.

First of all, the number of farm households decreased drastically during the period 1960–2005, a decrease of 3.04 and 0.32 million households within 45 years in Tofuken and Tohoku, respectively. From 1990 to 2005, the number of total farm households decreased by 950 and 143 thousand households within 15 years in Tofuken and Tohoku, respectively. These numbers are very close to the numbers of noncommercial farms. In other words, many of these farms might have become self-production and self-consumption.

In addition, in Tofuken, during the period 1960–1980, (i) the number of farm households with less than 2 hectares (ha, in short hereafter) declined from 5,586 to 4,207 thousands, (ii) those with 2.0–5.0 ha increased from 235 to only 322 thousands, and (iii) those with more than 5 ha increased from 2 to 13 thousands over 20 years. On the other hand, in Tohoku, the number of farms with less than 3 ha decreased from 313 to 262 thousands, while those with more than 5 ha increased from 13 thousands to 31 thousands in 2000 but decreased

Table 1.2 Number of farm households by size of cultivated land for Tofuken and Tohoku: 1960–2005 (unit: 1,000 Farm Households)

Tofuken							
Selected years	Total farm h.h.	Commercial farm household					Non-commercial farm h.h.
		Sub-total	0.0 – 1.0 ha	1.0 – 2.0	2.0 – 5.0	5.0	
1960	5,823 (100.0)	n.a. (n.a.)	4,181 (71.8)	1,405 (24.1)	235 (4.0)	2 (0.03)	n.a. (n.a)
1970	5,176 (100.0)	n.a. (n.a.)	3,603 (69.5)	1,272 (24.6)	296 (5.7)	5 (0.1)	n.a. (n.a.)
1980	4,542 (100.0)	n.a. (n.a.)	3,226 (71.0)	981 (21.6)	322 (7.1)	13 (0.3)	n.a. (n.a.)

Table 1.2 (*Continued*)

Selected years	Total farm h.h.	Commercial farm household					Non-commercial farm h.h.
		Sub-total	0.0 – 1.0 ha	1.0 – 3.0	3.0 – 5.0	5.0	
Tofuken							
1990	3,739 (100.0)	2,884 (77.1)	1,753 (46.9)	1,004 (26.9)	100 (2.7)	26 (0.7)	855 (23.0)
2000	3,050 (100.0)	2,274 (74.6)	1,358 (44.5)	774 (25.4)	99 (3.2)	43 (1.4)	776 (25.4)
2005	2,789 (100.0)	1,911 (68.5)	1,109 (39.8)	657 (23.6)	94 (3.4)	50 (1.8)	878 (31.5)
Tohoku							
1960	786 (100.0)	n.a. (n.a.)	401 (51.0)	273 (34.7)	209 (26.6)	1 (0.1)	n.a. (n.a.)
1970	749 (100.0)	n.a. (n.a.)	352 (47.0)	249 (33.2)	129 (17.2)	3 (0.4)	n.a. (n.a.)
1980	694 (100.0)	n.a. (n.a.)	443 (63.8)	207 (29.8)	125 (18.0)	7 (1.0)	n.a. (n.a.)

			0.0 – 1.0 ha	1.0 – 3.0	3.0 – 5.0	5.0-	
1990	607	521	206	167	112	13	87
	(100.0)	(85.8)	(33.9)	(27.5)	(18.5)	(2.1)	(14.3)
2000	507	426	180	129	85	31	81
	(100.0)	(84.0)	(35.5)	(25.4)	(16.8)	(6.1)	(16.0)
2005	464	371	150	112	86	23	93
	(100.0)	(80.0)	(32.3)	(24.1)	(18.5)	(5.0)	(20.0)

Sources: The Statistics Department, MAFF. *Poketto Norin Suisan Tokei* [*Pocket Size Statistical Yearbook of the Ministry of Agriculture, Forestry, and Fisheries*], Norin Tokei Kyokai [Association of Agriculture and Forestry Statistics]: Tokyo, various issues. *Norin Suisan-sho Tokei-hyo* [Statistical Yearbook of Ministry of Agriculture, Forestry, and Fisheries], Statistical Bureau of the MAFF: Tokyo, various issues.

Notes:

(1) Figures in parentheses are shares in the total number of farm households. There exist rounding errors by around plus or minus 0.1% in all years except for 1980.
(2) "h.h." stands for "household".
(3) "n.a." stands for "not available".

to 23 thousands in 2005. From these observations, we may say that the structural change for larger-scale farming during the period 1960 to 1980 proceeded very slowly both in Tofuken and in Tohoku.

In Tofuken, however, during the period 1990–2005, structural change Increased slightly. That is, even the number of farm households with less than 5 ha started declining during the period 1990–2005, the number of farm households with more than 5 ha gradually increased from 26 (in 1990) to 50 (in 2005) thousands. Unfortunately, however, this 50 thousand figure is only 1.8 percent of the total number of farm households. Even taking the 3–5 ha and 5 ha and over sizes together, the total share was only 5.2 percent in 2005. On the other hand, in Tohoku, the shares of the numbers of farms with 2–5 ha and 5 ha and over, were 20.6% (in 1990), 22.9% (in 2000), and 23.5% (in 2005), greater than those in Tofuken. This may imply that although land transfers were not that active, the number and the share of larger-scale farms had been steadily increasing in Tohoku compared to Tofuken. Nonetheless, we should say that even though the number of large-scale farms with more than 5 ha of farmland has been gradually increasing, in particular, in Tohoku, it is far behind our expectation.

In sum, in spite of the government's efforts to promote land transfers, the transition from small- to large-scale farming has not made significant progress. One major reason for this has been the rapid increase in the market price of farmland, caused in large part by the strong demand for land for nonagricultural purposes, such as construction of highways, railways, factories, and residential areas. These demands for land by nonagricultural sectors has given farmers strong incentives to keep their land as a profitable asset.

1.2.4 Post-war transfers of the agricultural budgets

Now, the purpose of this chapter has been that we examine the major important causes within agriculture for the slow and inactive land transfers for agricultural structural transformation of small- to large-scale farming. Needless to say, one of the major causes for this has been high farmland prices. As shown in Table 1.3, price-support programs have been an important agricultural policy measure. Furthermore, since production levels of wheat and barley were very low during the study period 1956–97, the budget assigned to price-support policies for rice, wheat, and barley shown in column (4) in Table 1.3 has in fact been allocated mainly to rice. In this sense, rice price-support programs have been a critical policy instrument in post-war Japanese agriculture.

Table 1.3 Agricultural budget, 1960–99 (unit: 1 billion yen)

Selected years	National budget (1)	Agricultural budget (2)	For Price-Support Policies		
			Total (3)	For rice, wheat, and barley (4)	For livestock (5)
1960	1,765	139	31	29	0
		(7.9)	(22.3)	(93.5)	(0.0)
1965	3,745	346	128	121	0.3
		(9.2)	(37.0)	(94.5)	(0.2)
1970	8,213	885	393	375	15
		(10.8)	(44.8)	(95.4)	(3.8)
1975	20,387	2,000	858	811	30
		(9.8)	(42.9)	(94.5)	(3.5)
1980	43,681	3,108	773	652	16
		(7.1)	(24.9)	(84.3)	(2.1)
1985	53,222	2,717	582	456	10
		(5.1)	(21.4)	(78.4)	(1.7)
1990	69,651	2,519	311	232	9
		(3.6)	(12.3)	(74.6)	(2.9)
1995	78,034	3,423	284	184	6
		(4.4)	(8.3)	(64.4)	(2.1)
1999	81,860	2,549	364	243	5
		(3.1)	(14.3)	(66.8)	(1.4)

Source: Statistics Department, MAFF. *Nogyo Hakusho Fuzoku Tokeihyo* [*Appendix Tables of Agricultural White Paper*], Government Printing Office: Tokyo, 1999, pp. 20–21.

Notes:

(i) Figures in parentheses in column (2) are the shares of agricultural budget in the national budget in percent.
(ii) Figures in parentheses in column (3) are the shares of the budget for price-support policies in the total agricultural budget in percent.
(iii) Figures in parentheses in column (4) are the shares of the budget for price-support policies for rice, wheat, and barley in percent.
(iv) Figures in parentheses in column (5) are the shares of the budget for price-support policies for livestock in percent.

1.2.5 Post-war transfers of the utilization of farmland

Furthermore, another important policy instrument for Japanese agriculture, in particular, rice production, is the set-aside program, which was introduced in 1969 for the first time in the history of Japanese agriculture because of the persistent surplus of rice supply since 1965. Since then, the set-aside areas have an increasing trend with some fluctuations over time as shown in Figure 1.4. The areas which gave up rice

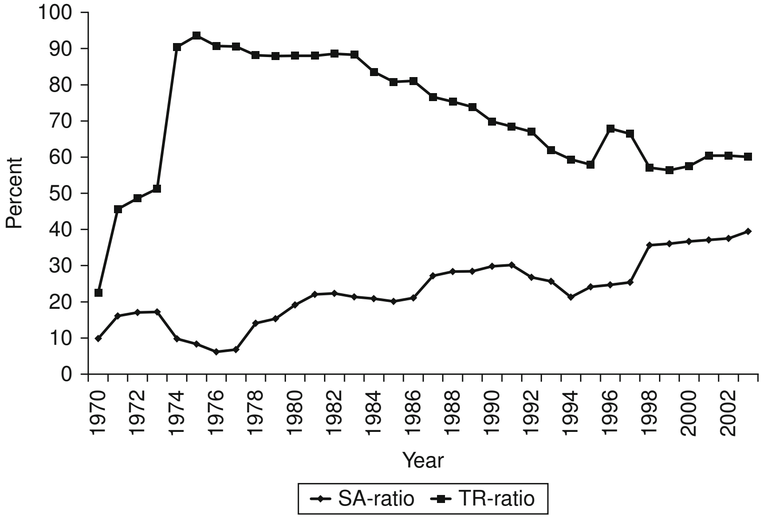

Figure 1.4 The ratio of the set-aside to total paddy area (SA-ratio) and the ratio of the transferred area to the set-aside area (TR-ratio) for 1970–2003: all Japan

Source: The same as in Figure 1.1.

production because of the set-aside programs amounted to around 500 thousand ha per year during the early-1970s, gradually increased up to around 800 thousand ha from the late-1980s through to the early-1990s, and then reached almost 1 million ha from the late-1990s through to the early-2000s. This means that the area of paddy fields attributable to the enforcement of the set-aside programs almost doubled in the 33-year period. Due mainly to the set-aside programs, the total arable land area of paddy fields decreased from around 3.5 million ha in 1970 to around 2.5 million ha in 2003, i.e., a decrease of as large as one million ha over the 33 years.

We will now look at the ratio of the area of set-aside paddy lands to the total area of arable paddy lands in Figure 1.4. The ratio was less than 20% for the ten years of the 1970s, kept around 20–21% for the period 1980–86, then jumped to 28–30% for the period 1987–1991, decreased somehow for the period 1992–97, but after then rebounded sharply to 37–40% for the period 1998–2003.

In addition, we observe in Figure 1.4 that the area changes in the set-aside paddy fields were transferred to the production of other crops such as wheat, soybeans, vegetables, and so forth. It appears that, except for the period 1974–78, the gap between the set-aside paddy area and transferred area became larger and larger as time passed. This finding may be confirmed by informally looking at the ratio of transferred to set-aside areas drawn in Figure 1.4. The ratio used to be around as high as 90% for the period 1974–83, but since then it consistently decreased from 1984 through to 2003 – except for the two-year period 1996–1997 when some increases were observed. It became as low as 60% for the early-2000s. This may have caused a tremendous expansion of abandoned farmland all over Japan. It should be noted here that restoring given-up paddy fields to the original state may require a huge amount of re-investments. Therefore, we may infer from these observations that the set-aside programs for the most important product, i.e., rice, in Japanese agriculture may have exerted great influences not only on rice production but also on production of all other agricultural products.

1.2.6 Post-war transfers of public investment in agricultural R&D and extension activities

At this point, we will look at Figures 1.5 and 1.6 which present the annual expenditures on and the accumulated capital stock of R&D

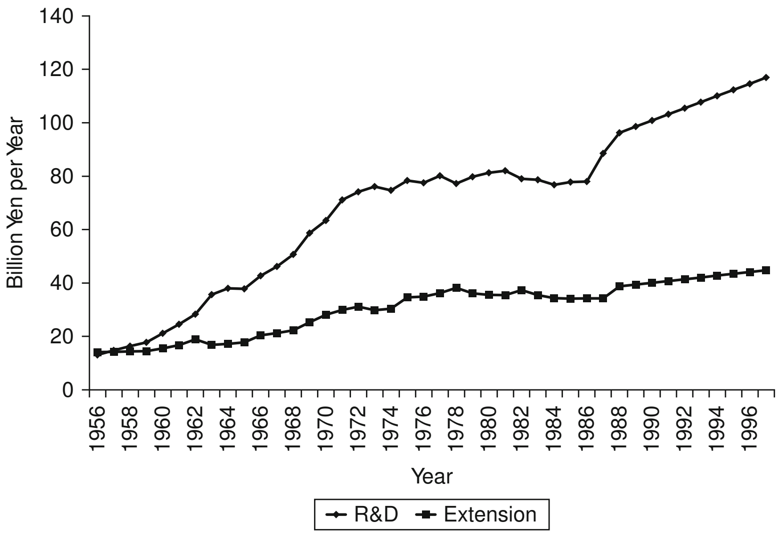

Figure 1.5 Agricultural public R&D and extension expenditures on rice production for 1956–97: all Japan (Unit: Billion Yen)

Sources: Refer to Appendix A of Chapter 2 for the sources of data.

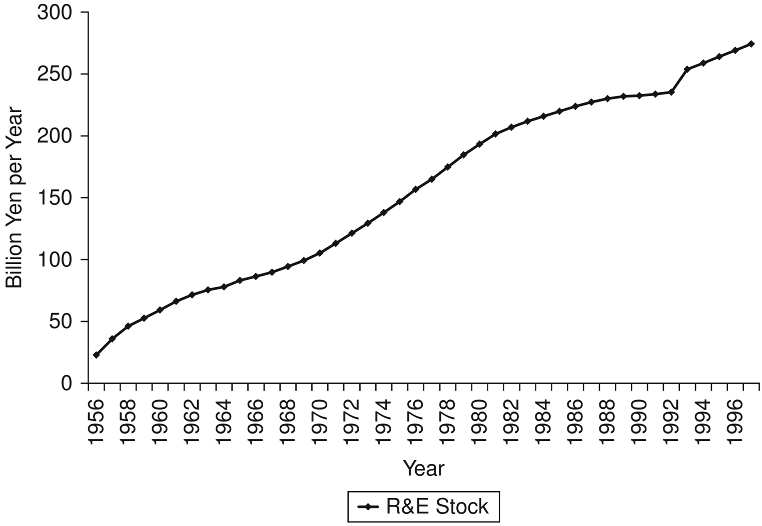

Figure 1.6 The stock of technological knowledge (or R&E stock) for rice production for 1956–97: all Japan (Unit: Billion Yen)

Note: Refer to Appendix A of Chapter 2 for the estimation procedure of the stock of technological knowledge.

and extension (R&E in short hereafter) investments for the agricultural sector as a whole, respectively. [1]

They are deflated by the research expenditure deflator and expressed at 1985 prices. According to Figure 1.6, the R&E capital stock increased fairly sharply from the early-1970s through to the late-1980s, and then the rate of increase started declining. As shown in Figure 1.5, these transfers reflect the rather sharp increase in research expenditures in the 1960s and the stagnation in both research and extension expenditures since the early-1970s up to the late-1980s. We will introduce the R&E capital stock as an exogenous variable into the VC and VP functions whose details will be exposed in Chapters 2 and 3. The reason why we use the national data for R&E expenditures are as follows. First, it is rather tedious to collect R&E capital stock data for a specific agricultural district. Second, it may be more relevant to introduce national aggregate data of R&E capital stock because of spill-over effects among different agricultural districts.

1.2.7 The outline of the quantitative investigations of the rice production structure and the effects of various policy measures

As above, we have executed macroscopic statistical observations on post-war Japanese agriculture as a whole as well as Tofuken and Tohoku. Based on these observations, we are going to investigate quantitatively the production structure of the Japanese rice sector by shedding a special light on rice farming in Tohoku. For this end, we are going to estimate the variable cost (VC) function.[2] Using the estimated parameters of the VC function, Chapter 2 will estimate the following most important economic indicators of production technology of the rice sector: (1) the elasticities of variable factor demands such as machinery, intermediate, and other factor inputs, (2) the elasticities of variable factor substitutions such as the AES, MES, and SES, (3) the rates and biases of technological change, (4) the degrees of returns to scale, (5) the shadow prices (marginal productivity) of paddy lands.[3] Thus, the major objective of Chapter 2 will be to quantitatively investigate and evaluate the estimates of these critical economic indicators in a comprehensive manner as much as possible, in order to capture the technical structure of the rice sector as accurate, robust, and reliably as possible.[4]

2
Technology Structure of the Rice Sector of Japanese Agriculture: (I) A Translog Variable Cost (VC) Function Approach

2.1 Introduction

The major objective of this chapter is to execute a comprehensive quantitative investigation on the technology structure of rice production which has still been a most important agricultural product in Japan in many senses. To pursue this objective, a so-called flexible functional model of the cost function will be developed and estimated for the second half of the 20th century, 1956–97, using a pooled cross section of time series data for Tohoku as a representative rice producing region in Japan.

Since the *duality* theorem, index number theories, and flexible functional forms such as translog, quadratic, generalized Cobb–Douglas, and generalized Leontief models have been developed and promoted extensively, in particular, in the U.S. academic world of economics since around the mid-1950s to the early-1970s, such approaches to empirical economic issues have become popular, and particularly among Japanese researchers not only in the arena of general economics but also in the field of agricultural economics since the late-1970s until recently.

Roughly speaking, however, Japanese researchers in the field of agricultural economics have mainly applied the newly developed methods to empirical analyses of rice production which has been losing its status of the most important product in Japanese agriculture. Figure 1.3 shows that the share of rice production in the total agricultural production has become smaller and smaller since the early-1960s.

For example, Kako (1978) and Kako (1979a, 1979b) focused on estimating the elasticities of demands for and substitutions between factor inputs, scale economies, and technological change biases, respectively, based on the data obtained for the Kinki agricultural district (Kinki in short hereafter). Chino (1984) made similar researches as executed by Kako. Ito (1989) analyzed for the first time in Japan the effects of public R&D and extension activities on Japanese rice production. Kusakari (1989) analyzed the effects of the set-aside programs for rice production by applying the VP function. Kondo (1991), by estimating the translog cost and profit functions, attacked an important issue of analyzing the effects of the price-support and set-aside programs on rice production.[1]

Although all these studies offer very interesting and important information on the effects of government agricultural policies such as the price-support and set-aside programs, they do not necessarily offer comprehensive and consistent information on the technology or production structure in general for post-war Japanese rice farming. In addition, many previous studies including those mentioned above specified total cost (TC in short hereafter) functions where all factor inputs are assumed to be optimally utilized i.e., to cost-minimizing levels. However, we may argue that the stocks of family labor and land need not be treated as variable factor inputs in the cost or variable profit function models which are estimated using general samples of annual data or pooled cross sections of annual time series data. In reality, farms may need more than one year to adjust their utilization of labor and land. In such a situation, a variable cost (VC) function approach, with labor and land being quasi-fixed factor inputs, may be more appropriate to investigate the technology structure of rice production.[2]

Therefore, this chapter will try to obtain a more comprehensive set of quantitative estimates on the technology structure of post-war rice production for the four decades of the second half of the 20th century, more specifically for the period 1956–97. Accordingly, we will develop and estimate the VC function models for this period, with labor and land being the quasi-fixed factor inputs. Based on the parameter estimates of the VC function models, a set of critical hypotheses on the technology structure will be tested. Furthermore, we will estimate and evaluate important economic indicators: such as, elasticity of demand for and substitution of factor inputs, the degrees of returns to scale, rates and biases of technological change, and the shadow values of the quasi-fixed factor inputs.

The rest of this chapter is organized as follows. Section two presents some background data related to the status of and changes in post-war rice production. Section three lays out in detail the analytical framework. Section four explains the variable processing and the estimation procedure. Section five reports and evaluates empirical results. Finally, Section six provides a brief summary and conclusion.

2.2 Agricultural production in Tohoku

At this point, it should be emphasized that we are going to restrict our study to only one agricultural district, Tohoku, which is located in the northernmost part of Tofuken and has been one of the most representative districts for rice production in Japan. The reasons for this are: First, the climate and land conditions seem to be similar within the same district. Second, the technology of rice production may also be similar among farms in the same agricultural district. Third, the price levels of output (rice) and factor inputs do not seem to be that different among farms in the same district. Accordingly, we may claim that the data obtained from one agricultural district are more homogeneous than the data from all Japan, so that it will be more relevant for econometrically investigating the technology structure of rice production.

We first look into the movements of agricultural outputs as a whole and then movements of factor inputs for rice production in Tohoku.

Figure 2.1 shows the real values of production of rice, vegetables, fruit, other crops, and livestock as the major agricultural products in Tohoku. First of all, though there were ups and downs, the real value

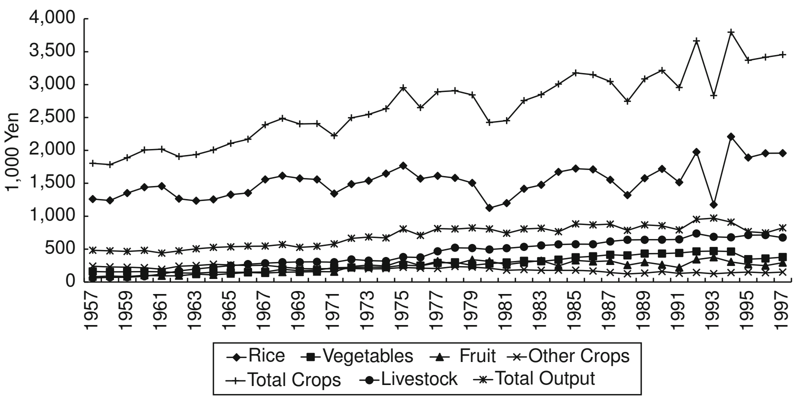

Figure 2.1 Changes in the amounts of total output, total crops, rice, vegetables, fruit, other crops, and livestock for 1957–97 at 1985 prices: average farm (Tohoku)

Source: The MAFF. *The Noka Keizai Chosa Hokoku (The Survey Report on Farm Household Economy)*, various issues.

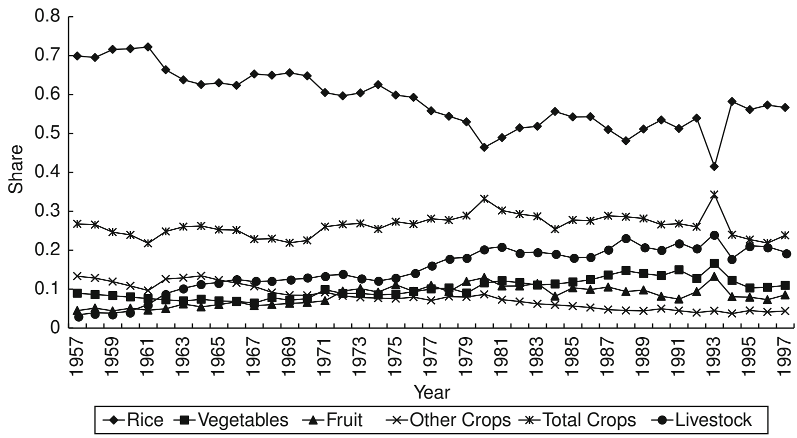

Figure 2.2 Changes in the shares of total crops, vegetables, fruit, other crops, and livestock in the agricultural output for 1957–97 at 1985 prices: average farm (Tohoku)

Source: The same as in Figure 2.1.

of rice production had an increasing trend for the entire study period 1956–97 in spite of the introduction of set-aside programs in 1969. On the other hand, although production of vegetables, fruit, and livestock consistently increased during 1956–97, it was far less than that of rice.

Reflecting the price movements of Figure 2.1, Figure 2.2 indicates a decreasing trend in rice production (though with some fluctuation). On the other hand, the share of vegetables, fruit and livestock increased between 1956 and 1993 but returned a decreasing trend from 1993 onwards. These movements of agricultural products over time were considerably different from those in all Japan (see Figure 1.1 in Chapter 1). So, although the share of rice production in Tohoku had a decreasing trend and the share of livestock had an increasing trend over time, the share of rice absolutely overwhelmed the share of livestock for the entire study period 1956–97. In other words, rice was still the most important product in Tohoku during the entire study period 1956–97.

What about the movements of factor inputs for rice production in Tohoku? First of all, the indexes of factor inputs presented in Figure 2.3 show that machinery input increased very sharply for the whole (except 1994–1997) during which the index showed a decreasing trend though with an increase in the index again in 1997. Similarly, intermediate and other input (farm buildings and land improvement equipment) had

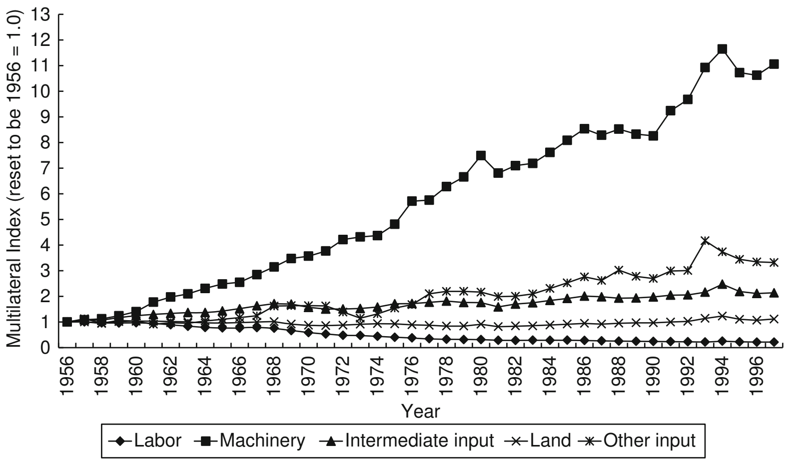

Figure 2.3 Multilateral indexes of factor prices for 1956–97 at 1985 prices: average farm (Tohoku)

Source: The same as in Figure 2.1.

increasing trends over time until 1994 and 1993, respectively, and then decreased slightly. On the other hand, the index of labor input had consistently a decreasing trend for the entire study period 1956–97. As for land, the index showed almost constant movement for the period 1956–80 around 0.9–1.0, with a very slightly increasing trend since 1981 towards the late-1990s. These movements of factor inputs were in general opposite to those of the price indexes of factor inputs normalized by the output price index (real price index, hereafter) as presented in Figure 2.4.

On the other hand, the real price index of labor had a sharp increasing trend for the whole period 1956–97; from 1.0 in 1956 to around 12.4 1997. As for land, the real price index also sharply increased for the period 1956–88, with a stagnant period between 1978–88. However, from 1988 through to the late-1990s, the real price index of land had a sharp decreasing trend, though it increased in 1993 due perhaps to the bad harvest in the previous year.

Reflecting the movements of the utilization levels and the real price indexes of factor inputs, an intriguing picture of the cost shares of the five factor inputs is captured in Figure 2.5. To begin with, due to rapid mechanization, the cost of machinery increased consistently from around 0.12 in 1956 to 0.37 in 1997; about threefold. On the contrary,

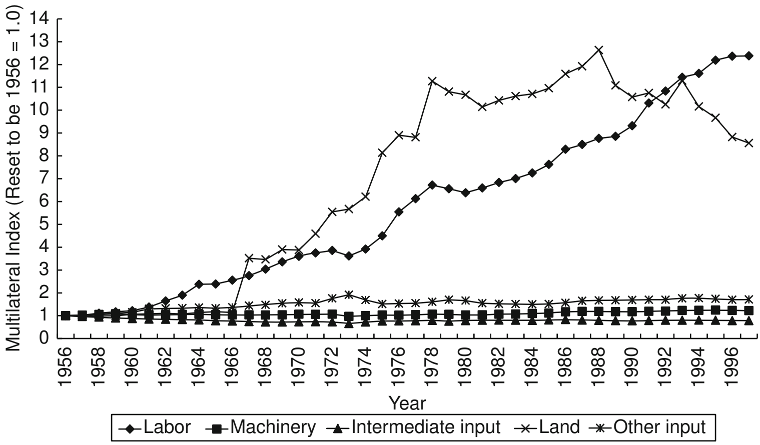

Figure 2.4 Multilateral price indexes of factor inputs normalized by the output price index for 1956–97 at 1985 prices: average farm (Tohoku)

Source: The same as in Figure 2.1.

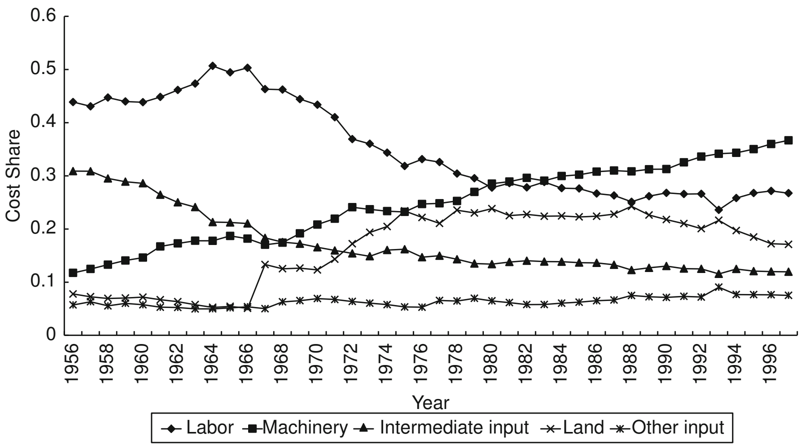

Figure 2.5 Factor cost shares in the total production cost for 1956–97 at 1985 prices: average farm (Tohoku)

Source: The same as in Figure 2.1.

in spite of consistent increases in the use of intermediate input, its cost share decreased consistently from around 0.31 in 1956 to 0.12 in 1997. This may have been due mainly to the consistently low real price levels of intermediate input. For other input, the movement in the cost share was similar to that of intermediate input. That is, because although the usage of other input had an increasing trend, real price levels did not increase that much. The cost share of other input had only a slight increasing trend during the study period, from around 0.7 in 1956 to around 0.8 in 1997, though with a sudden increase in 1993.

On the other hand, the cost share of labor increased from around 0.43 in 1956 to around 0.50 in the mid-1960s, but since then it had a consistent decreasing trend towards the late-1990s; around 0.27 in 1997. The cost share of land, though, was very low during the 1956–66 period due to the strongly regulated land rent. Since 1966 to 1975 it had an increasing trend; in 1975 it was around 0.23. However, for the period 1975–88, the land cost share was almost constantly around 0.22–0.23, which corresponds to the stagnancy of the real land price index for the period 1978–88. Between 1988 and the late-1990s, the land cost share had a decreasing trend; it was around 0.17 in 1997. This corresponds to the sharp decreasing trend of land prices for the period 1988–97 as shown in Figure 2.4.

Based on these observations from the background data of all Japan and Tohoku, we will next develop an econometric model to statistically analyze the technology structure of rice production represented by Tohoku.

2.3 Analytical framework

2.3.1 The variable cost (VC) function model

As clearly mentioned in section one, the major objective of this chapter is to quantitatively investigate the technology structure of post-war Japanese rice production; in particular, the second half of the 20th century, 1957–97. Furthermore, as also briefly mentioned in the previous section, we recognize that in many situations the stock of family labor and land may be fixed in the short run (one crop year), thus requiring the farm-firm to deviate from its expansion path. In such a case, the estimated TC functions may have failed to depict the true extents of, say, demand and substitution elasticities of factor inputs, scale economies, rates and biases of technological change, and so on, because one of the assumptions underlying the TC function in particular – the assumption of cost minimization – has been violated.

It is then assumed that the farm-firm minimizes the variable factor costs conditional on a given stock of fixed factor inputs. That is, the farm-firm is assumed to attain static equilibrium with respect only to the variable factor inputs, given the observed levels of the fixed factor inputs. In this sense, this chapter may be regarded as dealing with the short-run behavior of the farm-firm in that the stocks of family labor and land are assumed to remain unchanged within the one-year observation period.

A word needs to be mentioned about the treatment of family labor and land as quasi-fixed factor inputs. Generally speaking, it is often difficult in agricultural production to adjust land stock to the optimal level within the observation period of one year in response to changes in exogenous variables such as the quantity of output, the prices of variable inputs, and changing technology. Such factor input is often more like a fixed factor input rather than a variable input in the short run. On the other hand, family labor is more like a variable input than a fixed factor input, since its stock appears to be more easily adjusted to changes in exogenous variables than land. In reality, however, more than 97% of labor is on average composed of family labor in post-war Japanese agriculture, for which a market does not exist. Accordingly, its shadow price is usually unobservable. In such a situation, treating family labor as variable, and hence the cost function as its dual, by arbitrarily assuming a priori that the price of family labor is equal to the market price, may cause biased results in the parameter estimates of the cost function. Such a bias might affect economic indicators: the elasticity of demand, the substitution of factor inputs, degrees of scale economies, the rate and type of technological change, and so forth. The market price includes factors such as wage rates: for temporary agricultural labor, nonagricultural employment, etc.

Now, we will develop a VC function where labor and land are treated as quasi-fixed factor inputs. More specifically, we will develop and derive the translog VC function and derive the variable factor input-variable cost share equations and the indicators for testing the various hypotheses on the technology structure of post-war Japanese rice production.[3]

We define the following VC function,

$$CV = G(Q, \mathbf{w}, \mathbf{Z}, Z_R, t, \mathbf{D}), \tag{2.1}$$

where CV is the amount of nominal variable cost; Q is the quantity of output; **w** denotes a vector of nominal variable factor prices which consists of the prices of machinery (w_M), intermediate input (w_I), and other input (w_O); **Z** is a vector of quasi-fixed factor inputs composed of labor (Z_L) and land (Z_B); Z_R is the stock of technological knowledge brought about from investments in public agricultural R&D and E activities; t is a time index as a proxy for technological innovations which is assumed not to include the effects of Z_R; and **D** consists of dummy variables for period (D_p), farm sizes (D_s, $s = II, III, IV, V, VI$), and weather conditions (D_w). The details of the definitions and specifications of the variables in this VC function are presented in Appendix A of this chapter.

Now, for econometric analysis the following translog VC function is specified:

$$
\begin{aligned}
\ln CV = & \alpha_0 + \alpha_Q \ln Q + \sum_i \alpha_i \ln w_i + \sum_k \beta_k \ln Z_k + \beta_R \ln Z_R + \beta_t \ln t \\
& + \sigma_p D_p + \sum_s \sigma_s D_s + \sigma_w D_w \\
& + \frac{1}{2}\gamma_{QQ}(\ln Q)^2 + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln w_i \ln w_j \\
& + \sum_i \delta_{Qi} \ln Q \ln w_i + \frac{1}{2}\sum_k \sum_l \phi_{kl} \ln Z_k \ln Z_l \\
& + \sum_k \theta_{Qk} \ln Q \ln Z_k + \sum_i \sum_k \theta_{ik} \ln w_i \ln Z_k \\
& + \mu_{Qt} \ln Q \ln t + \sum_i \mu_{it} \ln w_i \ln t + \frac{1}{2}\mu_{tt}(\ln t)^2 \\
& + \nu_{QR} \ln Q \ln Z_R + \sum_i \nu_{iR} \ln w_i \ln Z_R \\
& + \nu_{tR} \ln t \ln Z_R + \frac{1}{2}\nu_{RR}(\ln Z_R)^2, \\
& i,j = M, I, O, \quad k,l = L, B, \quad s = II, III, IV, V, VI.
\end{aligned} \tag{2.2}
$$

Applying Shephard's (1953) Lemma to the translog VC function (2.2), we obtain the following variable factor cost share functions.

Assuming that the farm-firm takes the prices of the variable factor inputs as given, the following variable factor cost share equations are derived:

$$S_i = \frac{\partial CV}{\partial w_i}\frac{w_i}{CV} = \frac{\partial \ln CV}{\partial \ln w_i}$$
$$= \alpha_i + \sum_i \gamma_{ij} \ln w_i + \delta_{Qi} \ln Q + \sum_k \theta_{ik} \ln Z_k + \mu_{it} \ln t + \nu_{iR} \ln Z_R, \qquad (2.3)$$

$i, j = M, I, O, \quad k = L, B.$

The translog VC function (2.2) can be used along with the variable profit-maximizing condition to derive additional equation representing the optimal choice of the endogenous output (Q) (Fuss and Waverman, 1981, pp. 288–89), Ray (1982), and Capalbo (1988). That is, the variable revenue-variable cost share equation (R_Q) is given by,

$$R_Q = \frac{\partial CV}{\partial Q}\frac{Q}{CV} = \frac{\partial \ln CV}{\partial \ln Q}$$
$$= \alpha_Q + \gamma_{QQ} \ln Q + \sum_i \delta_{Qi} \ln w_i + \sum_k \theta_{Qk} \ln Z_k + \mu_{Qt} \ln t + \nu_{QR} \ln Z_R, \qquad (2.4)$$

$i = M, I, O, \quad k = L, B.$

In addition, following again Fuss and Waverman (1981, pp. 288–89), we introduce an analogous assumption that the ordinary translog VC function (2.2) can be used along with the variable profit-maximizing condition to derive an additional equation representing the optimal choice of a quasi-fixed factor input, i.e., labor (Z_L). In doing this, we are assuming that the farm-firm attains the optimal allocation of labor input by equating the marginal productivity of labor to the market price of labor represented by the wage rate of temporary-hired labor. Accordingly, the labor-cost share equation is given by,[4]

$$R_{Z_L} = \frac{\partial CV}{\partial Z_L}\frac{Z_L}{CV} = \frac{\partial \ln CV}{\partial \ln Z_L}$$
$$= \beta_L + \phi_{QL} \ln Q + \sum_i \theta_{Li} \ln w_i + \sum_k \phi_{kL} \ln Z_k + \nu_{LR} \ln Z_R + \mu_{Lt} \ln t, \qquad (2.5)$$

$k, n = M, I, O, \; h = L, B.$

Introduction of the revenue-variable cost share (R_Q) and the labor-variable cost share equations (R_{Z_L}) into the estimation of the system of equations will in general lead to a more efficient estimation of the coefficients; in particular, of the output and labor input-associated variables due to the additional information provided by the revenue-variable cost and labor-variable cost share equations.

Any sensible cost function must be homogeneous to degree one in input prices. In the translog VC function (2.2) this requires that $\sum_i \alpha_i = 1$, $\sum_n \gamma_{ij} = 0$, and $\sum_k \theta_{ik} = 0 \quad (i = M, I, O,\ k = L, B)$. The ordinary translog VC function (2.2) has a general form in the sense that the restrictions of input-output separability and Hicks neutrality of technological change are not imposed *a priori*. Instead, these restrictions will be statistically tested *via* the estimation process of this function.

The translog VC function (2.2) has a general form, in the sense that the restrictions of homotheticity, constant returns to scale, and Hicks (1932) neutrality of technological change with respect to t and Z_R are not imposed *a priori*. Instead, these restrictions will be statistically tested *via* the estimation process of this function, together with other restrictions to be mentioned immediately in the next subsection.

For statistical estimation, the system of equations consists of the ordinary translog VC function (2.2), three of the variable factor-cost share equations (2.3), the revenue-cost share equation (2.4), and one labor-cost share equation (2.5). Note here that in this system of equations, output and labor are treated as "quasi-endogenous" variables. Thus, the estimation model is "complete" in the sense that it has as many (six) equations as endogenous variables (six). Therefore, the full information likelihood (FIML in short hereafter) method was chosen.

It is critical to note at this point that the FIML estimation of the six-equation system exposed above was unfortunately not successful due to the multicolinearity between the time variable t and the stock of technological knowledge Z_R. We then decided to estimate two different systems of equations with only one variable for representing technological change: (A) with a time index t and (B) with the stock of technological knowledge Z_R. Note here however that the time variable t of Model (A) is now assumed to represent all kinds of technological innovations, including the effects of the stock of technological knowledge Z_R.

In both cases, however, we could not obtain any statistically significant coefficients for all dummy variables. Thus, all dummy variables were omitted from the two VC function models (A) and (B). These two models are:

2.3.1.1 The VC function model (A)

The VC function Model (A) can be written as follows:

$$CV^A = G(Q, \mathbf{w}, \mathbf{Z}, t). \tag{2.6}$$

The translog specification is written as,

$$\begin{aligned}\ln CV^A =\ & \alpha_0 + \alpha_Q \ln Q + \sum_i \alpha_i \ln w_i + \sum_k \beta_k \ln Z_k + \beta_t \ln t \\ & + \frac{1}{2}\gamma_{QQ}(\ln Q)^2 + \frac{1}{2}\sum_i\sum_j \gamma_{ij} \ln w_i \ln w_j \\ & + \sum_i \delta_{Qi} \ln Q \ln w_i + \frac{1}{2}\sum_k\sum_l \phi_{kl} \ln Z_k \ln Z_l \\ & + \sum_i\sum_k \theta_{ik} \ln w_i \ln Z_k + \sum_k \theta_{Qk} \ln Q \ln Z_k \\ & + \mu_{Qt} \ln Q \ln t + \sum_i \mu_{it} \ln w_i \ln t \\ & + \sum_k \mu_{kt} \ln Z_k \ln t + \frac{1}{2}\mu_{tt}(\ln t)^2, \end{aligned} \tag{2.7}$$

$$i,j = M,I,O, \quad k,l = L,B.$$

The variable cost share equations are given by,

$$\begin{aligned} S_i^A &= \frac{\partial CV^A}{\partial w_i}\frac{w_i}{CV^A} = \frac{\partial \ln CV^A}{\partial \ln w_i} \\ &= \alpha_i + \delta_{Qi} \ln Q + \sum_i \gamma_{ij} \ln w_i + \sum_k \theta_{ik} \ln Z_k + \mu_{it} \ln t, \end{aligned} \tag{2.8}$$

$$i,j = M,I,O, \quad k = L,B.$$

The revenue-variable cost and labor-variable cost share equations are given by the following Equations (2.9) and (2.10), respectively,

$$\begin{aligned} R_Q^A &= \frac{\partial CV^A}{\partial Q}\frac{Q}{CV^A} = \frac{\partial \ln CV^A}{\partial \ln Q} \\ &= \alpha_Q + \gamma_{QQ} \ln Q + \sum_i \delta_{Qi} \ln w_i + \sum_k \theta_{Qk} \ln Z_k + \mu_{Qt} \ln t, \end{aligned} \tag{2.9}$$

$$i = M,I,O, \quad k = L,B,$$

$$\begin{aligned} S_{Z_L}^A &= \frac{\partial CV^A}{\partial Z_L}\frac{Z_L}{CV^A} = \frac{\partial \ln CV^A}{\partial \ln Z_L} \\ &= \beta_L + \phi_{QL} \ln Q + \sum_i \theta_{iL} \ln w_i + \sum_k \phi_{kL} \ln Z_k + \mu_{Lt} \ln t, \end{aligned} \tag{2.10}$$

$$i = M,I,O, \ k = L,B.$$

2.3.1.2 The VC function model (B)

Similarly, the VC function (B) is given by:

$$CV^B = G(Q, \mathbf{w}, \mathbf{Z}, Z_R). \tag{2.11}$$

The translog specification of the VC function (B) is given as,

$$\begin{aligned}
\ln CV^B = {} & \alpha_0 + \alpha_Q \ln Q + \sum_i \alpha_i \ln w_i + \sum_k \beta_k \ln Z_k + \beta_R \ln Z_R \\
& + \frac{1}{2}\gamma_{QQ}(\ln Q)^2 + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln w_i \ln w_j \\
& + \sum_i \delta_{Qi} \ln Q \ln w_i + \frac{1}{2}\sum_k \sum_l \phi_{kl} \ln Z_k \ln Z_l \\
& + \sum_i \sum_l \theta_{il} \ln w_i \ln Z_l + \sum_k \theta_{Qk} \ln Q \ln Z_k \\
& + \nu_{QR} \ln Q \ln Z_R + \sum_i \nu_{iR} \ln w_i \ln Z_R \\
& + \sum_k \nu_{kR} \ln Z_k \ln Z_R + \frac{1}{2}\nu_{RR}(\ln Z_R)^2,
\end{aligned} \tag{2.12}$$

$$i, j = M, I, O, \quad k, l = L, B.$$

The variable cost share equations are given by,

$$\begin{aligned}
S_i^B &= \frac{\partial CV^B}{\partial w_i}\frac{w_i}{CV^B} = \frac{\partial \ln CV^B}{\partial \ln w_i} \\
&= \alpha_i + \delta_{Qi} \ln Q + \sum_i \delta_{ij} \ln w_i + \sum_k \theta_{ik} \ln Z_k + \nu_{iR} \ln Z_R,
\end{aligned} \tag{2.13}$$

$$i, j = M, I, O, \quad k = L, B.$$

The revenue-variable cost and labor-variable cost share equations are given by the following Equations (2.14) and (2.15), respectively.

$$\begin{aligned}
R_Q^B &= \frac{\partial CV^B}{\partial Q}\frac{Q}{CV^B} = \frac{\partial \ln CV^B}{\partial \ln Q} \\
&= \alpha_Q + \gamma_{QQ} \ln Q + \sum_i \delta_{Qi} \ln w_i + \sum_k \theta_{Qk} \ln Z_k + \nu_{QR} \ln Z_R,
\end{aligned} \tag{2.14}$$

$$i = M, I, O, \quad k = L, B,$$

$$S_{Z_L}^B = \frac{\partial CV^B}{\partial Z_L} \frac{Z_L}{CV^B} = \frac{\partial \ln CV^B}{\partial \ln Z_L}$$
$$= \beta_L + \phi_{QL} \ln Q + \sum_i \theta_{iL} \ln w_i + \sum_k \phi_{kL} \ln Z_k + \nu_{LR} \ln Z_R, \qquad (2.15)$$
$$i = M, I, O, \ k = L, B.$$

Needless to say, for statistical estimation of the two systems, Model (A) and Model (B), the FIML method was chosen, since in both models the number of estimating equations are equal to the number of the endogenous variables in both models.

At this point, we should note the following. First of all, the observed values of CV^A and CV^B, S_i^A and S_i^B ($i = M, I, O$), and R_Q^A and R_Q^B are the same, though the estimated values may be different between pairs. This applies to the case of $S_{Z_L}^A$ and $S_{Z_L}^B$. Furthermore, although the estimated values of those parameters may naturally be different between Model (A) and Model (B), we will use the same symbols for the parameters in the ordinary translog VC functions of Model (A) and Model (B), except for those with time variable t and the stock of technological knowledge Z_R, to avoid messy mathematical expressions.

2.3.2 Tests for the technology structure of rice production

This subsection deals with important concepts representing the technology structure of rice production: namely, homotheticity, constant returns to scale, C–D production function, no technological change, and Hicks (1932) neutral technological change. The developments and expositions of these hypotheses are as follows.[5]

Note, however, that since the procedures for testing these hypotheses are similar for both models – except for the differences in the variables representing technological change, i.e., t and Z_R – we will present the test procedures only for Model (A) to save space.

2.3.2.1 Homotheticity

According to Lau (1978), the technology is homothetic if and only if the VC function (2.6) of Model (A) can be written as,

$$CV^A(Q, \mathbf{w}, \mathbf{Z}, t) = G(Q, t) H(\mathbf{w}, \mathbf{Z}, t). \qquad (2.16)$$

Taking the natural logarithms of both sides of Equation (2.16), we have

$$\ln CV^A = \ln G(Q, t) + \ln H(\mathbf{w}, \mathbf{Z}, t). \qquad (2.17)$$

In the translog form given in Equation (2.7), homotheticity requires that the parameters of the translog approximation satisfy the following condition,

$$\delta_{Qi} = \theta_{Qk} = \mu_{Qt} = 0, \quad i = M, I, \ k = L, B. \tag{2.18}$$

This implies that changes in the output level do not give any impacts on the cost shares of the variable factor inputs (machinery, intermediate input, and other input), the shadow cost shares (or the shadow values) of the quasi-fixed factor inputs (labor and land), and the rate and bias of technological change.

2.3.2.2 No technological change

Above all, it is critical to examine whether or not there exists technological change in Japanese rice production at all. This implies that the following parameters associated with technological change are all zero in the translog VC function (2.7).

$$H_0 : \beta_t = \mu_{Qt} = \mu_{it} = \mu_{kt} = \mu_{tt} = 0, \tag{2.19}$$
$$i = M, I, O, \quad k = L, B.$$

2.3.2.3 Hicks neutral technological change

Based on the procedure developed by Binswanger (1974), Hicks neutrality of technological change with respect to the variable factor inputs can be tested by examining the following null hypothesis, using parameters of the translog VC function (2.7):

$$H_0 : \mu_{it} = 0, \quad i = M, I, O. \tag{2.20}$$

2.3.2.4 Extended *Hicks neutral technological change*

Slightly modifying Halvorson and Smith (1986, p. 400), we can modify the null hypothesis of Hicks neutrality as an extended Hicks neutrality, by additionally testing the neutrality with respect to the level of output and the quantities of quasi-fixed factor inputs. The modified *extended* Hicks neutrality can be tested by examining the following null hypothesis, using parameters of the translog VC function (2.7).[6]

$$H_0 : \mu_{it} = \mu_{Qt} = \mu_{kt} = 0, \quad i = M, I, O, \ k = L, B. \tag{2.21}$$

The result of the test for this hypothesis will, not only give information on whether or not technological innovations have an output-augmenting bias, but also offer information on whether such innovation brings about a saving or biases towards the quasi-fixed factor inputs.

2.3.2.5 Cobb–Douglas (C–D) production function

The hypothesis whether or not the rice production technology is specified as a C–D production function can be tested by examining the following hypothesis,

$$H_0 : \gamma_{QQ} = \gamma_{ij} = \delta_{Qi} = \phi_{kn} = \theta_{Qk} = \theta_{ik} = \mu_{Qt} = \mu_{it} = \mu_{kt} = \mu_{tt} = 0, \quad (2.22)$$

$$i, j = M, I, O, \quad k, n = L, B.$$

That is, the coefficients of the quadratic terms of the translog VC function (2.7) are all jointly zero.

2.3.2.6 Constant returns to scale (CRTS)

Following Lau (1978), CRTS can be tested by examining the null hypothesis given below,

$$\begin{aligned} H_0 : \alpha_Q + \sum_k \alpha_k &= 1, \\ \gamma_{QQ} + \sum_k \theta_{Qk} &= 0, \\ \delta_{Qi} + \sum_k \theta_{Qk} &= 0, \\ \theta_{Qk} + \sum_k \phi_{kn} &= 0, \\ \mu_{Qt} + \sum_k \mu_{kt} &= 0, \qquad (2.23) \\ i = M, I, O, \ k, n = L, B. \end{aligned}$$

If this null hypothesis is rejected statistically, CRTS does not exist, indicating increasing returns to scale (IRTS) or decreasing returns to scale (DRTS).

2.3.3 Basic economic indicators of the technology structure of post-war rice production

In this subsection, we will estimate the basic economic indicators using the two translog VC function models. For this objective, the estimated parameters of Equations (2.7) and (2.12) will be used for the estimation of each equation. However, since the basic formulation for each indicator is the same between Models (A) and (B), except for the variables t and R for the proxies for technological innovations between the two models, we will stick to Model (A) for the derivations and expressions of the formulas for all indicators.

2.3.3.1 Factor demand elasticities and the Allen, Morishima, and McFadden (shadow) elasticities of substitutions

First, the own- and cross-price elasticities of factor demands at the approximation points are given by the following Equations (2.24) and (2.25), respectively:

$$\varepsilon_{ii} = (\gamma_{ii} + \alpha_i^2 - \alpha_i)/\alpha_i, \quad i = M, I, O, \tag{2.24}$$

$$\varepsilon_{ij} = (\gamma_{ij} + \alpha_i \alpha_j)/\alpha_i \quad i \neq j = M, I, O. \tag{2.25}$$

Second, the AES's are obtained by

$$\sigma_{ii}^A = (\gamma_{ii} + \alpha_i^2 - \alpha_i)/\alpha_i^2, \quad i = M, I, O, \tag{2.26}$$

$$\sigma_{ij}^A = (\gamma_{ij} + \alpha_i \alpha_j)/\alpha_i \alpha_j \quad i \neq j = M, I, O. \tag{2.27}$$

Third, the MES's are given by,

$$\sigma_{ij}^M = \alpha_j(\sigma_{ij}^A - \sigma_{jj}^A) = \varepsilon_{ij} - \varepsilon_{jj}, \quad i \neq j = M, I, O. \tag{2.28}$$

Finally, the SES's are given by,

$$\sigma_{ij}^S = \frac{\alpha_i}{\alpha_i + \alpha_j}\sigma_{ij}^M + \frac{\alpha_j}{\alpha_i + \alpha_j}\sigma_{ij}^M, \quad i \neq j = M, I, O.^7 \tag{2.29}$$

2.3.3.2 Returns to scale

Following again Caves, Christensen, and Swanson (CCS) (1982), returns to scale (*RTS* in short hereafter) can be estimated in our translog VC function Model (A). This can be executed by estimating the following equations given below:

$$RTS = \frac{1 - \sum_k \partial \ln CV^A/\partial \ln Z_k}{\partial \ln CV^A/\partial \ln Q} = \frac{1 - \sum_k \varepsilon_{CV^A Z k}}{\varepsilon_{CV^A Q}}, \quad k = L, B, \tag{2.30}$$

where

$$\sum_k \varepsilon_{CV^A Zk} = \sum_k \frac{\partial \ln CV^A}{\partial \ln Z_k} = \sum_k \beta_k + \sum_k \theta_{kQ} \ln Q + \sum_i \theta_{ik} \ln w_i + \sum_k \phi_{kn} \ln Z_k + \sum_k \mu_{kt} \ln t, \quad (2.31)$$

and

$$\varepsilon_{CV^A Q} = \frac{\partial \ln CV^A}{\partial \ln Q} = \alpha_Q + \gamma_{QQ} \ln Q + \sum_i \delta_{Qi} \ln w_i + \sum_k \theta_{Qk} \ln Z_k + \mu_{Qt} \ln t, \quad (2.32)$$

$$i = M, I, O, \quad k = L, B,$$

which are defined respectively as the variable cost-fixed factor input elasticities and variable cost-output elasticity.

At the approximation points, *RTS* can simply be estimated by,

$$RTS = (1 - \sum_k \beta_k)/\alpha_Q, \quad k = L, B. \quad (2.33)$$

We will estimate *RTS* both at the approximation points and for each observation of all six size classes for each year of the entire study period, in order to capture movements in *RTS* over time in different class sizes.

2.3.3.3 The "factor input-saving" (PGX) and "output-augmenting" (PGY) technological change "rates" based on the parameter estimates of model (A) of the VC function

Based on the estimated results of Model (A), we can compute the magnitude of technological progress from an increase in the index of conglomerate technological innovations, t, and the degree of economies of scale. Using the procedure developed by Caves, Christensen, and Diewert (1982), and CCS (1981), we will compute two indicators of technological progress in terms of "elasticities".[8] They are (i) the "index" of "input-saving" technological progress with respect to t with output held fixed (*PGX*); and (ii) the "index of "output-augmenting" technological progress with respect to t with inputs held fixed (*PGY*). According to CCS (1981), $PGY = RTS \cdot PGX$ where *RTS* denotes returns to scale. Thus, if there are constant returns to scale (CRTS), i.e., $RTS = 1$, then $PGX = PGY$.

Now, using the parameters of the translog VC function (2.7) of Model (A), the *PGX* is given by,

$$PGX = -\frac{\partial \ln CV^A/\partial \ln t}{1-\partial \ln CV^A/(\sum_k \partial \ln Z_k)} = -\frac{\varepsilon_{CV^A t}}{1-\sum_k \varepsilon_{CV^A Zk}}, \quad k = L, B, \quad (2.34)$$

and, the *PGY* is given by,

$$\begin{aligned} PGY &= -\frac{\partial \ln CV^A/\partial \ln t}{\partial \ln CV^A/\partial \ln Q} = -\frac{\varepsilon_{CV^A t}}{\varepsilon_{CV^A Q}} \\ &= RTS \cdot PGX, \end{aligned} \quad (2.35)$$

where *RTS*, $\varepsilon_{CV^A Zk}(k = L, B)$, and $\varepsilon_{CV^A Q}$ are already defined in Equations (2.30), (2.31), and (2.32), respectively.

At the approximation points, the *PGX* and *PGY* can simply be estimated by,

$$PGX = -\beta_t/(1-\sum_k \beta_k), \quad k = L, B, \quad (2.36)$$

and

$$PGY = -\beta_t/\alpha_Q. \quad (2.37)$$

Both *PGX* and *PGY* will be estimated at the approximation points as well as for each sample observation of the six size classes for each year of the entire study period 1956–1997. This way we can capture the movements of and the differences in the rates of technological change over time and among different size classes.

2.3.3.4 The biases of technological change

Following Antle and Capalbo (1988, pp. 33–48), we will define the bias of technological change below:

$$\begin{aligned} B_i^e &= \partial \ln S_i(Q, \mathbf{w}, \mathbf{Z}, t)/\partial \ln t \Big|_{dCV^A=0} \\ &= B_i - \left[\left(\partial \ln S_i/\partial \ln Q\right)\left(\partial \ln CV^A/\partial \ln Q\right)^{-1}\right]\left(\frac{\partial \ln CV^A}{\partial \ln t}\right), \end{aligned} \quad (2.38)$$

$$i = M, I, O,$$

where $B_i \equiv \partial \ln S_i(Q, \mathbf{w}, \mathbf{Z}, t)/\partial \ln t$ $(i = M, I, O)$ is the *pure bias effect*. The second term of equation is the *scale bias effect*.

Using the parameters of the translog VC function (2.7), Equation (2.38) can be expressed as,

$$
\begin{aligned}
B_i^e &= \frac{\mu_{it}}{S_i} + \mu_{Qt} S_i \lambda \\
&= B_i + B_{iQ}^s, \quad i = M, I, O,
\end{aligned} \tag{2.39}
$$

where

$$
\lambda = -\frac{\partial \ln CV^A / \partial \ln t}{\partial \ln CV^A / \partial \ln Q} = \frac{-\varepsilon_{CV^A t}}{\varepsilon_{CV^A Q}}, \tag{2.40}
$$

where,

$$
\begin{aligned}
\varepsilon_{CV^A t} &= \frac{\partial \ln CV^A}{\partial \ln t} \\
&= \beta_t + \mu_{Qt} \ln Q + \sum_i \mu_{it} \ln w_i + \sum_k \mu_{kt} \ln Z_k + \mu_{tt} \ln t, \\
& i = M, I, O, \quad k = L, B.
\end{aligned} \tag{2.41}
$$

At the approximation points, the *pure*, *scale*, and *overall bias effects* can be estimated as follows:

$$
B_i^e = \mu_{it}/\alpha_i + (\delta_{Qt}/\alpha_i), \quad i = M, I, O. \tag{2.42}
$$

Estimating the *pure* and *scale bias effects* based on Equation (2.42), we can compute the degrees of contribution of each effect in the *overall bias effect* for each variable input. Note here that the *pure, scale,* and *overall bias effects* will be expressed in terms of elasticities as is clear from the original definition of technological bias given in Equation (2.38).[9]

2.3.3.5 The shadow price of paddy land

Finally, but not least important, it is a good idea to check the validity of the long-run equilibrium, or, in other words, the validity of applying the TC function model where all factor inputs are treated as variable inputs.

In general,

> departures from the long-run equilibrium arise only due to firms employing non-optimal levels of quasi-fixed factor inputs. This should be contrasted with a situation where the departures from the long-run equilibrium can also arise from incomplete adjustment of

prices, as captured by differences between the shadow values evaluated at the observed levels of the quasi-fixed factor inputs and the market prices. [Kulatilaka, 1985, p. 257, footnote 9].

Following this idea, we will estimate the shadow value (or price) of paddy land (w_B^S) at the observed level of paddy land (Z_B) based on the parameter estimates of the translog VC function (2.7) and will compare it with the market price of land which has been regulated by the government in order to examine how much different they were during the entire study period 1956–97.

Now, the shadow price of land at the observed level can be estimated using the estimated parameters of the translog VC function (2.7), as follows:

$$\begin{aligned} w_B^S &= -\frac{\partial CV^A}{\partial Z_B} = -\frac{\partial \ln CV^A}{\partial \ln Z_B}\frac{CV^A}{Z_B} \\ &= -(\beta_B + \theta_{QB}\ln Q + \sum_i \theta_{iB}\ln w_{+} \sum_k \phi_{kn}\ln Z_k \\ &\quad + \mu_{Bt}\ln t)\frac{CV^A}{Z_B}, \qquad (2.43) \\ & i = M, I, O, \ k, n = L.B. \end{aligned}$$

The estimated shadow price w_B^S will be compared with the observed land price (rent) w_B using a graph. By doing so, we can visually capture the differences between the shadow price and the actual price of land and can carry out an informal investigation of the existence of the long-run equilibrium regarding farms' utilization of land input.[10]

2.4 The data and estimation procedure

The data required for the estimation of the VC function Models (A) and (B) consist of the variable cost (VC), the revenue-variable cost share (R_Q) and the quantity of rice production (Q), three variable factor input cost-variable cost shares (S_i, $i = M, I, O$), prices and quantities of the three variable factor inputs which are composed of machinery (w_M and X_M), intermediate input (w_I and X_I), and other input (w_O and X_O) for the VC functions. The time trend (t) and the stock of technological knowledge (R_Z) are respectively employed as proxies for technological innovations for Model (A) and Model (B) and dummy variables for period (D_p), farm sizes (D_s, $s = II, III, IV, V, VI$) and weather (D_w) are also introduced. These variables are common both in Model (A) and in Model (B). Details of the sources of data and definitions of variables are provided in Appendix A of this chapter.

Since the quantity of output (*Q*) on the right hand side of the VC functions (2.1) and (2.11) is in general endogenously determined, a simultaneous procedure should be employed for the estimation of the set of equations. The set of equations for each VC function model consists of the translog VC function, the three variable factor input-variable cost share equations, the revenue-variable cost share equation, and the shadow land input cost-variable cost share equation. Note here that the estimation model is complete, in the sense that it has as many (six) equations as endogenous variables (six). Therefore, the FIML method is employed both for Model (A) and for Model (B). In this method, the restrictions due to symmetry and linear homogeneity in prices are imposed. Due to the linear-homogeneity-in-prices property of the cost functions, one cost share equation can be omitted from the simultaneous equation systems for the statistical estimation. In this chapter, the other input share equation is omitted for the two Models (A) and (B). The coefficients of the omitted other input cost share equation in each model can easily be obtained after each system is estimated, using the imposed linear homogeneity restrictions.

2.5 Empirical results

2.5.1 Parameter estimates of the VC functions: model (A) and model (B)

The estimated parameters of the translog VC functions of Model (A) and Model (B), and the associated *P* (Probability, P in short hereafter)-values, are reported in Tables 2.1 and 2.2, respectively. First, of the 36 parameters of the VC function of Model (A), only four parameters are not statistically significant, at worse than the 5% level. Goodness-of-fit statistics are given in the lower part of Table 2.1, which indicates a fairly good fit for the VC function of Model (A). On the other hand, in the case of the estimates of the translog VC function of Model (B), out of the 36 parameters of the VC function of Model (B), only two are not statistically significant – worse than the 5% level. Goodness-of-fit statistics given in the lower part of Table 2.2 also indicate a fairly good fit for the VC function of Model (B).

In addition, based on the parameter estimates of the VC functions of Model (A) and Model (B) given in Tables 2.1 and 2.2, respectively, the monotonicity and concavity conditions with respect to input prices

Table 2.1 Parameter estimates of the translog variable cost function for the rice sector of Tohoku for 1956–97: model (A) with a time index as a proxy for technological innovations

Parameter	Coefficient	*P*-value	Parameter	Coefficient	*P*-value
α_0	6.322	0.000	ϕ_{LL}	−0.549	0.000
α_Q	2.724	0.000	ϕ_{BB}	−2.799	0.000
α_M	0.492	0.000	ϕ_{LB}	−1.190	0.000
α_I	0.353	0.000	θ_{QL}	1.685	0.000
α_O	0.155	0.000	θ_{QB}	3.443	0.000
β_L	−0.726	0.000	θ_{ML}	−0.120	0.000
β_B	−1.241	0.000	θ_{IL}	0.159	0.000
β_t	−0.177	0.000	θ_{OL}	−0.040	0.000
γ_{QQ}	−4.561	0.000	θ_{MB}	−0.339	0.000
γ_{MM}	−0.234	0.000	θ_{IB}	0.383	0.000
γ_{II}	0.126	0.000	θ_{OB}	−0.044	0.392
γ_{OO}	−0.034	0.082	μ_{Qt}	0.423	0.000
γ_{MI}	0.037	0.129	μ_{Mt}	0.054	0.000
γ_{MO}	0.197	0.000	μ_{It}	0.029	0.001
γ_{IO}	−0.163	0.000	μ_{Or}	−0.083	0.000
δ_{QM}	0.413	0.000	μ_{Lt}	−0.242	0.000
δ_{QI}	−0.487	0.000	μ_{Bt}	−0.222	0.003
δ_{QO}	0.074	0.122	μ_{tt}	−0.202	0.000

Estimating equations	*R*-squared	*S.E.R.*
Variable cost function	0.972	0.141
Machinery cost share equation	0.965	0.028
Intermediate input cost share equation	0.915	0.034
Shadow labor cost share equation	0.741	0.120
Revenue cost share equation	0.723	0.491

Notes:

(1) The symmetry and homogeneity-of-degree-one-in-input-prices restrictions are imposed in the estimation.

(2) *S.E.R.* denotes standard error of regression.

(3) *P*-value indicates the degree of probability which gives directly the extent of statistical significance.

were checked at each observation. Since all the estimated cost shares are positive – both for outputs and for inputs, the production technology satisfies the monotonicity condition for both Models (A) and (B). Furthermore, we found that all the eigenvalues of the Hessian matrix were negative for all samples, implying that the concavity conditions with respect to the prices of the variable factor inputs are also satisfied for in both models. This implies that the estimated factor demand elasticities with respect to their own prices are all negative, which is economically meaningful both in both models.

Table 2.2 Parameter estimates of the translog variable cost function for the rice sector of Tohoku for 1956–97: model (B) with the stock of technological knowledge as a proxy for technological innovations

Parameter	Coefficient	*P*-value	Parameter	Coefficient	*P*-value
α_0	6.315	0.000	ϕ_{LL}	−0.610	0.000
α_Q	2.722	0.000	ϕ_{BB}	−2.427	0.000
α_M	0.492	0.000	ϕ_{LB}	−1.158	0.000
α_I	0.353	0.000	θ_{QL}	1.702	0.000
α_O	0.155	0.000	θ_{QB}	3.049	0.000
β_L	−0.724	0.000	θ_{ML}	−0.101	0.000
β_B	−1.240	0.000	θ_{IL}	0.172	0.000
β_R	−0.227	0.000	θ_{OL}	−0.071	0.000
γ_{QQ}	−4.180	0.000	θ_{MB}	−0.291	0.000
γ_{MM}	−0.214	0.000	θ_{IB}	0.389	0.000
γ_{II}	0.164	0.000	θ_{OB}	−0.098	0.084
γ_{OO}	−0.063	0.001	μ_{QR}	0.557	0.000
γ_{MI}	−0.006	0.801	μ_{MR}	0.087	0.000
γ_{MO}	0.220	0.000	μ_{IR}	0.057	0.001
γ_{IO}	−0.157	0.000	μ_{OR}	−0.143	0.000
δ_{QM}	0.349	0.000	μ_{LR}	−0.384	0.000
δ_{QI}	−0.501	0.000	μ_{BR}	−0.248	0.041
δ_{QO}	0.152	0.006	μ_{RR}	−0.412	0.000

Estimating Equations	*R*-squared	*S.E.R.*
Variable cost function	0.969	0.147
Machinery cost share equation	0.970	0.026
Intermediate input cost share equation	0.906	0.036
Shadow labor cost share equation	0.675	0.135
Revenue cost share equation	0.713	0.500

Notes:
(1) The symmetry and homogeneity-of-degree-one-in-input-prices restrictions are imposed in the estimation.
(2) *S.E.R.* denotes standard error of regression.
(3) *P*-value indicates the degree of probability which gives directly the extent of statistical significance.

As for the convexity condition with respect to labor and land as quasi-fixed factor inputs, the eigenvalues of the Hessian matrix with respect to the quasi-fixed factor inputs given by $[\phi_{kk} + S_k(S_k - 1)]$ $(k = L, B)$ in this section must be greater than or equal to zero, where S_k is the estimated shadow cost share of the k-th quasi-fixed factor input. The estimated eigenvalues with respect to labor were positive for all observations, for both Models (A) and (B) indicating that the convexity condition is satisfied with respect to labor for both models. On the other hand, the

Table 2.3 Tests for hypotheses for the production structure based on the parameter estimates of the translog VC functions of model (A) and model (B) for Tohoku: 1956–97

Hypothesis		VC function (A)			VC function (B)		
		Wald test stat.	D.F.	*P*-value	Wald test stat.	D.F.	*P*-value
(1)	Homotheticity	555.2	5	0.000	525.1	5	0.000
(2)	No technological change	670.4	7	0.000	406.8	7	0.000
(3)	Hicks neutrality	210.4	2	0.000	191.3	2	0.000
(4)	*Extended* Hicks neutrality	516.3	5	0.000	287.1	5	0.000
(5)	Cobb–Douglas production function	6940.8	21	0.000	6106.8	21	0.000
(6)	Constant returns to scale	416.7	5	0.000	392.1	5	0.000

Notes:
(1) D.F. (Degrees of Freedom, D.F. in short hereafter) stands for degrees of freedom.
(2) *P*-value indicates the degree of probability which gives directly the extent of statistical significance.

estimated eigenvalues with respect to land were not always positive for all samples in each model. There were about five negative eigenvalues in each class, about 30 negative eigenvalues altogether out of all 252 samples, which violated the convexity condition with respect to land for both Models.

Nevertheless, we may claim that these results indicate roughly that the estimated VC functions of Model (A) and Model (B) represent second order approximations to the *true* data that satisfy the curvature conditions. The estimated parameters given in Tables 2.1 and 2.2 may therefore be claimed to be reliable and are utilized for further analyses in the following sections.

2.5.2 Results of the tests for the six hypotheses

First, according to Table 2.3, homotheticity was strongly rejected in both Models. This implies that changes in the level of output impact on the cost shares of the variable factor inputs (machinery, intermediate input, and other input), the revenue-cost share, the shadow cost shares of the quasi-fixed factor inputs (labor and land), and the rate and bias of technological change in both models.

Second, the estimated *P*-values for the Wald test for technological change were 0.000 both for Model (A) and for Model (B), indicating a strong rejection of the hypothesis of no technological change. So, there was some form of technological change in post-war Tohoku's (and Japan's) rice sector by applying either model.

Third, Table 2.3 shows that the null hypothesis of Hicks neutral technological change in the variable factor inputs was strongly rejected for both models. This means that technological change in post-war rice production, for Tohoku and Japan, is biased towards or against specific factor inputs. The estimates of the directions of the biases will be discussed in detail in the next section. However, we can easily capture the direction of the *pure* biases by looking at the values of the coefficients μ_i $(i = M, I, O)$ in Table 2.1 for Model (A) and ν_i $(i = M, I, O)$ in Table 2.2 for Model (B). They are expressed in elasticity terms with respect to t for Model (A) and to Z_R for Model (B). If $\mu_i > 0$ (and $\nu_i > 0$), then the bias is said to be the *i*-th input-*using*; if $\mu_i < 0$ (and $\nu_i < 0$), then the bias is said to be the *i*-th input-*saving*, and if $\mu_i = 0$ (and $\nu_i = 0$), then the bias is said to be the *i*-th input-*neutral*.

In the case of Model (A), the coefficients μ_M, μ_I, and μ_O are respectively 0.054, 0.029, and −0.083 with the *P*-values 0.000, 0.001, and 0.000 in Table 2.1, indicating that these coefficients are absolutely statistically significant and the biases are machinery-*using*, intermediate input-*using*, and other input-*saving*. On the other hand, in the case of Model (B), the coefficients ν_M, ν_I, and ν_O are respectively 0.087, 0.057, and −0.143 with the *P*-values 0.000, 0.001, and 0.000 in Table 2.2, indicating also that these coefficients are absolutely statistically significant and the biases are machinery-*using*, intermediate input-*using*, and other input-*saving* as in the case of Model (A).

Fourth, as clearly shown in Table 2.3, the null hypothesis of *extended* Hicks neutrality was strongly rejected both for Model (A) and for Model (B). Several findings are noteworthy from this result. First, the estimated *scale* bias effects μ_{Qt} and ν_{QR} in terms of elasticity are respectively 0.423 and 0.557 whose computed *P*-values are both 0.000 as given in Tables 2.1 and 2.2, respectively. This may indicate that both t and Z_R, as proxies for technological innovation in Model (A) and Model (B), had statistically significant output-*augmenting* effects for the entire study period 1956–97. Second, the estimated fixed factor input bias effects with respect to labor μ_{Lt} and ν_{LR} in terms of elasticities are respectively −0.242 and −0.384 for Model (A) and Model (B) as presented in Tables 2.1 and 2.2, respectively, whose computed *P*-values are both 0.000, meaning that these negative values are statistically significant.

This may indicate that, in both models, t and Z_R are proxies for technological innovation, with statistically significant labor-saving effects over the period of study.

Finally, as seen in Tables 2.1 and 2.2, the estimated fixed factor input bias effects with respect to land μ_{Bt} and ν_{BR} in terms of elasticities are −0.222 and −0.248 respectively for Model (A) and Model (B); computed P-values are both 0.000, meaning that these negative values are statistically significant. This may indicate that both t and Z_R, as proxies for technological innovation in Model (A) and Model (B) had statistically significant land-*saving* effects.[11]

Fifth, the null hypothesis of C–D production function was strongly rejected in both models. This means that the strict assumption of unitary elasticity of substitution between any pair of factor inputs is not realistic at all in specifying the technology structure of post-war rice production. Furthermore, since the C–D production function assumes Hicks neutrality from the outset, this rejection of C–D's null hypothesis is consistent with the above Hicks neutrality results for the third and fourth hypotheses.

Sixth, the null hypothesis of constant returns to scale was also strongly rejected in both models. The estimated degrees of scale economies were 1.089 at the approximation points for both Models.[12] These results indicate that the existence of IRTS for VC function Models (A) and (B), respectively, for post-war Japanese rice production.

In sum, we may assert that the most important finding in this subsection is that the technology structure of rice production, in particular, for the second half of the 20th century was characterized to be nonohomothetic and Hicks non-neutral. Keeping this critical finding in mind, we will in the following subsection investigate quantitatively the elasticities of demand and substitution among variable factor inputs, scale economies, rates and biases of technological change, and the shadow value of paddy land based on the estimated coefficients of the VC functions of Model (A) and Model (B).

2.5.3 Various economic indicators estimated based on model (A) and model (B)

2.5.3.1 Own-price variable factor demand elasticities

The own-price demand elasticities for the variable factor inputs were obtained using the estimated parameters of the VC functions of Model (A) and Model (B) at the approximation points. They are presented in Table 2.4. Needless to say, the own-price demand elasticities for labor

Table 2.4 Comparison of own-price demand elasticities of the variable factor inputs at the approximation points based on the parameter estimates of the VC functions for 1956–97: model (A) and model (B)

Factor input	Model (A)	Model (B)
Machinery (ε_{MM})	−0.983	−0.944
	(0.000)	(0.000)
Intermediate input (ε_{II})	−0.289	−0.183
	(0.000)	(0.019)
Other input (ε_{OO})	−1.064	−1.250
	(0.000)	(0.000)

Notes:
(1) Numbers in parentheses are estimated *P*-values which indicate the degrees of probability which give directly the extents of statistical significance.
(2) The own-price elasticities of demands for variable factor inputs were estimated using Equation (2.24) both for Model (A) and for Model (B).

and land could not be estimated, since they are treated as quasi-fixed factor inputs.

According to Table 2.4, the estimated elasticities are all negative. This is consistent with the economic theory; i.e., the concavity conditions with respect to the variable factor prices are satisfied. In addition, the own-price demand elasticities for machinery and other inputs are fairly high in terms of absolute value; they are close to or slightly larger than unity. Recall that other input consists of the expenditures on farm buildings and land improvement and water. We may thus conjecture that the finding that the demands for machinery and other input are relatively more elastic may have been closely related to the rapid mechanization of rice production, regardless of scale – small, medium or large – during the study period 1956–97. On the other hand, it is clear that the demand for intermediate input was inelastic, judging from the rounded elasticity values –0.3 and –0.2 for Model (A) and Model (B), respectively.

At this point, we will compare our estimates with those of representative previous studies done by Kako (1978) and Chino (1984). Kako and Chino used fertilizer as a representative of intermediate input and obtained elasticity values of –0.458 and –0.817 for the periods 1953–70 and 1958–78, respectively, both of which are larger in absolute terms than those in the present study. As for machinery, this study obtained the own-price demand elasticities –0.983 and –0.944 which are larger in absolute terms than those obtained by Kako and Chino, i.e., –0.566 and

Table 2.5 Estimates of own-price demand elasticities of variable factor inputs for rice production in previous studies

Factor input	Kako (1978)	Chino (1984)
Machinery (ε_{MM})	–0.566	–0.423
	(n.a.)	(0.256)
Fertilizer (ε_{II})	–0.458	–0.817
	(n.a.)	(0.114)
Other input (ε_{OO})	–1.897	–1.386
	(n.a.)	(n.a.)
Labor (ε_{LL})	–0.430	–0.562
	(n.a.)	(0.026)
Land (ε_{BB})	–0.481	–0.528
	(n.a.)	(0.059)

Sources and Notes:

(1) Kako (1978, table 3 on p. 632): Kako estimated the five-variable translog TC function for the period 1953–70 for the Kinki using data obtained from the RCRWB by the MAFF. The estimates of elasticities in this table were calculated as the simple averages of the values for the selected four years 1953, 1958, 1964, and 1970.

(2) Chino (1984, table 5–4 on page 43): Chino estimated also the five-variable translog TC function for the period 1958–78 for the Hokkaido using data from the RCRWB by the MAFF. The numbers in parentheses are the computed standard errors.

–0.423, respectively. On the other hand, estimates of own-price demand elasticities for other input, by Kako and Chino and this study, obtained elasticities larger than unity in absolute terms.

In sum, roughly speaking, the results obtained in this section support the estimates obtained by Kako and Chino, who applied TC functions instead of the VC function used in this chapter.

2.5.3.2 Elasticities of substitutions among variable factor inputs

The estimated AES, MES, and SES based on the VC function models of (A) and (B) are presented in Table 2.6. As shown earlier in the methodology section, the AES's and SES's are symmetric while the MES's are asymmetric. In addition, we could not obtain in this chapter the labor- and land-related substitution elasticities based on the parameter estimates of the VC functions of Model (A) and Model (B), since labor and land are treated as quasi-fixed factor inputs (Z_L and Z_B).

For the sake of comparisons of elasticities of substitution, we collected estimates of σ_{ij}'s of previous studies conducted by several researchers for rice production. In general, they applied the TC functions to specify the

Table 2.6 Estimates of the AES, MES, and SES based on the parameter estimates of the translog VC functions for 1956–97: model (A) and model (B)

σ_{ij}	AES		MES		SES	
	Model (A)	Model (B)	Model (A)	Model (B)	Model (A)	Model (B)
σ_{MI}	1.211 (0.000)	–0.669 (0.219)	0.717 (0.000)	0.522 (0.000)	1.077 (0.000)	0.896 (0.000)
σ_{IM}			1.579 (0.000)	1.417 (0.000)		
σ_{MO}	3.585 (0.000)	3.885 (0.000)	1.619 (0.000)	1.854 (0.000)	1.889 (0.000)	2.094 (0.000)
σ_{OM}			2.747 (0.000)	2.853 (0.000)		
σ_{IO}	−1.980 (0.001)	−1.868 (0.000)	0.758 (0.001)	0.959 (0.000)	0.402 (0.012)	0.520 (0.000)
σ_{OI}			–0.410 (0.017)	−0.477 (0.004)		

Notes:

(1) Numbers in parentheses are estimated *P*-values which indicate the degrees of probability. They give directly the extent of statistical significance.

(2) The AES, MES, and SES were estimated using equations respectively (2.27), (2.28), and (2.29) at the approximation points both for Model (A) and for Model (B).

technology of rice production, though the definitions of the variables they used are slightly different. The summary of the results are presented in Table 2.7. Furthermore, Kuroda (2009) estimated the AES, MES, and SES based on the parameters of the five-variable translog TC function using data obtained from the *Survey Report on Farm Household Economy* (FHE in short hereafter) published annually by the MAFF for the period 1957–97. The results are shown in Table 2.8.

Several features are noteworthy from Tables 2.6, 2.7, and 2.8.

First, we evaluate the estimates of AES's in Table 2.6. In general, the tendencies of substitutability and complementarity relationships are consistent between the two series of estimations, based on the VC functions of Model (A) and Model (B). In addition, the absolute values of the AES's are in general larger than those of the MES's and SES's. We will come back immediately to comparisons among the AES's, MES's, and SES's. However, at this moment we will concentrate on the elasticity values of the AES's.

Table 2.7 Estimates of the AES's for post-war Japanese rice sector: a survey of previous studies

Author	Period	σ_{LM}	σ_{LI}	σ_{LB}	σ_{LO}	σ_{MI}	σ_{MB}	σ_{MO}	σ_{IB}	σ_{IO}	σ_{BO}
Kako (1978)	1955–70	0.93	−0.90	0.82	1.91	−0.42	0.36	1.35	0.51	6.04	0.70
Lee (1980)	1955–75	1.58	0.72	0.86	n.a.	0.52	1.05	n.a.	1.14	n.a.	n.a.
Chino (1984)	1958–78	1.17	0.63	−0.14	2.20	−3.98	2.41	−0.93	1.23	4.34	0.99
Chino (1985)	1961–63	1.47	0.16	0.003	n.a.	0.87	−0.06	n.a.	1.24	n.a.	n.a.
Chino (1985)	1967–69	1.16	1.04	−0.05	n.a.	0.27	−0.39	n.a.	1.07	n.a.	n.a.
Chino (1985)	1977–79	0.51	1.00	0.09	n.a.	0.23	0.30	n.a.	0.13	n.a.	n.a.
Kondo (1992)	1969–88	1.19	0.45	−0.33	n.a.	0.39	0.26	n.a.	0.90	n.a.	n.a.
Godo (1993)	1975–89	0.84	−0.10	0.39	n.a.	0.55	−0.53	n.a.	−0.01	n.a.	n.a.

Notes:

(1) All studies in this table estimated the translog TC functions, although the specifications of the TC functions and the variables defined are not always the same among them. The major source of data for all the studies quoted in this table are the RCRWB and the PWRV by the MAFF.

(2) L, M, I, B, O denote labor, machinery, intermediate input, land, and other input.

(3) All studies employed the ordinary translog TC functions except for Lee (1980) who specified a translog production function. In addition, Lee (1980), Chino (1984), Kondo (1992), and Godo (1993) employed respectively four-variable total production and cost functions.

(4) "n.a." indicates "not applicable" due to the four-variable translog total production or cost functions.

(5) Kako (1978) and Chino (1984, 1985) used fertilizer instead of current input as a whole which is composed of fertilizer, seeds, agri-chemicals, feeds, materials, and others.

(6) Kako (1978) reports the values of σ_{ij} for the years, 1953, 1958, 1964, and 1970. We chose those of the year 1970.

(7) In the case of Lee (1980), simple averages of the values of the σ_{ij}'s of 1955, 1960, 1965, 1970, and 1975 were used.

Table 2.8 The AES's, MES's, and SES's based on the estimated parameters of the ordinary and G-S type multiple-product translog TC functions, 1957–97: Tofuken

σ_{ij}	Ordinary Model			S–G Model		
	AES	MES	SES	AES	MES	SES
σ_{LM}	0.542	0.464	0.639	0.646	0.548	0.561
	(0.138)	(0.038)	(0.008)	(0.115)	(0.113)	(0.048)
σ_{ML}		0.688			0.587	
		(0.003)			(0.020)	
σ_{LI}	1.273	0.529	0.684	0.870	0.434	0.527
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)
σ_{IL}		1.022			0.667	
		(0.000)			(0.000)	
σ_{LB}	0.146	0.251	0.295	−0.281	0.194	0.209
	(0.671)	(0.010)	(0.006)	(0.561)	(0.292)	(0.240)
σ_{BL}		0.507			0.258	
		(0.012)			(0.320)	
σ_{LO}	0.910	0.765	0.779	0.490	0.518	0.521
	(0.001)	(0.000)	(0.000)	(0.000)	(0.007)	(0.001)
σ_{OL}		0.857			0.532	
		(0.000)			(0.000)	
σ_{MI}	−1.385	−0.026	0.085	−0.596	0.083	0.194
	(0.076)	(0.928)	(0.750)	(0.412)	(0.781)	(0.568)
σ_{IM}		0.167			0.290	
		(0.554)			(0.474)	
σ_{MB}	0.665	0.301	0.370	0.908	0.320	0.415
	(0.288)	(0.001)	(0.001)	(0.221)	(0.081)	(0.025)
σ_{BM}		0.482			0.602	
		(0.024)			(0.055)	
σ_{MO}	4.234	1.047	1.042	2.480	0.703	0.773
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
σ_{OM}		1.033			0.928	
		(0.000)			(0.001)	
σ_{IB}	0.423	0.278	0.301	0.874	0.316	0.352
	(0.240)	(0.002)	(0.002)	(0.122)	(0.136)	(0.085)
σ_{BI}		0.352			0.435	
		(0.032)			(0.053)	
σ_{IO}	−1.720	0.542	0.358	−0.558	0.421	0.329
	(0.001)	(0.001)	(0.008)	(0.000)	(0.028)	(0.023)
σ_{OI}		−0.095			0.093	
		(0.573)			(0.511)	

Table 2.8 (*Continued*)

	Ordinary Model			S–G Model		
σ_{ij}	AES	MES	SES	AES	MES	SES
σ_{BO}	−0.236	0.668	0.454	−0.788	0.399	0.278
	(0.572)	(0.000)	(0.000)	(0.000)	(0.037)	(0.028)
σ_{OB}		0.215			0.141	
		(0.019)			(0.390)	

Notes:

(1) Table 4 of Kuroda (2009) was extended to include the elasticity estimates based on the S–G model.
(2) All the σ_{ij}'s were estimated at the approximation points.
(3) L, M, I, B, O stand for labor, machinery, intermediate input, land, and other input.
(4) In the cases of the AES's and SES's, $\sigma_{ij} = \sigma_{ji}$, i.e., symmetric.
(5) Numbers in parentheses are estimated *P*-values.

To begin with, the rounded elasticity values of σ^A_{MI} are 1.2 and –0.7 for Model (A) and Model (B), respectively. This contradictory result indicates that machinery and intermediate input were fairly good substitutes in Model (A) but complements in Model (B), though the statistical significance of the latter is a little weak. Turning our eyes to the estimates of σ^A_{MI} obtained by previous researchers in Table 2.7, we observe either positive or negative values for σ^A_{MI}. Furthermore, Table 2.8 (part of it is copied from Kuroda (2009)) gives an estimate of –1.39 for σ^A_{MI} for aggregate agricultural production, which is statistically significant.[13] This indicates that machinery and intermediate input were complements. As such, we may say that it is hard for one to give a consistent judgement on whether machinery and intermediate input were substitutes or complements during the post-war years.

Next, the rounded elasticity values of σ^A_{MO} are 3.59 and 3.89 for Model (A) and Model (B), respectively, indicating that machinery and other input had strong and almost equal substitutability for the two models. According to Table 2.7, Kako (1978) obtained 1.35 while Chino (1984) obtained –0.93 for σ^A_{MO}. Kuroda (2009) obtained 4.23 as reported in Table 2.8 for aggregate agricultural production which is fairly similar to those obtained presented in Table 2.6. Judging from these estimates, we may conclude that machinery and other input were strong substitutes during the post-war years. Finally, the elasticity values of σ^A_{IO} are –1.98 and –1.87 for Model (A) and Model (B), respectively, indicating that machinery and other input have strong and almost equal complementarity for the two models. On the contrary, according to Table 2.7, Kako (1978) and Chino (1984) obtained very strong substitutability between intermediate and other inputs as shown by the estimates of 6.04 and 4.34, respectively, for σ_{IO}^{A}. However, as shown in Table 2.8, Kuroda (2009) obtained –1.72 for aggregate agricultural production, which is fairly similar to those obtained in this chapter. Again, it seems to be difficult to judge whether or not intermediate and other inputs were substitutes or complements during the entire study period 1956–97.

At this point, as compactly noted by Kuroda (2009) and quoted in Kuroda (2013), Blackorby and Russell (1989) present very important and robust comments on the AES which are one-price-one-factor elasticities of substitution (OOES). According to them,

> while the AES reduces to the original Hicksian concept in the two-dimensional case, in general, it preserves none of salient properties of the Hicksian notion. In particular, the AES [originally, Allen elasticity of substitution] (i) is *not* a measure of the "ease" of substitution, or curvature of the isoquant, (ii) provides *no* information about relative factor shares (the purpose for which the elasticity of substitution was originally defined), and (iii) *cannot* be interpreted as a (logarithmic) derivative of a quantity ratio with respect to a price ratio (or the marginal rate of substitution). As a quantitative measure, it has no meaning; as a qualitative measure, it adds no information to that contained in the (constant output) cross-price elasticity. In short, the AES is incrementally completely uninformative. [Blackorby and Russell (1989), pp. 882-*r*-883-*l*].

However, Blackorby and Russell (1989) seem to be fairly pleased at finding the following important features that the MES contains. In other words, the MES "does preserve the salient characteristics of the original Hicksian concept." [Blackorby and Russell (1989), p. 883-*l*]. That is, the MES which is a two-factor-one-price elasticity of substitution (TOES):

> (i) *is* a measure of curvature, or ease of substitution, (ii) *is* a sufficient statistic for assessing–quantitatively as well as qualitatively– the effects of changes in price or quantity ratios on relative factor shares, and (iii) *is* a logarithmic derivative of a quantity ratio with respect to a marginal rate of substitution or a price ratio. [Blackorby and Russell (1989), p. 883-*l*].

Furthermore, we should note another critical point. That is,

> the MES is *not* [originally, Morishima elasticity is not] sign symmetric, and the classification of inputs *i* and *j* as Morishima substitutes

or complements depends critically on which input price changes. [Chambers (1988), pp. 97].

Third, McFadden (1963) developed the "so-called" shadow elasticity of substitution (SES) which is considered as *TTES*; i.e., two-factor-two-price elasticities of substitution (TTES). According to McFadden, the SES is a weighted average of two Morishima elasticities where the weights are given by the relative cost shares. Note, in particular, that this *TTES* is in fact symmetric, in addition to providing a more complete measure of relative input responsiveness (Chambers (1988), p. 97).

The estimated MES and SES based on Model (A) and Model (B) are also presented in Table 2.6. Roughly speaking, although there are slight differences, the estimates of the MES's and SES's seem to be more stable and consistent than those of the AES's, both for Model (A) and for Model (B). In general, machinery and intermediate inputs, machinery and other inputs, and intermediate and other inputs were all substitutes, and the degrees of substitutability were rather comparable for both Models (A) and (B). In particular, the substitutability between machinery and other inputs were stronger in both MES and SES, than in AES. One interesting finding is that if the price of other input changes, then the intermediate and other inputs turned out to be substitutes, but if the price of intermediate input changes the two inputs turned out to be complementary, as in the case of AES. Based on these findings, what we may say is that all pairs of factor inputs were basically substitutes if we resort to the assertion of Chambers (1988) referred to just above.

2.5.3.3 Estimates of the degrees of returns to scale (RTS)

Needless to say, economies of scale are critically important – and a necessary precondition for the development of paddy lands from small-and-inefficient to large-and-efficient rice-producing farms. We estimated the degrees of *RTS* at the approximation points of the VC functions of Model (A) and Model (B) using Equation (2.33). They are reported in Table 2.9, according to which the degrees of RTS were 1.089 in both models. This indicates that a ten percent increase in the level of output will decrease the short-run average variable cost by almost one percent on the average.

At this point, in order to capture the movement over time of the *RTS*, we estimated the *RTS* for each observation of the six class sizes for each year of the entire study period 1956–97. Although we executed this estimation both for Model (A) and for Model (B), we will show the result only for Model (A) in Figure 2.6 since the result for Model (B) was very

Table 2.9 Estimates of the RTS and the PGX and PGY at the approximation points based on the parameter estimates of the VC functions for 1956–97: model (A) and model (B)

	Model (A)	Model (B)
RTS	1.089 (0.000)	1.089 (0.000)
PGX	0.060 (0.000)	0.077 (0.000)
PGY	0.065 (0.000)	0.083 (0.000)

Notes:

(1) The *RTS* and the *PGX* and *PGY* were estimated at the approximation points using Equations (2.33), (2.36), and (2.37) of the VC function Model (A) and Model (B), respectively.

(2) Numbers in parentheses are estimated *P*-values which indicate the degrees of probability. They give directly the extents of statistical significance.

similar to that of Model (A) for the entire estimation period 1956–97. At least two intriguing findings are noteworthy.

First, it is clear that all size classes enjoyed scale economies for the entire study period 1956–97. It is also clear that there seem to have been two distinct stages of the extents of scale economies during the study period. The first stage is the period 1956–70 during which the extents of scale economies were consistently around 1.07 or so; the second stage is the period 1971–97 during which the extents of scale economies increased fairly sharply from around 1.08 in 1971 to around 1.13 in 1997. These two stages may have been intimately related to the different types of mechanization of rice production during the study period. The first stage is characterized by a rapid introduction of small-scale mechanization represented by hand-driven tiller-type cultivators which became popular from around the mid-1950s. We may infer that this type of machinery did not have such a strong "indivisibility" that the extents of scale economies were not that large. On the other hand, during the second stage of mechanization which became popular around the late-1960s, rice farmers rapidly introduced medium- and larger-scale machinery: riding-type tractors, harvesters, and rice transplanters. Such machinery may have had much stronger "indivisibility" than the

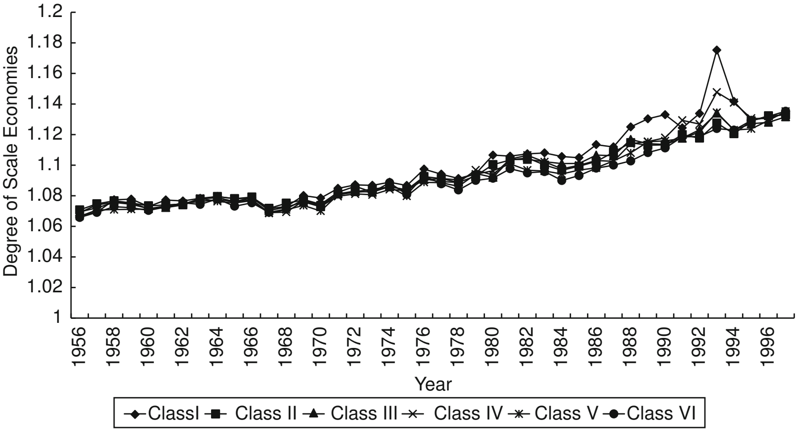

Figure 2.6 Returns to scale in rice production for 1956–97 based on parameter estimates of model (A): all size classes (Tohoku)

Note: Economies of scale were estimated using Equation (2.30).

first stage of mechanization and hence increased the extents of scale economies.

Second, it is clear that the smaller the size class, the greater the extents of scale economies for the entire study period 1956–97.[14] This may be interpreted in such a way that larger-scale farms always took the initiative of introducing machinery on their farms, so that they lost the advantages of scale economies relatively more quickly than smaller-scale farms did. On the other hand, smaller-scale farms tried hard to catch up with their larger competitors by mechanizing rice production, which made it possible for the smaller farms to enjoy scale economies too. However, they also gradually lost the advantages of scale economies as mechanization proceeded, and hence the extent of "indivisibility".

2.5.3.4 Estimates of the "rates" of "input-saving" and "output-augmenting" technological change (PGX and PGY)

Next, we will examine quantitatively the rates of technological change in post-war rice production using Equations (2.36) and (2.37) based on the estimates of the "rates" of input-*saving* (*PGX*) and output-*augmenting* (*PGY*) technological change at the approximation points of the VC functions of Model (A) and Model (B). The results are reported in the lower part of Table 2.9.

Note here, however, that, as mentioned earlier, both *PGX* and *PGY* are expressed in terms of elasticity-like “indexes” (or “rates”). Note further that the “rates” of both *PGX* and *PGY*, with respect to the time index *t* for Model (A), include all innovative activities for rice production by rice farmers, including the effect of public R&E activities. Both *PGX* and *PGY*, with respect to the stock of technological knowledge Z_R, reflect the effect only of Z_R; that is, they do not reflect general improvements by individual rice farmers.

According to Table 2.9, the magnitudes of the “rates” of *PGX* and *PGY* for Model (A) were 0.060 and 0.065, respectively, while those for Model (B) were 0.077 and 0.083, respectively. For example, a one percent increase in innovative activities, represented by time index *t*, entailed improvements in the input-*saving* (*PGX*) and the output-*augmenting* (*PGY*) technological change by 0.60 and 0.65 percent, respectively, in the case of Model (A). On the other hand, for Model (B), a one percent increase in the stock of technological knowledge Z_R increased the “rate” of *PGX* and *PGY* by 0.77 and 0.83 percent, respectively. In both models, we found that *PGY* was slightly larger than *PGX*. This is because of scale economies; recall the relation given by the following equation, i.e., $PGY = PGX \cdot RTS$.

At this point, it may be interesting to see the development of the *PGX* and *PGY* both for Models (A) and (B) for the entire study period 1956–97. Using Equations (2.34) and (2.35), we estimated *PGX* and *PGY* for Model (A). We applied the same procedure to Model (B). The results show that the development of the *PGX* and *PGY* were almost the same in each model. The only difference was the magnitude of *PGX* and *PGY* due to scale economies. Accordingly, we will stick only to the *PGX* estimates for Model (A) and Model (B) in order to save space. The estimated results are presented in Figures 2.7 and 2.8. Incidentally, as far as our extensive survey goes, no past study has been found which estimated over-time technological change rates for post-war Japanese rice production.

Now, it is found in Figure 2.7 that the input-saving technological change rates of *PGX* with respect to the time index *t*, as a proxy for aggregate technological innovations in terms of “elasticities,” were fairly high for the period 1956 to the early-1970s, though they sharply decreased during that period in all size classes. For example, the *PGX* in 1960 was around 0.13 on an average for the six size classes. This means that a ten percent increase in the activities of aggregate innovations caused an increase in the rate of technological change by 1.3 percent on average, indicating relatively high technological progress for an agricultural product. After around 1975 towards the late-1990s, *PGX*,

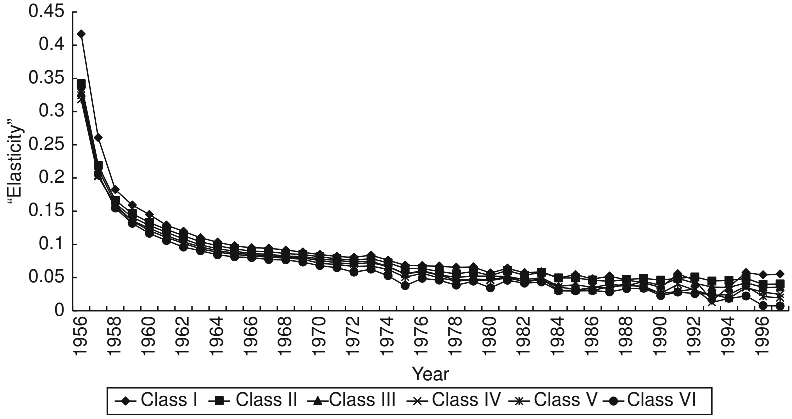

Figure 2.7 "Input-saving" technological change "rates" for 1956–97 based on the parameter estimates of model (A): all size classes (Tohoku)

Note: The "input-saving" technological change "rate" for each size class was estimated using Equation (2.34).

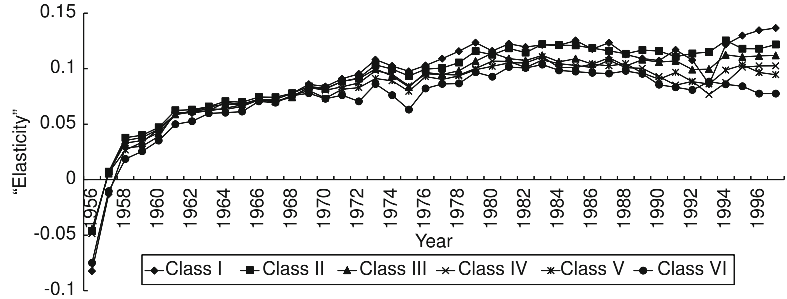

Figure 2.8 "Input-saving" technological change "rate" for 1956–97 based on the parameter estimates of model (B): all size classes (Tohoku)

Note: The "input-saving" technological change "rate" for each size class was estimated using the modified version of Equation (2.34).

in terms of elasticity, was stagnant or even consistently decreasing – though at a slow pace. The elasticities ranged from around 0.07 in 1975 (size class (I)) to 0.01 in 1997 (size class (VI)).

Turning to the *PGX* obtained in Model (B) and presented in Figure 2.8, we find a totally different picture from that observed in Figure 2.7 for

Model (A). That is, except for the first two years, where we found negative elasticity-like "rates" of technological change with respect to the stock of technological knowledge (Z_R), we observed increasing trends in all six size classes of technological progress in terms of elasticity-like "rates" from the late-1950s through to the early-1980s. However, from the early-1980s to the early-1990s, the elasticity-like "rates" of technological change became stagnant in all size classes. However, the trends were different among different size classes for the period 1993–97: the largest size class (VI) still had a decreasing trend; the second largest size class (V) trended upward over 1993–95 but decreased during 1995–97; furthermore, size classes (I), (II), (III), and (IV) had weak increasing trends for the period 1993–97. This could be interpreted to mean that larger-scale farms always take the initiative of introducing new innovations for their rice farming, and consequently lose their front runners' advantage of enjoying new innovations relatively faster than did smaller-scale farms. Furthermore, as presented in Figure 2.8, the finding that smaller-scale farms had increasing trends for the period 1995–97 may have been related to the slightly sharper increasing trend of the stock of technological knowledge Z_R, as shown in Figure 1.6 in Chapter 1.

More specifically in terms of the elasticity values of the *PGX*, it was found that the "rates" ranged from around 0.01 in 1957 (size class (II)) to 0.14 in 1997 (size class (I)), which are comparable with the results observed in Figure 2.7 based on Model (A), though the trends of technological change are totally opposite to each other.

Roughly speaking, the findings observed in Figure 2.7 support the results obtained in Kuroda (2010, figure 4, p. 26) where he found increasing trends of the estimated *PGX* for the period 1965–93 and slightly decreasing trends for the period 1994–97 in smaller three size classes but a still increasing trend in the largest size class (IV) (corresponding to size class (VI) in this book). This estimation was executed for a pooled cross section of time series data for aggregate agricultural production for Tofuken obtained from the FHE published annually by the MAFF.

In addition, the magnitudes of the "rates" of the *PGX* for the case of aggregate agricultural production obtained in Kuroda (2010, figure 4, p. 26) ranged from around 0.12 in 1965 to 0.27 in 1997 which are larger than the present case, 0.01–0.14, mentioned above. This may imply that farmers who have been engaged in agricultural products other than rice, e.g., livestock, vegetables, and fruit may have had stronger incentives to take advantage of new innovations than did rice-only farmers.

2.5.3.5 Estimates of the biases of technological change

Using Equation (2.42) for Model (A), the *pure*, *scale*, and *overall* biases of technological change were estimated for the variable factor inputs, i.e., machinery, intermediate input, and other input at the approximation points. As for Model (B), Equation (2.42) was modified by replacing μ_{it} and δ_{Qt} by ν_{iR} and δ_{QR} based on Model (B), respectively. The estimates are expressed in terms of elasticities and presented in Table 2.10.

According to Table 2.10, the *pure* bias effects, which are equivalent to Binswanger's (1974) definitions of technological change biases, are respectively 0.109, 0.082, and –0.534 for machinery, intermediate input, and other input for Model (A). Since the *P*-values for these elasticities were all 0.000, they are all statistically significant. The corresponding estimates for Model (B) are respectively 0.176, 0.160, and –0.923 for

Table 2.10 Degrees of *pure, scale*, and *overall* biases of variable factor inputs based on the parameter estimates of the translog VC functions for 1957–97: model (A) and model (B)

Tech. change biases	Model (A)			Model (B)		
	Degree of bias	*P*-value	Contri. to overall bias	Degree of Bias	*P*-value	Contri. to overall bias
Pure bias-M	0.109	0.000	66.7	0.176	0.000	74.9
Scale bias-M	0.054	0.000	33.3	0.059	0.002	25.1
Overall bias-M	0.163	0.000	100.0	0.236	0.000	100.0
Pure bias-I	0.082	0.001	−1157.7	0.160	0.000	382.6
Scale bias-I	–0.089	0.000	1257.7	–0.118	0.000	–282.6
Overall bias-I	–0.007	0.743	100.0	0.042	0.209	100.0
Pure bias-O	–0.534	0.000	106.2	–0.923	0.000	109.7
Scale bias-O	0.031	0.122	−6.2	0.082	0.006	−9.7
Overall bias-O	–0.502	0.000	100.0	–0.841	0.000	100.0

Notes:

(1) The degrees of Variable factor biases were estimated using Equation (2.33) for Model (A). As for the estimates for Model (B), the same version of Equation (2.39) modified for Model (B) was applied.

(2) M, I, O designate machinery, intermediate input, and other input, respectively.

(3) The degrees of biases are expressed in terms of elasticities at the approximation points.

(4) *P*-value is employed which indicates the degree of probability of each bias. It gives directly the extent of statistical significance of each of the estimated biases.

machinery, intermediate input, and other input which are all statistically significant since the *P*-values of them were 0.000, 0.002, and 0.000, respectively. Furthermore, the magnitudes of the elasticities obtained for Model (B) are larger than those for Model (A) as a whole in absolute terms. The signs of the elasticities indicate that technological change in post-war rice production estimated by either Model (A) or Model (B) was biased towards machinery-*using*, intermediate input-*using*, and other input-*saving*.

At this point, going back to Figure 2.4, we found that the price indexes of machinery and intermediate input, normalized by the output (i.e., rice) price, were either almost constant or slightly decreasing, respectively, for the study period 1956–97. On the other hand, the price index of other input relative to the output price showed a slight increasing trend until around the mid-1970s and then remained almost constant during the study period (1976–97). Based on these observations of price movements and the directions of biases of technological change, we may say that our results support the "induced innovation" hypothesis proposed by Hicks (1932) and further developed by Hayami and Ruttan (1971).

In addition, we will develop a procedure to evaluate the bias effects of the quasi-fixed factor inputs, labor and land ($Z_k, k = L, B$). To begin with, the "shadow labor cost-share" equation with respect to labor (Z_L) can be derived as the following Equations (2.44) and (2.45), respectively (as a matter of fact, Equations (2.10) and (2.15) given already in this chapter are rewritten here with different equation numbers (2.44) and (2.45)):

$$\begin{aligned} S_{Z_L}^A &= \frac{\partial CV}{\partial Z_L}\frac{Z_L}{CV} = \frac{\partial \ln CV}{\partial \ln Z_L} \\ &= \beta_L + \phi_{QL}\ln Q + \sum_i \theta_{iL}\ln w_i + \sum_k \phi_{kL}\ln Z_k + \mu_{Lt}\ln t, \end{aligned} \tag{2.44}$$

and

$$\begin{aligned} S_{Z_L}^B &= \frac{\partial CV}{\partial Z_L}\frac{Z_L}{CV} = \frac{\partial \ln CV}{\partial \ln Z_L} \\ &= \beta_L + \phi_{QL}\ln Q + \sum_i \theta_{iL}\ln w_i + \sum_k \phi_{kL}\ln Z_k + \nu_{LR}\ln Z_R, \end{aligned} \tag{2.45}$$

$$i = M, I, O, \ k = L, B.$$

The quasi-fixed factor input bias effects with respect to labor can be obtained by μ_{Lt} for Model (A) and ν_{LR} for Model (B) in terms of elasticities. They are –0.242 and –0.384 respectively for Model (A) and Model (B) as presented in Tables 2.1 and 2.2 (the parameter estimates of Model (A) and Model (B)), respectively, both of which are absolutely statistically significant. This may indicate that changes in both t and Z_R as a proxy for technological innovations in Model (A), and as the stock of technological knowledge in Model (B), had statistically significant "labor-*saving*" effects for the study period 1956–97.

Similarly, the "shadow land cost-share" equations with respect to land (Z_B) can be rewritten as follows:

$$S^A_{Z_B} = \frac{\partial CV}{\partial Z_B}\frac{Z_B}{CV} = \frac{\partial \ln CV}{\partial \ln Z_B}$$
$$= \beta_B + \phi_{QB}\ln Q + \sum_i \theta_{iB}\ln w_i + \sum_k \phi_{kB}\ln Z_k + \mu_{Bt}\ln t, \qquad (2.46)$$

and

$$S^B_{Z_B} = \frac{\partial CV}{\partial Z_B}\frac{Z_B}{CV} = \frac{\partial \ln CV}{\partial \ln Z_B}$$
$$= \beta_B + \phi_{QB}\ln Q + \sum_i \theta_{iB}\ln w_i + \sum_k \phi_{kB}\ln Z_k + \nu_{BR}\ln Z_R, \qquad (2.47)$$
$$i = M, I, O, \; k = L, B.$$

The quasi-fixed factor input bias effects with respect to land can be obtained respectively by μ_{Bt} and ν_{BR} in terms of elasticities. They are –0.222 and –0.248 respectively for Model (A) and Model (B) as presented again in Tables 2.1 and 2.2, respectively, both of which are statistically significant at better than 5% levels. This may indicate that changes in both t and Z_R as a proxy for technological innovations in Model (A) and as the stock of technological knowledge in Model (B) had statistically significant "land-*saving*" effects for the study period 1956–97.

If these interpretations of the quasi-fixed factor input bias effects as given by μ_{kt} and ν_{kR} ($k = L, B$) are permitted, we may compare the labor-*saving* and land-*saving* biases with the actual movements of the relative prices of labor and land, presented in Figure 2.4 in this chapter. The price of labor increased sharply for the entire study period 1956–97, while the price of land also increased sharply for the period 1956–88; from 1988 it had a decreasing trend. Roughly speaking, the *saving* biases of labor and land may have been intimately associated with the sharp increases in the prices of labor and land. Accordingly, we may claim that the Hicksian induced innovation hypothesis may be said to be valid for the case of labor and land as well as machinery, intermediate input, and other input.

It may be interesting here to compare our results with those of Kako (1979b). Kako obtained machinery-*using*, fertilizer-*using*, other input-*using*, and labor-*saving* biases for the period 1953–69. As for land, he obtained land-*saving* bias for the period 1953–65 and land-*using* bias for the period 1966–69. Except for the biases with respect to other input, i.e., *saving* in our case and *using* in Kako's case, the results of machinery-*using*, intermediate input-*using* (fertilizer-*using* in Kako's case), labor-*saving*, and land-*saving* biases in the present study support Kako's result as a whole.

Coming back to Table 2.10, we will evaluate the *scale* bias effect given also in terms of elasticity for each variable factor input both for Model (A) and for Model (B). First, the *scale* effect for machinery input was 0.054 and the *P*-value was 0.000, which is statistically significant for Model (A). This implies that an increase in output had machinery-*using* bias. Accordingly, the *overall* machinery-*using* bias was 0.163. On the other hand, for the case of Model (B), the *scale* bias effect was 0.059 and the *P*-value was 0.002, which is also statistically significant. The *overall* machinery-*using* bias became 0.236 which is larger than that of Model (A). Both in Model (A) and in Model (B), the relative contributions of the machinery-*using scale* effects were 33.3 and 25.1 percent, respectively. This implies that the contributions of the *pure* machinery-*using* effect were respectively 66.7 and 74.9 percent which were much larger than the *scale* effects.

Second, the *scale* bias effect for intermediate input for Model (A) was –0.089 and statistically significant since the *P*-value was 0.000. This implies that an expansion of output scale had an intermediate input-*saving* effect. This may indicate in reality that increases in rice production entailed more efficient utilization of fertilizer, agri-chemicals, seeds, and so forth. Moreover, this *scale* effect was larger than the *pure* effect in absolute terms, so that the *overall* effect turned out to be −0.007, whose *P*-value was 0.743, meaning intermediate input-*neutral*. For Model (B), on the other hand, the *scale* effect was –0.118 and statistically significant, implying intermediate input-*saving* bias. However, this *scale* effect was smaller than the *pure* effect. As a result, the *overall* effect turned out to be 0.042, with a *P*-value of 0.209, meaning intermediate input-*using* bias, though statistically a little weak.

Finally, the *scale* bias effect for other input for Model (A) was 0.031 and statistically barely significant at less than 10% level. This may imply that an increase in the level of rice production had other input-*using* effects. This may indicate in reality that increases in rice production required larger-scale farm buildings and land improvement equipment and so on. However, this *scale* effect was much smaller than the *pure* effect in absolute terms, so that the *overall* effect turned out to be −0.502, whose *P*-value was 0.000, meaning other input-*saving*. As for Model (B), on the other hand, the *scale* effect was 0.082 and statistically significant, implying other input-*using* bias. However, this *scale* effect was much smaller than the *pure* effect in absolute terms. As a result, the *overall* effect turned out to be –0.841, with a *P*-value of 0.000, meaning other input-*saving* bias.

2.5.3.6 Estimation of the shadow value of paddy land

Using Equation (2.43), the shadow value of paddy land was estimated for each sample observation of the six different size classes for each year of the entire study period 1956–97. The result is presented in Figure 2.9. As already mentioned in Section 2.3.5, it is possible to check informally the validity of the long-run equilibrium, or in other words, the validity of applying the TC function model where all factor inputs are treated as variable inputs. For this examination, we will try to capture differences between the shadow values evaluated at the observed levels of paddy lands of the six size classes and the market prices, i.e., rents of paddy lands. By doing so, we can carry out an informal investigation of the existence of the long-run equilibrium regarding farms' utilization of paddy lands.[15] Accordingly, we obtained the actual land rents for the six size classes for the entire period 1956–97. In reality, there exist some differences in the land rents among the six size classes; the larger the size classes, the larger the actual land rents. However, the differences were fairly minor, because the level of land rent has been regulated by the government for all farms. We then decided to show the actual land rent only of the smallest size class (I) as a representative. It is shown in Figure 2.9.

It is noted here however that the shadow value of labor as another quasi-fixed factor input in this chapter can be estimated together with the shadow value of land using Equation (2.43). However, as mentioned earlier in Section 2.1 where the VC function models were developed, the labor cost-variable cost share equation was included in the system of estimating equations. This means that we assume the farm-firm minimizes the cost with respect to labor input; or, in other words, the farm-firm utilizes the "optimal" level of labor input with regard to the actual market price of labor. Thus, we will not present the shadow value of labor in this section.[16]

However, several important findings are worth mentioning from Figure 2.9.

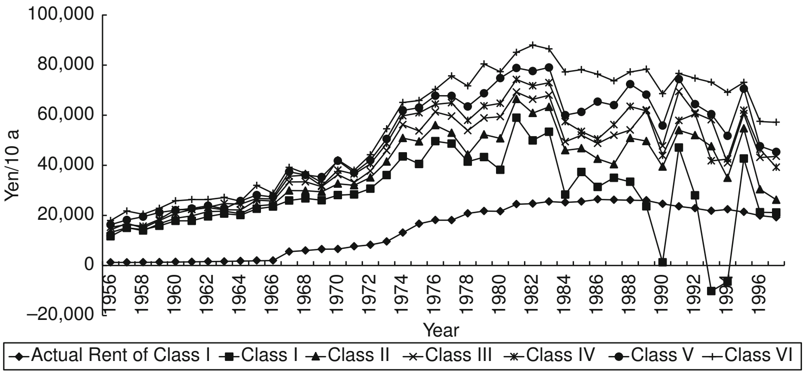

Figure 2.9 The shadow values of paddy lands and actual land rent of class (i) for 1957–97: all size classes (Tohoku)

Note: The shadow value of paddy land for each size class was estimated using Equation (2.43).

To begin with, it is very clear that the larger the farm size, the larger the shadow value of the land for the entire study period 1956–97. Incidentally, we obtained unusually low or even negative shadow values for size class (I) for three years, 1990, 1993, and 1994. Actually, we observe similar sharp decreases in the shadow values of paddy lands for the other size classes. This may have been related to the bad rice harvests in these years. Except for these thee years in size class (I), the estimated shadow values of paddy lands in all six size classes were much larger than the actual land rent for the entire study period 1956–97. However, a careful observation of Figure 2.9 leads us to recognize that in the case of size class (I), the levels of estimated shadow values of paddy land came fairly close to the level of actual land rent for the period 1984–97. Thus, we may say that, except for size class (I) for this period 1984–97, rice farmers in all size classes never attained the optimal utilization of paddy lands for the entire study period 1956–97. This finding in turn leads us to confirm that applications and estimations of the TC functions with all factor inputs being variable factor inputs may cause biases in the estimated results for post-war Japanese rice production.

Next, we observe in Figure 2.9 that the estimated shadow values of paddy lands increased very sharply from 1956 to the early-1980s; size classes (I), (II), and (III) reached a peak in 1981; size classes (IV) and (V) reached their peaks in 1983; and size class (VI) reached its peak in 1982. After these years, however, all size classes experienced stagnant and/or decreasing trends in the shadow value of paddy lands, though with ups and downs. A more careful observation of Figure 2.9 tells us that the smaller three size classes (I), (II), and (III) (and probably size class (IV) also) started to stagnate between 1975 and 1983. This finding supports a similar finding presented by Kusakari (1989) who also obtained stagnant trends for all five size classes for the period 1977–86 in Tohoku and Hokuriku.[17] The decreasing shadow value of paddy lands seems to have been intimately related to the stagnant rice price by the changes in the government price-support programs for rice production during the 1980s and 1990s, as observed in Figure 2.9. Such changes in government agricultural policies were critical to reducing the pervasively tremendous deficits (close to one trillion yen per year in the 1970s) which resulted from the "back spreads" in producer and consumer prices of rice during the 1970s and 1980s; i.e., producer prices were higher than consumer prices for a fairly long period.

Another important finding is that, since around the early-1970s to the late-1990s, the gaps in the shadow values of paddy land, between the largest and smallest size classes (i.e., size classes (VI) and (I)), seem to have widened. This may have been because large-scale farms were able to rent in paddy lands from small-scale farms. This finding supports the finding obtained by Kuroda (2009, 2010) for aggregate agricultural products: small-scale farms were ready to transfer their land to large-scale farms because the shadow value of their land was much smaller than that of the larger farms.

However, the existence of these differentials may only be one of the necessary preconditions for land transfers. We will pursue this topic further in the next chapter.

2.6 Summary and concluding remarks

The major objective of this chapter has been to quantitatively investigate the technology structure of post-war Japanese rice production: in particular for the second half of the 20th century. To pursue this objective, we introduced the VC function Models (A) and (B) with a time index as a proxy for technological innovation and the stock of technological knowledge as the proxy for public technological innovation. In both models, labor and land were treated as quasi-fixed factor inputs for which the farm-firm does not attain optimal utilization within the observation period (one year). So, both Model (A) and Model (B) can be deemed short-run VC function models.

Using the same set of data for Tohoku as a representative rice producing district in Japan (excluding Hokkaido), obtained from the RCRWB, the translog VC functions of Model (A) and Model (B) were estimated using the FIML procedure. Based on the parameter estimates, we computed various economic indicators: such as factor demand and substitution elasticities, scale economies, rates and biases of technological change, and the shadow values of paddy lands for the entire study period 1956–97. The empirical results may briefly be summarized as follows.

First of all, the estimated parameters and economic indicators are in general very similar between the two VC function models, except for the development of technological change. The input-saving rate of technological change based on Model (A) was fairly high from the mid-1950s through the early-1970s but then stagnated until the late-1990s. On the other hand, the input-saving rate of technological change based on Model (B) was very low during the late 1950s but then increased sharply until the early-1980s, and then stagnating until the late-1990s.

Second, for other economic indicators – such as, factor demand and substitution elasticities, scale economies, technological change biases – both translog VC function Model (A) and Model (B) yielded very similar and robust results. In particular, the degrees of scale economies were around 1.07 during the 1950s and 1960s and then increased since to around 1.13 in the late-1990s. Such movements may have been intimately related to the transition of small-scale to medium- and larger-scale mechanization of rice production during the study period 1956–97.

Third, the estimated shadow value of land for all six of Tohoku's size classes were in general greater than the land rent which was regulated by the government for the entire study period 1956–97. This indicates that government-regulated land rent cannot be regarded as the market price of land. Which in turn implies that approaches based on a TC function – in which all factor inputs are assumed to be employed at the optimal level – may cause serious biases in the results and hence in the derived policy implications.

Based on these findings, we may conclude as follows. To begin with, it may have been correct to introduce the VC function framework rather than the TC function framework in order to obtain reliable and robust results in various important economic indicators. Above all, the increasing trend of scale economies, and the large differentials in the shadow value of paddy lands – between small- and large-scale farms – may indicate that the time was right for small-scale farms to transfer their paddy lands to large-scale farms. In reality, however, land movements were very slow during the study period. Furthermore, it seems to be critical not only for farmers themselves but also for research and extension people to make more efforts to transform rice farming in Japan to be more efficient and productive on larger-scale farms.

Finally, one important caveat is worth mentioning. Since land is treated as a quasi-fixed factor input in the VC function models, we could not obtain land-related indicators, such as the factor demand and substitution elasticities. To solve this critical problem, the method proposed by Kulatilaka (1985) may be useful. Kulatilaka's technique allows us to simultaneously estimate the shadow price and the optimal level of utilization of a fixed factor input (e.g., land). Using the estimated shadow price of land in the TC function may give us reliable (long-run) estimates of various important economic indicators with regard to land input for rice production.[18]

Appendix A: Variable Definitions

The major sources of data used to process the variables are the *Kome oyobi Mugirui no Seisan-Hiyo Hokoku* [the *Survey Report on Production Costs of Rice, Wheat, and Barley*] (RCRWB in short hereafter) and the *Noson Bukka Chingin Chosa Hokoku* [the *Survey Report on Prices and Wages in Rural Villages*] (PWRV in short hereafter) published annually by the MAFF.

In each year of the 1956–97 period, one average farm was taken from each of the six size classes of Tohoku, (I) 0.3–0.5, (II) 0.5–1.0, (III) 1.0–1.5, (IV) 1.5–2.0, (V) 2.0–3.0, (VI) 3.0 ha or over. Thus, the sample size is $42 \times 6 = 252$. The Törnqvist (1936) indexes of the quantity and price indexes of rice (Q and P) were computed by the Caves-Christensen-Diewert's (CCD) (1982) multilateral index method. The CCD method is most relevant for the estimation of the Törnqvist (1936) index for a pooled cross section of time series data set. In the following paragraphs, wherever possible all indexes were obtained based on this method. It is noted here that the base year for the price indexes is 1985.

The quantity and price indexes of machinery (X_M and w_M), intermediate input (X_I and w_I), and other input (X_O and w_O) were also constructed by the CCD method. The cost of machinery ($C_M = w_M X_M$) was defined as the sum of the expenditures on machinery, energy, and rentals; the cost of intermediate input ($C_I = w_I X_I$) is the sum of the expenditures on fertilizer, feed, agri-chemicals, materials, clothes, and others; and the cost of other input ($C_O = w_O X_O$) is the sum of the expenditures on farm buildings and water improvement equipment and cost of land improvement and water.

The variable cost (VC) was defined as the sum of the expenditures on these three categories of variable factor inputs, i.e., $VC = \sum_i w_k X_k$ ($k = M, I, O$). The output revenue-cost share was obtained by dividing the total revenue of rice (PQ) by the variable cost (VC).

The variable factor input cost-share ($S_k, k = M, I, O$) was obtained by dividing the expenditure on each category of the variable factor inputs ($w_k X_k, k = M, I, O$) by the variable cost (VC).

The period dummy (D_p) is defined as 1 for 1965–74, i.e., before the "oil crisis", and 0 for 1975–97, i.e., after the "oil crisis". The size dummies (D_s) are for size (II) 0.5–1.0, (III) 1.0–1.5, (IV) 1.5–2.0, (V) 2.0–3.0, and (VI) 3.0 ha or over. The weather dummy (D_w) is defined as 1 for bad harvest years and 0 for normal harvest years. The data was obtained from the *Sakumotsu Tokei* [the *Crop Statistics*] published annually by the MAFF.

The quantity of labor (Z_L) was the total number of male-equivalent labor hours of operator, family, hired, and exchange workers. The male-equivalent labor hours of female workers were estimated by multiplying the number of female labor hours by the ratio of female daily wage rate to the male wage rate. Finally, the quantity of labor was divided by the 1985 value and expressed in index term. The price of labor (w_L) was obtained by dividing the wage bill for temporary hired labor by the number of male-equivalent labor hours of temporary hired labor. The labor cost ($C_L = w_L Z_L$) was defined as the sum of labor shadow cost for operator, family workers, and exchange workers imputed by w_L and the wage bill for hired labor. The labor shadow cost-variable cost share (S_L) was obtained by dividing the labor shadow cost by the variable cost ($S_L = C_L/VC$). In addition, the labor shadow cost-variable profits share (R_L) was obtained by dividing the labor shadow cost ($C_L = w_L Z_L$) by the variable profits ($R_L = C_L/VP$).

The quantities of land (Z_B) and the stock of technological knowledge (Z_R) were obtained as follows:

The quantity of land (Z_B) was defined as the total area of planted land. This was divided by the 1985 value to express it in index term.

As for the stock of technological knowledge (Z_R), the present study employed the estimating procedure and the basic data for public research and extension activities used in Ito (1989). These basic data are already deflated by an appropriate deflator by Ito and expressed in 1985 prices.

According to Ito, the stock of technological knowledge is determined by annual investment on research activities and the appropriate weights. The weights are determined by the lag structure and the speed (or rate) of obsolescence of the stock of technological knowledge.

The *Norinsuisan Shiken-Kenkyu Nenpo* [the *Yearbook of Research and Experiments of Agriculture, Forestry, and Fisheries*] by the MAFF reports researches on agriculture, forestry, and fisheries in Japan by various national research institutions. It documents the beginning year, the ending year and the number of years (i.e., the research period) of each research topic. Ito regarded this research period as the development lag of each research topic, and obtained the number of research topics for each development lag for 1967 and 1987. He then computed the weighted average year of research lag period with the numbers of research topics as weights for each of these three years and obtained roughly five years both for 1967 and for 1987. As for the rate of obsolescence of the stock of technological knowledge, Ito derived it as 10 percent per year based on his observation that 50 percent of registered patents of agricultural technologies vanish roughly after seven years. Another major source of data is the *Norinsuisan Kankei Shiken Kenkyu Yoran* [the *Abstract Yearbook of Research and Experiment on Agriculture, Forestry, and Fisheries*] by the MAFF which was utilized as a reference wherever necessary.

Ito estimated the stock of technological knowledge (Z_R) by the benchmark year method as follows. Suppose that Z_{R_t} is the stock of technological knowledge at the end of year t. Then, the following equation can be obtained:

$$Z_{R_t} = G_{t-5} + (1 - \delta_{Z_R}) Z_{R_{t-1}}, \tag{A.1}$$

where δ_{Z_R} is the rate of obsolescence of the stock of technological knowledge and G_t is the research expenditure (investment) in year t which is added to the stock of technological knowledge with a 5-year lag. Assume at this point that the annual rate of change in this stock is g. Then, (A.1) can be written as $Z_{R_t} = G_{t-5} + (1 - \delta_{Z_R})Z_{R_{t-1}} = (1 + g)Z_{R_{t-1}}$. Thus, the stock at the bench mark year (in this chapter 1960) Z_{R_s} can be expressed as:

$$Z_{R_s} = G_{s-4} / (\delta_{Z_R} + g). \tag{A.2}$$

Note that one cannot obtain the value of g before obtaining the stock of technological knowledge. Ito approximated this rate by the growth rate 10 percent of investment in research for the 1957–59 period when the stock of technological knowledge was still small.

Using Equations (A.1) and (A.2), Ito estimated the stock of technological knowledge (Z_R)for the period 1960–87. Using the same procedure, this chapter extended the estimates up to 1997 by extrapolating the expenditures on agricultural research up to 1995. Furthermore, for a sensitivity analysis, this chapter obtained another series of stocks of technological knowledge for the 1956–97 period assuming an eight-year lag, since there were still ten to 50 research topics with eight-year development lags for the above-mentioned two years, 1967 and 1987. In these cases, however, the same rates, ten percent, were also assumed for for δ_{Z_R} and for g.

Next, Ito did not introduce any lag structure for extension activities. That is, he added the flow amount of expenditures on extension activities to the stock of technological knowledge each year.

However, it appears to be more realistic to assume a certain lag structure for the case of extension activities, since it often takes several years for a new technology to be adopted and materialized in real agricultural production. This chapter thus assumes five years as the maximum for extension activities for a particular innovation.[19]

In addition, for a sensitivity analysis purpose, it assumes a three-year lag also. Using a procedure similar to that used for the stock of technological knowledge, i.e., the benchmark year method, two series of capital stocks of extension activities were estimated for three- and five-year lags. In this case, one percent was assumed for the rate of growth of the capital stocks based on the growth rate of extension expenditures (investments) for the 1957–59 period which was very close to one percent. However, since there is no reliable information for the rate of obsolescence of the capital stock of extension activities, this chapter assumes simply ten percent as in the case of the stock of technological knowledge.

Following Ito, this chapter assumes that the capital stock of R&D investments and the capital stock of extension investments together yield the stock of technological knowledge which is materialized on actual farms. Thus, the two capital stocks were added together for each year for the period 1956–97. Since two series of stocks for technological knowledge and two series of stocks for extension expenditures were estimated, there are altogether four different combinations. These four combinations of the R&E capital stocks were used for the sensitivity analysis for the equation systems of Model (B). The estimated results for these four options of the R&E capital stocks were in general very similar.

However, the combination of eight-year lag for R&D and a three-year lag for extension investments gave the best results in terms of the R^2s and the *P*-values of the coefficients, as well as monotonicity and concavity conditions. Thus, this option was regarded as the best and used for the variable Z_R in the present study.

Note further that we will use the stock of technological knowledge Z_R of rice production for all Japan instead of the Z_R only for Tohoku, because it may be realistic to recognize some sort of spill-over effects from R&D and extension activities in other agricultural districts.

Finally, all the variables entering the translog VC functions (2.7) and (2.12), except for dummy variables, are expressed in index form, using the CCD method.

3

Technology Structure of the Rice Sector of Japanese Agriculture: (II) A Translog Variable Profit Function Approach

3.1 Introduction

As mentioned already in “The Objectives of Part I,” this chapter seeks to introduce a single-product variable profit (VP) function to investigate the rice production structure for the period 1956–97 in a parallel fashion to the VC function approach employed in Chapter 2. Based on the parameter estimates of the VP function system, we will investigate quantitatively the output supply elasticity, the variable factor demand elasticities with respect to output price and variable factor inputs prices, the degrees of returns to scale, and the shadow prices of the quasi-fixed factor inputs, in particular, land. Several features of introducing the VP function may be listed as follows.

First of all, it explicitly introduces the output *price* instead of the quantity of output. This indicates that the level of output is not treated as an exogenous variable in this chapter: output is now an endogenous variable. This means that the farm-firm is able to control the level of output, which may be considered to be more realistic than in the cases of fixed-output VC function models when we observe the actual situation of rice production.

Second, introducing the output price allows us to estimate output supply and variable factor demand elasticities with respect to output price as an exogenous variable. It will be clear later in this chapter that these elasticities are so-called *mutatis mutandis* elasticities which are obtained with all other variable factors and output level taking on their optimal values. It will thus be intriguing to compare the estimated results of these economic indicators when it comes to evaluating the corresponding results based on the VC function model.

Third, though repetitive, it is also possible, as in the case of the VC function approach, to estimate own-price variable factor demand elasticities, the degrees of returns to scale, and the shadow price of land.[1] Unfortunately, however, it is fairly complicated to define and formulate the estimation procedures of the factor substitutions in the VP function framework – unlike in the VC function framework employed in Chapter 2 – since the quantity of output is not fixed. Accordingly, we will not try to estimate the AES, MES, and SES in this chapter.

Fourth, as in Chapter 2, where the VC function was employed, it is also critical to quantitatively examine several hypotheses concerning the technology structure of rice production based on the estimation of the VP function.

Finally, again, as in the previous chapter, using the estimated shadow value of land, we will investigate the possibilities of land transfers from small- to large-scale farms. The empirical investigations of these estimates will present important and intriguing information on the production structure obtained by the VP function approach, which may or may not support the corresponding estimates obtained from the VC function model employed in Chapter 2 of this book.

The rest of this chapter is organized as follows. Section two presents the VP function-based analytical framework. Section three explains the data and estimation procedure. Section four presents empirical results. Finally, Section five provides a brief summary and conclusion.

3.2 Analytical framework

3.2.1 The variable profit (VP) function model

Consider the following single-product VP function,

$$VP' = G(P', \mathbf{w}', \mathbf{Z}, t, \mathbf{D}), \tag{3.1}$$

where VP' is a nominal variable profit, P' is the nominal price of output (rice); $\mathbf{w}'$ denotes a vector of nominal variable factor input prices which consists of the prices of machinery (w'_M), intermediate (w'_I), and other (w'_O) inputs; $\mathbf{Z}$ is a vector composed of labor (Z_L) and land (Z_B) as quasi-fixed factor inputs[2] and a stock of technological knowledge (Z_R) which can be regarded as a productivity parameter external to all of the farms; t is a time trend as a proxy for technological innovations which are expected to capture the effects of autonomous technological change which occurs independently from public R&E activities such as an introduction of information technology in farm management; and $\mathbf{D}$ consists of dummy variables for period (D_p), farm sizes ($D_s,\ s = II, III, IV, V, VI$), and weather condition (D_w).[3]

By normalizing nominal VP' and $\mathbf{w}'$ by the nominal output price P', we rewrite the nominal VP' function in (3.1) in order to obtain the real VP function as,

$$VP = F(\mathbf{w}, \mathbf{Z}, t, \mathbf{D}), \tag{3.2}$$

where $VP = VP'/P'$ and $\mathbf{w} = \mathbf{w}'/P'$.

Now, for econometric estimation, we will employ the ordinary translog form following Diewert (1974). Note here however that the estimation was not statistically satisfactory because of the multicolinearity between the time trend variable t and the stock of technological knowledge Z_R as occurred in the case of the VC function approach employed in Chapter 2. In addition, all of the coefficients of the dummy variables (D_p, D_s, $s = II, III, IV, V, VI$, and D_w) were not statistically significant at any conventional levels. We therefore omitted the time variable (t) and all dummy variables ($\mathbf{D}$) in the estimation of the translog VP function developed based on Equation (3.2). Accordingly, we re-specified the real VP function as,

$$VP = H(\mathbf{w}, \mathbf{Z}, Z_R), \tag{3.3}$$

where $\mathbf{Z}$ is now a vector composed only of labor (Z_L) and land (Z_B) as quasi-fixed factor inputs. The translog specification of the newly defined VP function (3.3) is given by,

$$\begin{aligned}\ln VP &= \alpha_0 + \sum_k \alpha_k \ln w_k + \sum_l \beta_l \ln Z_l \\ &\quad + \frac{1}{2}\sum_k\sum_n \gamma_{kn} \ln w_k \ln w_n + \frac{1}{2}\sum_l\sum_h \delta_{lh} \ln Z_l \ln Z_h \\ &\quad + \sum_k\sum_l \phi_{kl} \ln w_k \ln Z_l \\ &\quad + \sum_k \mu_{kR} \ln w_k \ln Z_R + \sum_l \mu_{lR} \ln Z_l \ln Z_R + \frac{1}{2}\mu_{RR}(\ln Z_R)^2, \end{aligned} \tag{3.4}$$

$$k, n = M, I, O,\ h, l = L, B,$$

where $\gamma_{kn} = \gamma_{nk}$, $\delta_{hl} = \delta_{lh}$. Applying the Hotelling (1932)-Shephard's (1953) Lemma to the translog *VP* function (3.4), we can obtain the variable factor input cost-variable profit share functions. Assuming that the farm-firm takes the prices of the variable factor inputs as given, the following variable factor input cost-variable profit share equations are derived as follows:

$$R_k = -\frac{\partial VP}{\partial w_k}\frac{w_k}{VP} = \frac{\partial \ln VP}{\partial \ln w_k}$$
$$= \alpha_k + \sum_n \gamma_{kn} \ln w_n + \sum_l \phi_{kl} \ln Z_l + \mu_{kR} \ln Z_R, \quad (3.5)$$
$$k, n = M, I, O, \ l = L, B.$$

Following Fuss and Waverman (1981, pp. 288–89), Ray (1982), and Capalbo (1988), we introduce an analogous assumption that the translog VP function can be used along with the variable profit-maximizing condition to derive an additional equation representing the optimal choice of a quasi-fixed factor input, i.e., labor (Z_L).[4] In doing this, we are assuming that the farm-firm attains the optimal allocation of labor input by equating the marginal productivity of labor to the market price of labor represented by the wage rate of temporary-hired labor.[5]

$$R_{Z_L} = \frac{\partial VP}{\partial Z_L}\frac{Z_L}{VP} = \frac{\partial \ln VP}{\partial \ln Z_L}$$
$$= \beta_L + \sum_k \phi_{kL} \ln w_k + \sum_h \delta_{Lh} \ln Z_h + \mu_{BR} \ln Z_R, \quad (3.6)$$
$$k, n = M, I, O, \ h = L, B.$$

Introduction of the labor cost-variable profit share equation (R_{Z_L}) into the estimation of the system of equations will in general lead to a more efficient estimation of the coefficients, in particular, of the labor input-associated variables due to the additional information provided by the labor cost-variable profit share equation.

Now, any sensible profit function must be homogeneous of degree one in output and input prices. In the translog VP function (3.4) this requires the following restrictions:

$$\sum_k \alpha_k = 1,$$
$$\sum_k \gamma_{Qk} = 0,$$
$$\sum_k \gamma_{kn} = 0,$$
$$\sum_k \gamma_{kl} = 0, \quad (3.7)$$
$$k, n = M, I, O, \ l = L, B, R.$$

The translog VP function (3.4) has a general form in the sense that the restrictions of homotheticity, constant returns to scale, and Hicks (1932) neutrality with respect to Z_R are not imposed *a priori*. Instead, these restrictions will be statistically tested *via* the estimation process of this function together with other restrictions to be mentioned immediately in the next subsection.[6]

3.2.2 Tests for the technology structure of rice production

To begin with, following similar procedures to those employed in Chapter 2, this subsection deals with important concepts representing the technology structure of production: namely, (i) homotheticity, (ii) no technological change with respect to the stock of technological knowledge Z_R, (iii) Hicks (1932) neutral technological change with respect to the stock of technological knowledge Z_R, (iv) C–D production function, and (v) constant returns to scale (CRTS).

3.2.2.1 Homotheticity

The homotheticity can be tested by examining that the VP function (3.3) can be written as,

$$H(\mathbf{w}, \mathbf{Z}, Z_R) = J^1(\mathbf{w}) J^2(\mathbf{Z}, Z_R). \tag{3.8}$$

This implies the existence of an aggregate index of fixed factor inputs. Or, more specifically, it tests that the demand for variable factor inputs are not functions of the fixed factor inputs. This test can be carried out by testing the following null hypothesis in terms of the parameters of the translog VP function (3.4):

$$H_0 : \phi_{kl} = 0, \quad k = M, I, O, \ l = L, B. \tag{3.9}$$

3.2.2.2 No technological change with respect to the stock of technological knowledge (Z_R)

The hypothesis of no technological change with respect to Z_R can easily be tested by examining the following null hypothesis. That is, the coefficients of the variables associated with Z_R are all zero:

$$H_0 : \beta_R = \mu_{kR} = \mu_{lR} = \mu_{RR} = 0, \quad k = M, I, O, \ l = L, B. \tag{3.10}$$

3.2.2.3 Neutral technological change with respect to Z_R

Binswanger (1974) proposed a single relative measure of bias in factor inputs using changes in cost shares of factors of production based on the translog TC function approach. Antle and Capalbo (1988, pp. 33–48) extended Binswanger's (1974) definition of the bias measure to nonhomothetic production technologies. According to their definitions, the *dual* measure of input bias (B_k) contains two distinct effects: (i) a *pure bias effect* owing to the shift in the expansion path (B_k^p) and (ii) a *scale effect* owing to the movement along the nonlinear expansion path (B_k^s). If the technology is homothetic, the *scale effect* is zero.

In the case of a (single-product) VP function model as in the present study, the cost share change with respect to the stock of technological knowledge (B_k^R) can be shown as follows (refer to Equations (2.23) and (2.24) on page 43 in Capalbo and Antle (1988)):

$$B_k^R = \frac{\partial \ln R_k}{\partial \ln Z_{R_k}} + \left(\frac{\partial \ln R_k}{\partial \ln P'}\right)\left(\frac{\partial \ln VP'}{\partial \ln P'}\right)^{-1}\left(\frac{\partial \ln VP'}{\partial \ln Z_R}\right), \quad k = M, I, O, \tag{3.11}$$

where the *pure bias effect* B_k^{Rp} is given by the first term of Equation (3.11) and the *scale effect* B_k^{Rs} by the second term of Equation (3.11), respectively. Note here that when technology is homothetic, $B_k^{Rs} = \partial \ln VP'/\partial \ln Z_R = 0$ so $B_k^R = B_k^{Rp}$.

If $B_k^R = 0$ ($k = M, I, O$), then technological change is said to be k-th factor *neutral*. If $B_k^R > 0$ (< 0), then technological change is said to be biased towards *using* (*saving*) the k-th factor.

Using the parameters of the translog VP function in the present study, Equation (3.11) can be expressed as,

$$\begin{aligned} B_k^R &= \frac{\mu_{k_R}}{R_k} + \frac{\gamma_{Qk}}{R_k}\lambda \\ &= B_k^{Rp} + B_k^{Rs}, \end{aligned} \tag{3.12}$$

where

$$\lambda = -\frac{\partial \ln VP'}{\partial \ln Z_R} = \beta_R + \sum_k \mu_{kR} \ln w_k' + \sum_l \mu_{lR} \ln Z_l + \mu_{RR} \ln Z_R,$$

$$k = m, I, O, \ l = L, B.$$

Thus, the test for Hicks neutrality is tantamount to testing the following null hypothesis,

$$H_0 : B_k^R = 0, \quad k = M, I, O. \tag{3.13}$$

If $B_k^R = 0$ ($k = M, I, O$), then the technological change is said to be Hicks *neutral* with respect to the k-th factor. If $B_k^R \neq 0$, the technological change is said to be Hicks *non-neutral*, and biased towards factor *k-saving* if $B_k^R < 0$ or factor *k-using* if $B_k^R > 0$.

3.2.2.4 C–D production function

The hypothesis whether or not the rice production technology is specified as a C–D production function can be tested by examining the following null hypothesis:

$$H_0 : \gamma_{kn} = \delta_{hl} = \phi_{kl} = \mu_{kR} = \mu_{lR} = 0, \quad k,n = M,I,O, \; h,l = L,B. \tag{3.14}$$

That is, the coefficients of the quadratic terms of the translog VP function (3.4) are all jointly zero.

3.2.2.5 Constant returns to scale (CRTS)

In their pioneering work, introducing the profit function for the first time in the arena of production economics, Lau and Yotopoulos (1972) developed a very useful formula of testing constant returns to scale (CRTS) in the profit function framework: as a *dual* transformation of a production function which is homogeneous of degree κ. Using the duality theorem, they derived the following very convenient equation for testing the degree of homogeneity of the *dual* profit function (Lau and Yotopoulos 1972, equation (19), p. 14) which can be written as follows using the corresponding variable notations of this section:

$$\frac{(\kappa-1)}{\kappa}\sum_n \frac{\partial VP'}{\partial w_n'} w_n' + \frac{1}{\kappa}\sum_l \frac{\partial VP'}{\partial Z_l} Z_l = VP', \quad n = M,I,O, \; l = L,B. \tag{3.15}$$

In other words, VP' is an *almost* homogeneous function of degrees $(\kappa - 1)/\kappa$ and $1/\kappa$ in the prices of variable factor inputs and the quantities of fixed factor inputs, respectively.[7] Dividing both sides of Equation (3.16) by VP', we obtain the following equation,

$$\frac{(\kappa-1)}{\kappa}\sum_n \frac{\partial VP'}{\partial w_n'} \frac{w_n'}{VP'} + \frac{1}{\kappa}\sum_l \frac{\partial VP'}{\partial Z_l} \frac{Z_l}{VP'} = 1,$$

or alternatively, the degrees of returns to scale (*RTS*) can be captured by,

$$RTS = \sum_l \frac{\partial \ln VP'}{\partial \ln Z_l} = \kappa - (\kappa - 1)\sum_n \frac{\partial \ln VP'}{\partial \ln w_n'}, \tag{3.16}$$

$$n = M,I,O, \; l = L,B.$$

Note that $\sum_n \partial \ln VP' / \partial \ln w_n' < 0$ by monotonicity conditions on the variable profit function. Hence, if $\kappa > 1$ (increasing returns to scale), $\sum_l \partial \ln VP' / \partial \ln Z_l > 1$. If $\kappa = 1$ (constant returns to scale), $\sum_l \partial \ln VP' / \partial \ln Z_l = 1$. If $\kappa < 1$ (decreasing returns to scale), $\sum_l \partial \ln VP' / \partial \ln Z_l < 1$.[8] Thus, the test for hypothesis of constant returns to scale in the case of the variable profit function can be carried out by examining the following null hypothesis:

$$H_0 : \sum_l \frac{\partial \ln VP'}{\partial \ln Z_l} = 1, \quad l = L, B. \tag{3.17}$$

Alternatively, we can estimate degrees of returns to scale (*RTS*) for each observation by,

$$RTS = \sum_l \frac{\partial \ln VP'}{\partial \ln Z_l}, \tag{3.18}$$

which is the sum of the elasticities of the variable profit function with respect to the fixed factors of production or the shadow value-variable profit shares of the quasi-fixed factor inputs, labor (R_{Z_L}) and land (R_{Z_B}) in the present study. They are given by the following equation derived from the VP function (3.4):

$$R_{Z_l} = \frac{\partial \ln VP'}{\partial \ln Z_l} = \beta_l + \phi_{Ql} \ln P' + \sum_k \phi_{kl} \ln w_k' + \sum_l \delta_{lh} \ln Z_h + \mu_{lR} \ln Z_R, \tag{3.19}$$

$$k = M, I, O, \; h, l = L, B.$$

3.2.3 Estimations of output supply and input demand elasticities

Following and modifying the procedures presented in Sidhu and Baanante (1981) for the case of the VP function in this chapter,[9] we can derive the formulas for output supply and variable factor demand elasticities with respect to the output price (P'), the prices of the three variable factor inputs (w_k', $k = M, I, O$), and the quantities of the two quasi-fixed factor inputs (Z_l, $l = L, B$).

We note here that there are two types of price elasticity, which correspond to the total effect and substitution effect of price changes. These are the Marshallian *uncompensated* elasticities and the *Hicksian compensated* elasticities. The *uncompensated* elasticities correspond to the total effects of a price change. They measure the effect of price changes, holding other prices constant but allowing inputs and outputs to adjust to their new equilibrium levels under the new set of relative prices (Higgins 1986, p. 480). This is exactly what we try to do in this subsection. As compactly exposed by Yotopoulos and Nugent (1976, p. 52), the output supply and input demand elasticities obtained from the variable profit function are *mutatis mutandis* elasticities, which may be equivalent to *Marshallian uncompensated* elasticities: that is, the effect upon output (or input) of a change in one factor, with all other factors taking on their optimal values.

3.2.3.1 Estimation of output supply elasticities

The output supply elasticities with respect to the output price (P') can be derived using the definition of the output revenue-variable profit share as follows:

$$\frac{\partial \ln VP'}{\partial \ln P'} = \frac{\partial VP'}{\partial P'}\frac{P'}{VP'} = \frac{P'Q}{VP'} = R_Q, \tag{3.20}$$

where, as already mentioned in the exposition of Equation (3.1) the prime (′) indicates that the variables are expressed in nominal terms. Taking the natural logarithms of both sides of the last equation and rearranging gives,

$$\ln Q = \ln R_Q - \ln P' + \ln VP'. \tag{3.21}$$

Now, using the parameters of the translog VP function (3.4), the supply elasticity with respect to the output price P' (ε_{QQ}) can be estimated by,

$$\varepsilon_{QQ} = \frac{\partial \ln Q}{\partial \ln P'} = \frac{\gamma_{QQ}}{R_Q} + R_Q - 1. \tag{3.22}$$

At the approximation points of the VP function (3.4), this can be rewritten as,

$$\varepsilon_{QQ} = \frac{\gamma_{QQ}}{\alpha_Q} + \alpha_Q - 1. \tag{3.23}$$

In deriving ε_{QQ}, the parameters α_Q and γ_{QQ} can easily be obtained from the homogeneous-of-degree-one-in-output-and-input-prices restrictions.

Second, the supply elasticities of output with respect to the prices of the variable factor inputs ε_{Qk} $(k=M,I,O)$ can similarly be derived as:

$$\varepsilon_{Qk}=\frac{\gamma_{Qk}}{R_Q}-R_k, \quad k=M,I,O. \tag{3.24}$$

At the approximation points, Equation (3.24) can be rewritten as,

$$\varepsilon_{Qk}=\frac{\gamma_{Qk}}{\alpha_Q}-\alpha_k, \; k=M,I,O, \tag{3.25}$$

where

$$\gamma_{Qk}=-\sum_k \gamma_{nk}, \; k,n=M,I,O.$$

Third, the supply elasticities of output with respect to the quantities of the quasi-fixed factor inputs Z_l $(l=L,B)$, i.e., ε_{Ql} $(l=L,B)$ can similarly be derived as:

$$\varepsilon_{Ql}=\frac{\phi_{Ql}}{R_l}+R_l, \; l=L,B. \tag{3.26}$$

At the approximation points, Equation (3.26) can be rewritten as,

$$\varepsilon_{Ql}=\frac{\phi_{Ql}}{\alpha_Q}+\beta_l, \; l=L,B, \tag{3.27}$$

where

$$\phi_{Ql}=-\sum_k \phi_{kl}, \; k=M,I,O, \; l=L,B.$$

3.2.3.2 Estimations of variable factor input demand elasticities

As in the case of output supply elasticities, we can easily derive the formulas for estimating the demand elasticities for variable factor inputs in a very similar manner to the former case.

First, variable factor demand elasticities with respect to the price of output $(\eta_{kQ}, \; k=M,I,O)$ can be derived by the following equation:

$$\eta_{kQ}=-\frac{\gamma_{Qk}}{R_k}+R_k, \quad k=M,I,O. \tag{3.28}$$

At the approximation points, Equation (3.28) can be rewritten as,

$$\eta_{kQ}=-\frac{\gamma_{Qk}}{\alpha_k}+\alpha_k, \quad k=M,I,O, \tag{3.29}$$

where, from the linear-homogeneity-in-prices restrictions, we have,

$$\gamma_{Qk}=-\sum_k \gamma_{kn}$$

$$k,n=M,I,O.$$

Second, variable factor demand elasticities with respect to the prices of the variable factor inputs ($\eta_{kn},\ k,n=M,I,O$) can be derived as follows. To begin with, the own-price factor demand elasticities are given by,

$$\eta_{kk}=-\frac{\gamma_{kk}}{R_k}-R_k-1,\quad k=M,I,O. \tag{3.30}$$

At the approximation point, this equation can be rewritten as,

$$\eta_{kk}=-\frac{\gamma_{kk}}{\alpha_k}-\alpha_k-1,\quad k=M,I,O. \tag{3.31}$$

Third, the cross-price factor demand elasticities are given by,

$$\eta_{kn}=-\frac{\gamma_{kn}}{R_k}-R_k,\quad k\neq n=M,I,O. \tag{3.32}$$

At the approximation points, Equation (3.32) can be rewritten as,

$$\eta_{kn}=-\frac{\gamma_{kn}}{\alpha_k}-\alpha_k,\quad k\neq n=M,I,O. \tag{3.33}$$

Fourth, the factor demand elasticities with respect to the quantities of the quasi-fixed factor inputs ($Z_l,\ l=L,B$) can be derived as follows:

$$\eta_{kl}=-\frac{\phi_{kl}}{R_k}+R_l,\quad k=M,I,O,\ l=L,B, \tag{3.34}$$

which can be rewritten at the approximation points as,

$$\eta_{kl}=-\frac{\phi_{kl}}{\alpha_k}+\alpha_l,\quad k=M,I,O,\ l=L,B. \tag{3.35}$$

3.2.3.3 Estimation of the degrees of returns to scale (RTS)

As already exposed in Subsection 2.2.2 in Chapter 2, where the procedure of testing the null hypothesis of CRTS is proposed, *RTS* can be estimated using Equation (3.19) as,

$$RTS=\sum_l\frac{\partial\ln VP'}{\partial\ln Z_l},\quad l=L,B. \tag{3.36}$$

This equation will be used to estimate scale economies for all the observations of the six size classes for the 1956–97 period.

3.2.3.4 Estimation of the shadow value of land

The shadow value of a quasi-fixed factor input can be obtained by differentiating the nominal variable profit function (3.1) with respect to the quantity of that quasi-fixed factor input (Diewert 1974, p. 140; Nadiri 1982, p. 452) as:

$$\frac{\partial VP'(P',\mathbf{w}',\mathbf{Z},Z_R)}{\partial Z_l} = w_l^{S'}(P',\mathbf{w}',\mathbf{Z},Z_R), \quad l=L,B, \tag{3.37}$$

where $w_l^{S'}$ is the nominal shadow value of the l-th quasi-fixed factor input. Derivatives of the VP function (3.1) and the *primal* production function (not presented in this paper) with respect to the l-th quasi-fixed factor input are equivalent due to the *dual* transformation relationships between the two functions (Lau 1978, p. 146; Nadiri 1982, p. 452).

These equations give the imputed value of a marginal unit of quasi-fixed factor input l. As clearly seen in Equation (3.38), the shadow value equation is a function of the output (rice) price (P'), the variable factor input prices (w_k', $k=M,I,O$), the quantities of the quasi-fixed factor inputs (Z_l, $l=L,B$), and the stock of technological knowledge (Z_R). In terms of parameters of the translog VP function (3.4) of this chapter, w_l' is given by,

$$\begin{aligned}\frac{\partial VP'}{\partial Z_l} &= w_l^{S'} \\ &= \frac{VP'}{Z_l}\frac{\partial \ln VP'}{\partial \ln Z_l} \\ &= \frac{VP'}{Z_l}\left(\beta_l + \sum_l \phi_{Ql}\ln P' + \sum_k \phi_{Qk}\ln w_k' + \sum_h \delta_{hl}\ln Z_h + \mu_{lR}\ln Z_R\right),\end{aligned} \tag{3.38}$$

$$k=M,I,O, \; h,l=L,B.$$

Given estimates of β_l ($l=L,B$), ϕ_{Ql} ($l=L,B$), ϕ_{Qk} ($k=M,I,O$), the shadow value can be computed for each sample observation of each size class for the study period 1956–97. In order to examine at what level the farm-firm evaluates the productive value of land, the computed shadow value of land will then be compared with the actual land rent which has been regulated by the government in certain forms based on the Land Basic Act.

It is noted here however that the shadow value of labor can be estimated together with the shadow value of land using Equation (3.38).

However, as mentioned earlier in the Subsection 3.2.1 of developing the VP function model, the labor cost-variable profit share equation is going to be included in the system of estimating equations. This means that we assume the farm-firm maximizes the amount of variable profits with respect to labor input; or, in other words, the farm-firm utilizes the "optimal" level of labor input with regard to the actual market price of labor. Thus, we will not present the shadow value of labor in this chapter.[10]

3.3 The data and estimation procedure

The data required for the estimation of the translog VP function model consists of: the variable profit (VP'); the output revenue-variable profit shares (R_Q) and price of output (P'); the prices and quantities of the three variable factor inputs, machinery (w'_M and X_M), intermediate input (w'_I and X_I), and other input (w'_O and X_O); the variable factor input cost-variable profit shares (R_M, R_I, R_O); the quantities of labor (Z_L) and land (Z_B) as quasi-fixed factor inputs; and the stock of technological knowledge (Z_R) as an exogenous input. In addition, the labor shadow cost-variable profits share (R_L) was obtained by dividing the labor shadow cost ($C_L = w'_L Z_L$) by the variable profits ($R_L = C_L/VP$). Furthermore, dummy variables for period (D_p), farm sizes (D_s, $s = II, III, IV, V, VI$), and weather (D_w) are introduced. The details of the sources of data and the variable definitions are described in Appendices A and B of Chapters 2 and 3.

For statistical estimation, the system of equations consists of the translog VP function (3.4), three of the variable factor cost-variable profit share equations (3.5), and one shadow labor cost-variable profit share equation (3.6). Note here that, in this system of equations labor is treated as, in a sense, a "quasi-endogenous" variable. Thus, the estimation model is "complete" in the sense that it has as many (five) equations as endogenous variables (five). Therefore, the full information maximum likelihood (FIML) method is chosen. In this process, the restrictions due to symmetry and linear homogeneity in prices are imposed. Due to the linear-homogeneity-in-prices property of the VP function, the revenue share equation can be omitted from the simultaneous equation system. The coefficients of the omitted revenue-variable profit share equation can easily be obtained after the system is estimated using the imposed linear homogeneity restrictions.

3.4 Empirical results

3.4.1 Results of the variable profit (VP) function

To begin with, the estimated parameters of the system and the associated *P*-values are reported in Table 3.1.[11] According to the *P*-value tests, five out of 24 coefficients are not statistically significant at better than 10% levels, which may be considered to be fairly statistically significant. Goodness-of-fit statistics are given in the lower part of Table 3.1 which indicate a fairly good fit for the model as a whole, though the magnitudes of the *R*-squared for intermediate input-variable profit share

Table 3.1 Parameter estimates of the translog variable profit (VP) function for the rice sector in Tohoku, 1956–97

Parameter	Coefficient	*P*-value	Parameter	Coefficient	*P*-value
α_0	−0.004	0.907	δ_{BB}	0.224	0.000
α_M	−0.358	0.000	δ_{LB}	−0.072	0.140
α_I	−0.224	0.000	ϕ_{ML}	0.277	0.000
α_O	−0.095	0.000	ϕ_{MB}	−0.140	0.010
β_L	0.474	0.000	ϕ_{IL}	0.083	0.000
β_B	0.700	0.000	ϕ_{IB}	−0.042	0.025
β_R	0.440	0.000	ϕ_{OL}	0.100	0.000
γ_{MM}	0.251	0.018	ϕ_{OB}	−0.069	0.000
γ_{II}	−0.186	0.000	μ_{MR}	−0.040	0.602
γ_{OO}	−0.049	0.072	μ_{IR}	−0.008	0.730
γ_{MI}	−0.085	0.001	μ_{OR}	0.005	0.737
γ_{MO}	−0.146	0.000	μ_{LR}	0.142	0.008
γ_{IO}	0.005	0.856	μ_{BR}	−0.297	0.000
δ_{LL}	0.271	0.000	μ_{RR}	0.166	0.089

Estimating equations	*R*-squared	*S.E.R.*
Variable profit function	0.952	0.199
Machinery cost-variable profit share equation	0.728	0.134
Intermediate input cost-variable profit share equation	0.574	0.050
Other input cost-variable profit share equation	0.783	0.027
Labor input cost-variable profit share equation	0.642	0.120

Notes:

(1) The symmetry and homogeneity-of-degree-one-in-output-input-prices restrictions are imposed in the estimation.

(2) *S.E.R.* denotes standard error of regression.

(3) *P*-value indicates the degree of probability which gives directly the extent of statistical significance.

and shadow labor cost-variable profit share equations, 0.574 and 0.642, respectively, appear to be a little low.

In addition, based on the parameter estimates of the translog VP function given in Table 3.1, the monotonicity and convexity conditions with respect to input prices were checked at each observation, respectively. Since the estimated variable profit-output share is positive but the variable profit-cost shares for inputs are all negative, the production technology satisfies the monotonicity condition. Furthermore, almost all of the eigenvalues of the Hessian matrix were positive for almost all observations of the six size classes for the entire study period 1956–97. This indicates that the convexity conditions with respect to the variable factor prices were also satisfied for almost all sample observations. Which implies that the estimated variable factor demand elasticities with respect to their own prices are almost all negative, which is economically meaningful.

As for the concavity conditions with respect to the quasi-fixed factor inputs, labor (Z_L) and land (Z_B), the eigenvalues given by $[\delta_{hh} + \beta_h(\beta_h - 1), h = L, B]$ in this chapter must be negative or equal to zero. All of the eigenvalues were negative for all observations of the six size classes for the entire study period 1956–97. This implies that the concavity conditions with respect to the quasi-fixed factor inputs (Z_L and Z_B) are satisfied for all sample observations.[12]

These findings indicate that the estimated VP function (3.1) represent second order approximations to the *true* data that satisfy the curvature conditions. The estimated parameters given in Table 3.1 are therefore reliable and are utilized for further analysis in the following sections.

3.4.2 Results of the tests for the five hypotheses

In this subsection, the technology structure of post-war Japanese rice farming are tested using the Wald test procedure, in order to examine whether or not our specification of the VP function model is valid. We will evaluate the test results presented in Table 3.2.

First, the hypothesis of homotheticity was strongly rejected. It immediately follows that the variable factor input cost-variable profit shares depend on changes in the quasi-fixed factor inputs ($Z_l,\ l = L, B$).

Second, the test for no technological change with respect to the stock of technological knowledge (Z_R) was strongly rejected. This implies technological change in post-war Japanese rice agriculture in some form or other.

Third, Hicks' (1932) neutral technological change with respect to Z_R was rejected. This means that technological change in post-war Japanese

Table 3.2 Tests for the technology structure of rice production

Hypothesis		Wald test statistic	Degrees of freedom	P-value
(1)	Homotheticity	71.6	6	0.000
(2)	No technological change	805.4	7	0.000
(3)	Hicks neutral	14.6	3	0.000
(4)	Cobb–Douglas production function	1875.9	21	0.000
(5)	Constant returns to scale	109.0	7	0.000

rice production with respect to Z_R is biased towards or against specific factor inputs. The estimated *overall bias effects* in terms of elasticities for machinery, intermediate, and other inputs were 0.370, 0.991, and 1.087 whose P-values were 0.316, 0.000, and 0.009, respectively. This indicates that technological change biases were machinery-, intermediate input-, and other input-*using* for the study period 1956–97, though the statistical significance for machinery-*using* bias is a little weak.

Fourth, the null hypothesis of the C–D production function was absolutely rejected. This means that the strict assumption of unitary elasticity of substitution between any pair of factor inputs is not realistic at all in specifying the production structure of post-war rice Japanese agriculture. Furthermore, since the C–D production function implicitly assumes from the beginning Hicks neutrality of technological change, this result of rejection of the C–D production function is consistent with the above results of the test for Hicks neutrality.

Fifth, constant returns to scale in rice production were strongly rejected in the present VP function model. The estimated degrees of scale economies were 1.174 at the approximation points for the VP function model. This result indicates that there was IRTS on the average for the VP function model for post-war Japanese rice production. We will estimate later in this section the degrees of IRTS for all observations of the six different size classes for the entire study period 1956–97.

In sum, the results of the statistical tests for the five null hypotheses support those of the conceptually same five null hypotheses tested in Chapter 2, where the VC function model was introduced. This implies that, either in the VC function model, or in the VP function model, the technology structure of rice production is characterized by: (1) nonhomotheticity, (2) existence of technological change, (3) non-neutral technological change, (4) non-C–D production function, and (5) non-CRTS in production. Needless to say, the econometrical estimations of the various economic indicators in the following sections of this chapter will be executed based on the results of the statistical Tests for the five null hypotheses.

3.4.3 Estimates of output supply and input demand elasticities

Using Equations (3.25), (3.27), and (3.29), output supply elasticities for rice were estimated at the approximation points. On the other hand, input demand elasticities were estimated using Equations (3.31), (3.33), and (3.35) at the approximation points. They are shown in Table 3.3. Recall that the estimated elasticities are the *Martiallian* elasticities instead of the *Hicksian* elasticities. Several intriguing findings emerge from this table.

3.4.3.1 Estimates of rice output supply elasticities

To begin with, the own-price supply elasticity of rice is 0.418. This implies that a ten percent increase in the price of rice will increase the quantities of rice supply by around 4.2 percent. This in turn implies that the rice price-support programs since the early-1960s had fairly significant effects on increasing the quantities of supply of rice.[13]

We will compare our results with those in previous studies. There are only a few studies which estimated output supply elasticities for Japanese agriculture. Chino (1984) applied the linear output supply system proposed by Laitinen and Theil (1978) to Japanese data for the period 1955–81 obtained from the *Seisan Nogyo Shotoku Tokei* [the *Statistics of Agricultural Production Income*] and the *Noson Bukka Chingin Chosa Hokoku* [the *Survey Report on Prices and Wages in Rural Villages*] (PWRV in short hereafter), published annually by the MAFF. He obtained 0.245 as the long-run own-price supply elasticity for rice.[14]

Second, the supply elasticities of rice, with respect to changes in the prices of the variable factor inputs, i.e., machinery, and intermediate inputs, are –0.370 (0.000) and –0.066 (0.175), respectively, where the numbers in parentheses are the estimated *P*-values. This indicates that, though not that sharply, increases in the prices of machinery and intermediate inputs reduce the supply of rice. On the other hand, the supply elasticities of rice with respect to changes in the price of other input 0.018 (0.568) will not have any significant impact, considering that the estimated *P*-value is too big for the elasticity to be statistically significant. This in turn indicates that factor inputs-subsidy programs, which reduce the prices of variable factor inputs, may have had a positive effect on the quantities of rice supply during the study period 1956–97.

Third, the supply elasticities of rice output with respect to the quasi-fixed factor inputs, labor and land, are positive: 0.200 (0.000) and 0.850 (0.000), respectively, where the numbers in parentheses are the estimated *P*-values. In particular, the output supply elasticity of rice with respect to land, 0.850, indicates that an increase in paddy planted area will increase the supply of rice fairly elastically. Conversely speaking, this implies that the set-aside programs may have had fairly strong effects of reducing the quantities of rice supply during the study period 1956–97.[15]

3.4.3.2 Estimates of variable factor demand elasticities

To begin with, Table 3.3 shows that, on average, an increase in the price of rice will increase the demand for machinery and intermediate inputs. However, we could tell nothing about other input since the estimate is not statistically significant. More specifically, the demand elasticities of machinery and intermediate inputs, with respect to an increase in the price of rice, are 1.736 (0.000) and 0.492 (0.171), respectively, where the numbers in parentheses are the estimated *P*-values. We may infer from the finding that, thanks to a fairly high demand elasticity, 1.736, the rice price-support programs may have had a considerable impact on the promotion of farm mechanization during the last four decades of the 20th century: in particular, 1956–97.

Second, according to Table 3.3, the *Martiallian* own-price demand elasticities for machinery, intermediate, and other inputs are –2.060 (0.000), –0.393 (0.000), and –0.582 (0.043), where the numbers in parentheses are the *P*-values. In particular, the absolute number of the own-price elasticity of machinery, around 2.1, indicates that farmers were very responsive to changes in the price of machinery. This in turn implies that government subsidies for machinery input which are equivalent to reducing the price of machinery input may have promoted rapid mechanization for rice production during the last four decades of the 20th century.

Finally, demand elasticity for the variable factor inputs, with respect to planted paddies, are all positive, indicating that increases in paddy land will fairly strongly increase the demands for machinery, intermediate, and other inputs; the elasticities are 1.091, 0.887, and 1.426 for

Table 3.3 Estimates of output supply and factor demand elasticities

	Price of output (P')	Price of machinery (w'_M)	Price of intermediate input (w'_I)	Price of other input (w'_O)	Quantity of labor input (Z_L)	Quantity of land (Z_B)
Supply of output(Q)	0.418 (0.000)	−0.370 (0.000)	−0.066 (0.175)	0.018 (0.568)	0.200 (0.000)	0.850 (0.000)
Demand for machinery input (X_M)	1.736 (0.000)	−2.060 (0.000)	0.012 (0.006)	0.313 (0.000)	−0.300 (0.096)	1.091 (0.000)
Demand for intermediate input (X_I)	0.492 (0.171)	0.019 (0.162)	−0.393 (0.000)	−0.118 (0.356)	0.105 (0.348)	0.887 (0.000)
Demand for other input (X_O)	−0.316 (0.570)	1.177 (0.000)	−0.279 (0.355)	−0.582 (0.043)	−0.574 (0.001)	1.426 (0.000)

Notes:

(1) The elasticities were estimated using Equations (3.25), (3.27), and (3.29) for the elasticities of output supply and Equations (3.31), (3.33), and (3.35) for the elasticities of variable factor inputs at the approximation points.

(2) Figures in parentheses are *P*-values which indicate the degrees of probability which gives directly the extent of statistical significance.

machinery, intermediate, and other inputs, respectively, and they are all statistically significant.

We are here more interested in the demand elasticities of these variable factor inputs with respect to planted paddy land than with respect to labor, since we may infer the impact of the set-aside programs on demand for the variable factor inputs. The estimated demand elasticities for machinery, intermediate, and other inputs are considerably high: for example, a ten percent reduction in paddy land, due to a set-aside program, reduces the demand for these variable factor inputs by around 10.9, 8.9, and 14.3 percent, respectively. This may have discouraged farmers from purchasing these variable factor inputs, indicating substantial reductions in the quantities of rice supply.

3.4.3.3 Estimates of the degrees of returns to scale (RTS)

Using Equation (3.36), the degrees of returns to scale were estimated for all observations for the six size classes for each year of the entire study period 1956–97 and are presented in Figure 3.1. Several important points are noteworthy from this figure.

First, all six size classes enjoyed fairly high IRTS for the study period 1956–97. The degrees of scale economies had decreasing and stagnant trends in all size classes during the 1956–83 period. This may

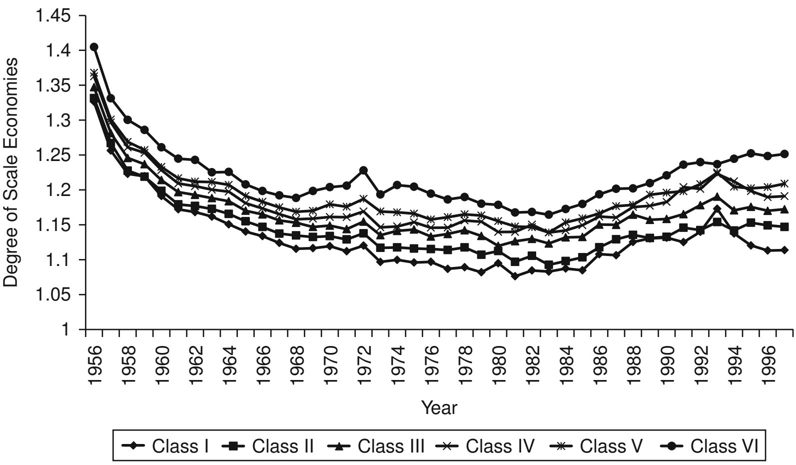

Figure 3.1 Estimates of returns to scale for 1956–97: all size classes (Tohoku)

Note: Returns to scale for each size class was estimated using eqution (3.37).

have been because smaller-scale mechanization, represented by hand-driven cultivators, prevailed all over Tohoku, even for smaller-scale farms; consequently, the degrees of "indivisibility" became smaller and smaller. However, as medium- and larger-scale mechanization – riding-type tractors, cultivators, and rice-transplanters – became popular in the early-1970s, the degrees of scale economies started increasing, for the period 1983–93, but then fell back from 1993 in all size classes; except for the largest (VI), which had an increasing trend even after 1993.

Second, it is intriguing to observe that the larger the farm the greater the scale economies for the entire study period 1956–97. For example, scale economies in size class (VI) in 1956 were as large as around 1.41, decreased to around 1.17 in 1983, and increased again to around 1.25 in 1997. On the other hand, the corresponding degrees of the smallest size class (I) were around 1.33, 1.08, and 1.11, respectively. This result implies that larger-scale farms enjoyed scale economies more than smaller-scale farms in rice production for the entire study period 1956–97. This in turn implies that the larger farms had more advantage in the production of rice: their unit costs were smaller than for smaller-scale farms.[16]

3.4.3.4 Estimates of the shadow value of paddy land

The shadow value of land was estimated using Equation (3.38) for all samples of all six size classes for the whole period 1957–97 and is presented in Figure 3.2. For the sake of comparison, we added in this figure the actual "market" land rent per 10 a of the average farm of the smallest size class (I), which was regulated by the government in some form for the entire study period 1956–97.[17] At least two important findings are worth mentioning.

First, it is very clear that the larger the farm, the larger the shadow values of land.

Second, a most significant finding is that the shadow value of land for the larger three size classes were much greater than the observed land rent. Even in the smallest size class (I), this value was much larger than the market land rent for the 1956–90 period, and even since 1990 the shadow value of land was greater than the "market" land rent (with the exception of a few years). This finding is very important when it comes to investigating the possibilities of land transfers from small- to large-scale farms in order to develop a structure which is characterized by much larger more efficient, and productive rice production.

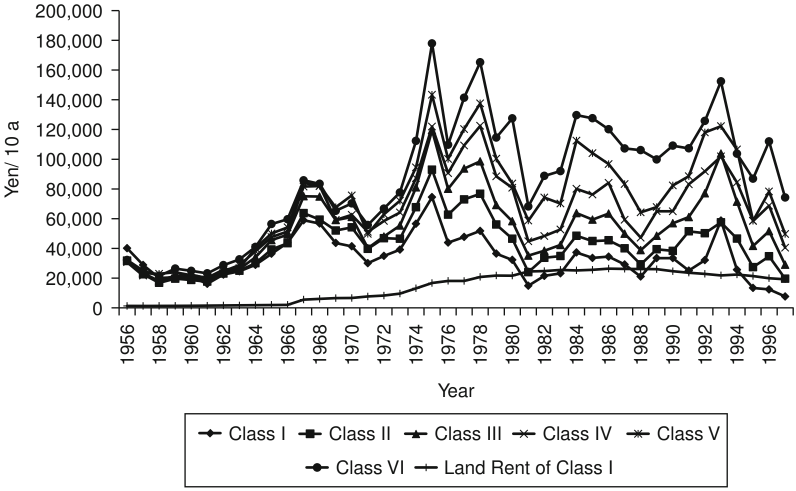

Figure 3.2 The shadow price of paddy land for all size classes and the actual land rent for class (I) for 1956–97: Tohoku

Note: The shadow value of paddy land for each size class was estimated using Equation (3.38).

3.4.3.5 Possibilities of land transfers from small- to large-scale farms

We will now try to investigate the possibilities of land movements from small- to large-scale farms based on the estimated shadow value of paddy lands. For this investigation, we will have to take into account the following small-scale farmers' behavior when it comes to making a decision of transferring their farmland to large-scale farms.

To begin with, land movements by selling and buying were limited during the whole study period 1956–97, despite the government's continuous efforts to promote land movements. One of the most important reasons for such limited transactions may be that farmers have a strong preference to possess their lands as profitable assets. It is thought that farmers have strong expectations that they could sell their land at much higher prices to be utlized as buildings, plants, highways, railroads, shopping centers, residential purposes, and so on.

Then, what about the possibilities of land movement by renting from smaller- to larger-scale farms? What economic conditions should at least be satisfied in order for small-scale farms to rent out their lands to large-scale farms? To simplify, in this subsection we will call size classes (I)

(0.3–0.5 ha) and (VI) (3.0 ha or larger) respectively small- and large-scale farms. Since more than 60% of farms in Tohoku are less than 1.0 ha, this investigation will have an important implications for achieving more efficient, more productive large-scale rice farming.

With reference to Shintani (1983), Kako (1984), Hayami (1986), and Chino (1990), this chapter proposes the following two economic norms for small-scale farms to make a decision on selling or renting out their lands to large-scale farms.

$$NormI : \frac{(w_B^{S'})^{VI}}{(w_B^{S'})^{I}} > 1$$

and

$$NormII : \frac{(w_B^{S'})^{VI}}{(FI)^{I}} > 1$$

where *FI* is "farm income" and defined as,

$$\begin{aligned} FI &= \sum_i P_i^{'} Q_i - (w_M^{'} X_M + w_I^{'} X_I + w_O^{'} X_O) - (w_L^{'} X_L^H + w_B^{'} Z_B^R) \\ &= VP^{'} - (w_L^{'} X_L^H + w_B^{'} Z_B^R), \end{aligned} \tag{3.39}$$

where the last two terms are respectively the paid wage bill to permanent and temporary-hired labor (X_L^H) and the rent paid for the rented land ($w_B^{'} Z_B^R$). That is, *FI* is a slightly modified "farm income" which accrues to the self-employed factor inputs, i.e., operator and family labor and own land.[18] It is noted here that both $w_B^{S'}$ and *FI* are estimated in terms of 1,000 yen per 10 a.

Theoretically speaking, farm income, or, more precisely, the "profits" of the *farm-firm* may in general be defined as total revenue minus total costs, which includes the costs for self-employed labor and land. In reality, however, many *farm-households* may not always count the costs for self-owned factor inputs as "costs," but rather as part of "farm income," which is in turn regarded as a part of "farm-household income."

It is noted here that *NormI* implies that, if the shadow value of land, or the "rent-bearing capacity"[19] of a the large farm, is greater than that requested by a small-scale farm, the small-scale farm will rent out its land to its larger cousin. This norm may be valid for small-scale farmers who can find better-paid off-farm jobs.

Now, we will examine the possibilities of land movement from small- to large-scale farms based on the two norms outlined above. *NormI* says that if the shadow value of land (i.e., "rent-bearing capacity") of size class (VI) farms is greater than that of size class (I) farms, then are likely

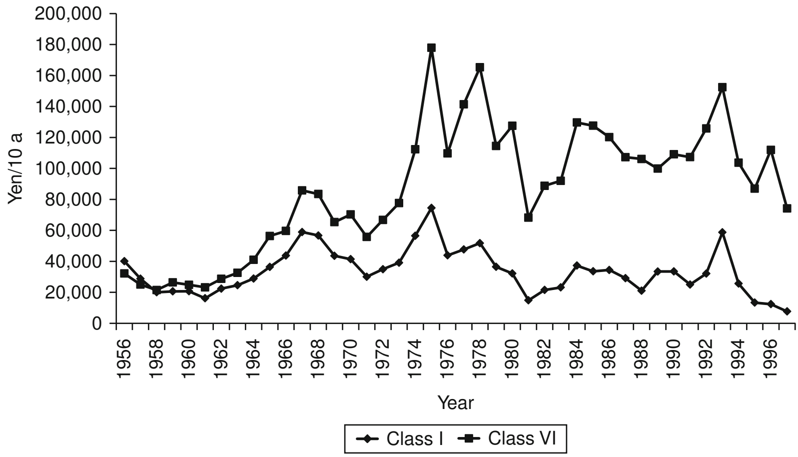

Figure 3.3 The shadow price of paddy land per 10 a of size classes (I) and (VI) for 1956–97: Tohoku

Source: Figure 3.2.

to rent out to the size class (VI) farms. According to Figure 3.3, the shadow price of land on size class (VI) farms was clearly much larger than for size class (I) farms for the entire study period 1956–97: *NormI* is absolutely satisfied for this period.

Next, *NormII* maintains that if the shadow value of paddy land on large (size class (VI)) farms is greater than the value of "farm income" accruing to family-labor paddy land on small (size class (I)) farms, then there is the possibility of land movement by renting out from small- to large-scale farms. When we look at Figure 3.4, it seems to be clear that this norm was satisfied for the period 1974–97, with the exception of 1981.

In sum, when farmers completely retire (for whatever reason) *NormII* may be more realistic when it comes to considering land movement by renting out by small- to large-scale farms. If so, we may conclude that small-scale farmers were ready, at least for the period 1974–97, to rent out their paddy lands to large-scale farms.

At this point, we will look into the actual movements of land by going back to Table 1.1 in Chapter 1. In this table, areas of land movement by (i) transfer of rights for land holdings and (ii) transfer of rights for lease are reported for selected years from 1960 to 2004, for Tohoku as well as Tofuken for reference.

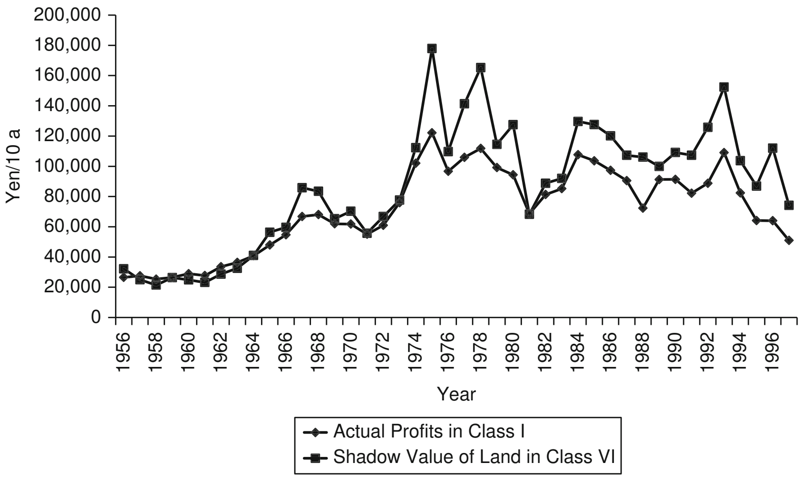

Figure 3.4 Actual amounts of variable profits per 10 a of class (I) and the shadow price of paddy land per 10 a of class (VI) for 1956–97: Tohoku

Sources: The shadow value of paddy land of class VI is from Figure 3.2. The actual profits of class I is from the Survey Report on Costs of Production of Rice, Wheat, and Barley by the MAFF, various years.

According to Table 1.1, the total renting-out area of paddy lands in the Tofuken district as a whole increased from 1980 when the Agricultural Management Reinforcement Law was inaugurated. On the other hand, land movements by transfer of rights for land holdings increased from 1990. Due largely to the latter movement, the ratio of total transferred land area to total cultivated area increased sharply from 2000; around 9 percent.

On the other hand, not only the total areas of land transfers but also the ratio of transferred to total cultivated areas in Tohoku seem to have been stagnant for the period 1970–2004, against our expectations, based on Figure 3.4.

We may argue that land transfers in Tohoku have been very inactive. Nevertheless, there must be a rational economic reason why the land transfers did not proceed smoothly, against the expectations of many agricultural economists and policy makers.

We hypothesize here that government agricultural policies – such as, rice price-supports, factor inputs-subsidies, production adjustment programs represented by set-asides, public R&E activities, and so on – may have had a significant influence on the slow and inactive transfers of farmland during the second half of the 20th century, not only in Tohoku but also in Japanese agriculture as a whole.

To test this critical hypothesis, we will here concentrate on evaluating the impacts of the four policy measures: (1) the rice price-support, (2) set-aside programs, (3) variable factor inputs-subsidies, and (4) public R&E programs, on the five economic indicators mentioned already elsewhere: (i) the supply of output (rice), (ii) the demands for variable factor inputs, (iii) the amount of variable profits, (iv) the degrees of returns to scale, and (v) the shadow value of paddy land.

3.5 Summary and concluding remarks

The major objective of Chapters 2 and 3 has been to quantitatively investigate the technology structure of rice production during the postwar period; roughly speaking, the second half of the 20th century, 1956–97. To pursue this objective, we introduced the VC and VP function frameworks in Chapters 2 and 3, respectively. The critical difference between the two models is that the VC function model treats the quantity of output (rice) as a fixed variable (in other words, the quantity of output is as an exogenous variable), while the VP function model employs the output price as an exogenous variable (that is, the quantity of output is an endogenous variable). In addition, both in Chapters 2 and 3 labor and land were defined to be quasi-fixed factor inputs, since it seems to be very difficult for the farm-firm to attain the optimal utilization of these factor inputs within the observation period (one year). Therefore, we may call both the VC function model and the VP function model short-run.

A brief summary and conclusions, based on the VC function, is already given at the end of Chapter 2. Accordingly, we will here briefly summarize the major analytical results based on the translog VP function model.

Now, a most noteworthy feature of Chapter 3 is that we have succeeded in estimating the *mutatis mutandis* elasticity of the supply of rice and the demand for variable factor inputs, both of which were fairly high in terms of absolute values. This may offer quantitative evidence that the rice price-support programs, introduced in the early-1960s, may have speedily facilitated mechanized rice production and hence increased rice supply during the entire study period 1956–97. Furthermore, we were able to estimate the degrees of returns to scale as well as the shadow values of paddy lands, which may have been intimately related to the transfer of paddy land from small- to large-scale farms, which led to more efficient and productive rice farming on highly enlarged paddy lands. Detailed interpretations and evaluations, with brief summaries of the estimated economic indicators, are offerred in the text. So, we will not repeat them here.

Instead, we will here offer the plan for the following Chapters 4 through 7.

We are going to quantitatively investigate and fully evaluate what impact the following four government policy measures had on the five economic indicators. Our estimates will be based on the translog VP function, from the viewpoint of transforming inefficient and low productive rice farms on small-scale paddy lands to more efficient and productive farms on much lager paddy lands by highly-motivated farm-firms. The four policy measures are: (1) price-support programs, (2) set-aside programs, (3) factor input subsidy programs, and (4) R&D and extension (R&E) programs. The economic indicators which we will carefully evaluate are: (i) the supply of rice, (ii) the demands for variable factor inputs – machinery, intermediate, and other inputs, (iii) the amount of variable profit, (iv) the degrees of returns to scale, (v) and the shadow value of paddy lands.

Appendix B: Variable Definitions

First of all, the sources and definitions of variables are basically the same as in Chapter 2. However, the symbol of the price of output (*Q*) is *P*. But the reader should keep in mind that *P* is also used as an abbreviation of statistical probability.

The reader should also note that the amount of variable profits is defined as *VP*. Again, VP is used as an abbreviation of the amount of variable profits. So, in order to mitigate any confusion, the author has designated variable profit used as a mathematical variable with the italic form *VP*.

Now, the nominal amount of variable profits ($VP^{'}$) was defined as total revenue minus the variable cost, which is in turn defined as the sum of the expenditures on the three categories of variable factor inputs (VC); i.e., $VC = \sum_i w_k^{'} X_k$ ($k = M, I, O$). The output revenue-variable profit share was obtained by dividing the total revenue of rice ($P^{'}Q$) by the amount of variable profits ($VP^{'}$). In addition, the quasi-fixed factor input shadow cost-variable profits shares ($R_{Zl}, l = L, B$) were obtained by dividing the quasi-fixed factor input shadow costs ($C_{Zl}^{'} = w_l^{'} Z_l$ ($l = L, B$)) by the amount of nominal variable profits (VP').

In addition, the variable factor input cost-variable profit share (R_k, $k = M, I, O$) was obtained by dividing the nominal expenditure on each category of the variable factor inputs ($w_k^{'} X_k, k = M, I, O$) by the nominal amount of variable profits ($VP^{'}$).

Part II

Impact of Agricultural Policies and Structural Transformation of the Rice Sector

The Objectives of Part II

The major objective of Part II is to extensively discuss the possibilities of agricultural structural transformation based on the estimated quantitative effects of the following four major agricultural policy instruments on the five critical economic indicators: that is, (1) rice-price support (Chapter 4), (2) set-asides (Chapter 5), (3) factor input-subsidies (Chapter 6), and (4) the public R&E programs on the five economic indicators (Chapter 7). Though repetitive, the five economic indicators are (i) the supply of rice, (ii) the demands for variable factor inputs – machinery, intermediate, and other inputs, (iii) the amount of variable profit, (iv) the degrees of returns to scale, (v) and the shadow value of paddy land.

For this objective, we claim that the VP function approach is more appropriate and relevant than the VC function approach. The most important reason for this choice is that, unlike the VC function approach, the VP function contains the price of output (rice) as an explanatory variable, which makes it possible to quantitatively estimate the effects of a change in output price on the five economic indicators, so that we may discuss the possibilities of land transfer for agricultural structural transformation due to the rice price-support programs.

Similarly, the effects of an increase in land input may indirectly offer us information on land movements from small- to large-scale farms by evaluating, though conversely, the quantitative effects of the set-aside programs.

In addition, it may be possible to quantitatively evaluate the impacts of factor input-subsidies though again indirectly, since increases in factor input-subsidies may have the same effects as declines in the real prices of the variable factor inputs. Based on the estimated results, we may evaluate the possibilities of land movements for the structural transformation from small- to large-scale farms.

Finally, it may be intriguing to quantitatively investigate the effects of the public R&E programs on the above-mentioned economic indicators. Based on the results, we may evaluate the possibilities of land transfers for larger-scale rice production.

Now, we are going to develop the procedures for challenging the above-mentioned major subjects of Part II in the following Chapters 4 through 7: that is, the quantitative investigation of the impact of changes in the four policy measures on the five economic indicators mentioned above. Needless to say, one can compute the impact of all the exogenous variables of the VP function $H(P^{'}, \mathbf{w}^{'}, \mathbf{Z}, Z_R)$ on the five economic indicators. However, Part II of this book will concentrate on evaluating the effects of the four policy instruments on the five economic indicators from the viewpoint of structural transformation of the rice-sector of the Japanese agriculture.

4

The Impacts of the Rice Price-Support Programs on the Structural Transformation of the Rice Sector

4.1 Introduction

One of the primary concerns in Japanese agriculture since the Basic Agricultural Act of 1961 has been the implementation of more efficient and productive farming on larger-scale farmlands. This concern has received even greater attention because of persistent pressure from foreign countries for the liberalization of Japanese markets, including in many senses the most important agricultural product in Japan, i.e., rice. As already seen in Chapter 1, in spite of the government's efforts to promote land movements, the transition from small- to large-scale farming has not thus far made significant progress. One major reason for this is the rapid increase in the market price of farmland, caused in large part by a strong demand for land for nonagricultural purposes such as: the construction of highways, railways, factories, and residential areas. This has given farmers a strong incentive to retain their lands as profitable assets.

The most significant feature of this chapter is that we examine the major causes of laggardly land transfers in the pursuit of large-scale efficient, productive, and profitable rice farming. Needless to say, one of the major causes for this has been high farmland prices. As shown in Table 1.3 in Chapter 1, price-support programs have been an important agricultural policy measure. Furthermore, since production levels of wheat and barley were very low during the study period 1956–97, the budget assigned to price-support programs for rice, wheat, and barley – shown in column (4) in Table 1.3 – has in fact been allocated mainly to rice. In this sense, rice price-support programs have been a critical policy instrument in post-war Japanese agriculture.

This chapter will therefore focus on the quantitative investigations of the impact of government rice price-support programs on our famous economic indicators. In particular, it will be intriguing to investigate quantitatively whether these rice price-support programs are neutral or systematically different among the various size classes. As Gardner and Pope (1978) have pointed out, consideration of the neutrality of such impacts among different size classes has important implications in size distribution. If, for example, a price-support program is found to yield higher (or even equal) rates of return to land in small-scale farms than in large-scale farms, the movement of land from small- to large-scale farms will restricted, and vice versa.

So, we will further investigate the rice price-support programs using the parameter estimates of the translog VP function model, which is most relevant analytical procedure. It is by now clear that, in the last four decades of the 20th century, the government's rice price-support programs disadvantaged rice production, by restricting the transfer of paddy lands from small- to large-scale farms and the consequent benefits of efficient production.

Many studies have been conducted to examine the impact of the price-support programs in Japanese rice agriculture. Although a few researchers have estimated the shadow value of land for Japanese agriculture (e.g., Egaitsu and Shigeno, 1983; Shigeno and Egaitsu, 1984; Kuroda, 1988a and 1988b; Kuroda, 1992; Kusakari, 1989; Kusakari, 1994), none has empirically documented the impact of price-support programs on the shadow value of farmland, or the above-mentioned four other important economic indicators.

Accordingly, this chapter may be considered the first attempt to present the influence of these programs in quantitative terms, and is expected to offer policymakers useful information on how to ease land movement in the agricultural sector.

The rest of this chapter is organized as follows. Section two presents the translog VP function-based analytical framework. Section three presents empirical results. Finally, section four provides a brief summary and conclusion.

4.2 Analytical framework

At the outset, we will elaborate on the hypothesis and describe the methodology used to assess the impact of rice price-support programs. More specifically, we elaborate our hypothesis that the government's programs have hindered the efficient development of Japanese rice farming.

On the other hand, the rapid economic growth in Japan during the post-war years, especially since the mid-1950s through to the early 1970s was accompanied by a sizable transfer of labor from the agriculture to nonagricultural sectors, mainly due to the strong demand for labor in the latter. Because of this sharp demand, labor became much more expensive compared to capital, which in turn induced a rapid mechanization and resulted in economies of scale in rice production due to the "indivisibility" characteristics of machinery input.[1]

Theoretically,[2] such mechanical (M in short hereafter) technological change has the following effects on the marginal productivity (or shadow value) of land. To take full advantage of the new technology and to achieve more efficient use of family labor and machinery, farmers who adopt the new technology want to have more paddy land. This implies that the demand (or, equivalently, marginal productivity) curve for paddy land will shift to the right, which in turn will cause an increase in the marginal productivity of farmland, since the supply of farmland is limited in the short run.

If, at the same time, price-support programs are adopted by the government, more farmers will want to add land to their farms to gain more profit. This will in turn increase the demand for land and hence raise marginal productivity. On the other hand, if the government does not adopt price-support programs, the result will be the complete opposite. Technology and scale allow farmers to produce more. The inelastic demand for rice would result in a sharp decrease in its price due to the shift to the right of the supply curve of rice. This decrease in rice price would then cause a decline in the derived demand for land, i.e., a downward shift in the marginal productivity curve of land and hence a decline in the shadow value of farmland.

This demonstrates the importance of price-support in the explanation of changes in land prices. From this theoretical explanation, one may say that price-support programs, together with M-technological change, may have played an important role in raising the price of farmland during the last four decades of the 20th century.

4.2.1 Impacts of changes in rice price on the five economic indicators

4.2.1.1 Impacts of changes in the rice price on the supply of rice

Now, the impact of changes in the price of rice (P') on the quantity of the supply of rice (Q) may be given in terms of elasticity using the same procedure employed when we derived in Chapter 3 the output supply elasticity with respect to the price of own output, as follows.

$$\frac{\partial \ln Q}{\partial \ln P'} = \varepsilon_{QQ} = \frac{\gamma_{QQ}}{R_Q} + R_Q - 1, \tag{4.1}$$

which is equivalent to the own-price output supply elasticity given by Equation (3.22) which was already derived in Chapter 3.

4.2.1.2 *Impacts of changes in the rice price on the demands for the variable factor inputs*

Second, the impacts of changes in the output price (P') on the demands for the variable factor inputs ($X_k,\ k = M, I, O$), in terms of elasticities can be obtained by,

$$\frac{\partial \ln X_k}{\partial \ln P'} = \eta_{Qk} = -\frac{\gamma_{Qk}}{R_k} + R_k,\ k = M, I, O, \tag{4.2}$$

where R_k ($k = M, I, O$) is the k-th variable factor input cost-variable profit share given in Equation (3.5) in Chapter 3. In fact, η_{Qk}'s are the elasticities of demand for the *k*-th factor input with respect to the output price as given in Equation (3.28) in Chapter 3.

4.2.1.3 *Impacts of changes in the rice price on the amount of variable profits*

Third, the impacts of changes in the output price (P') on the amount of variable profits (VP') in terms of elasticities can be obtained by,

$$\frac{\partial \ln VP'}{\partial \ln P'} = \alpha_Q + \gamma_{QQ} \ln P' + \sum_k \gamma_{Qk} \ln w'_k + \sum_l \phi_{Ql} \ln Z_l + \mu_{QR} \ln Z_R, \tag{4.3}$$

$$k = M, I, O,\ l = L, B,$$

which is equivalent to the output revenue-variable profit share (R_Q). Here, however, we are going to estimate the impacts given by Equation (4.3) using the estimated coefficients of the translog VP function (3.4) presented in Chapter 3, which are in general different from the actual output revenue-variable profit share used for the estimation of the system in Chapter 3.

4.2.1.4 Impacts of changes in the rice price on the degrees of returns to scale

Fourth, the impact of changes in the output price (P') on the degrees of returns to scale (*RTS*) in terms of elasticities can be obtained by,

$$\frac{\partial \ln(RTS)}{\partial \ln P'} = \frac{\sum_l \phi_{Ql}}{RTS}, \; l = L, B, \tag{4.4}$$

where *RTS* is given by Equation (3.36) presented in Chapter 3.

4.2.1.5 Impacts of changes in the rice price on the shadow value of land

Finally, the impact of changes in the output price (P') on the shadow value of land ($w_B^{'S}$) in terms of elasticities can be estimated by,

$$\begin{aligned}\frac{\partial \ln w_B^{'S}}{\partial \ln P'} &= \frac{\partial \ln VP'}{\partial \ln P'} + \frac{\partial \left(\frac{\partial \ln VP'}{\partial \ln Z_B} \right)}{\partial \ln P'} \left(\frac{\partial \ln VP'}{\partial \ln Z_B} \right)^{-1} \\ &= \frac{\partial \ln VP'}{\partial \ln P'} + \phi_{QB} \left(\frac{\partial \ln VP'}{\partial \ln Z_B} \right)^{-1}. \end{aligned} \tag{4.5}$$

All these five impacts caused by changes in the price of output (P') on (i) the quantity of the output supply (Q), (ii) the quantities of the variable factor demands (X_k, $k = M, I, O$), (iii) the amount of variable profits (VP'), (iv) the degrees of returns to scale (*RTS*), and (v) the shadow value of land ($w_B^{S'}$) will be estimated for all observations for all six size classes for each year of the entire study period 1956–97 and they will be shown in the form of graphs. In this way, one can visually capture differences in the magnitudes of the impacts among the different six size classes and changes in the impacts over time for the six different size classes.

4.3 Empirical results

4.3.1 Impacts of rice price-support programs on the five economic indicators

4.3.1.1 Impacts of rice price-support programs on the supply of rice

To begin with, we must admit that our procedure may be regarded as an *indirect* method for evaluating the impacts of rice price-support programs on the five economic indicators since we do not introduce in our VP function model any variable which can capture *directly* the impacts of rice price-support programs. Keeping this in mind, we will evaluate the impacts of the rice price-support programs on the five economic indicators reported in Figures 4.1 through to 4.7.

First, we will evaluate the impact of increases in the price of rice on the supply of rice (i.e., the own-price elasticities) in Figure 4.1. According to Figure 4.1, it is clear that the smaller the farm sizes, the larger the own-price elasticities of rice. In particular, the smallest size class (I) had the largest own-price supply elasticity of rice for the entire study period 1956–97. Furthermore, the own-price elasticities in all six size classes increased consistently during the entire study period 1956–97, although size classes (II), (III), (IV), (V), and (VI) had negative elasticities for the years before 1970.

The magnitudes of the own-price supply elasticities were fairly high: in the smallest size class (I), in particular, the elasticity increased from around 0.12 in 1956 to around 1.1 in 1997. These findings may indicate that the rice price-support programs played an important role in giving incentives to smaller-scale farms to stick to rice production for the entire study period 1956–97; in particular, since the early 1960s when the rice price-support programs were introduced.

In sum, the rice price-support programs implemented since the early-1960s seem to have given greater advantages and stronger incentives to smaller-scale farms than to larger-scale farms in increasing the supply

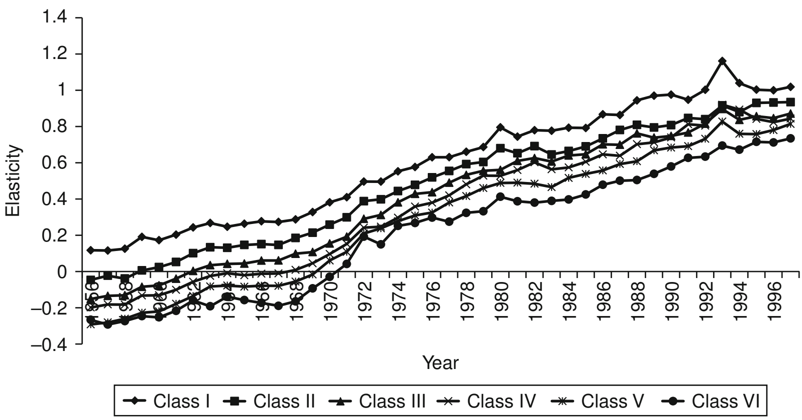

Figure 4.1 Impact of changes in the price of rice on the supply of rice for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (4.1).

of rice by persistently sticking to rice farming. We may conjecture from this finding that the rice price-support programs may have played an important role in restricting the transfer of paddy land from small- to large-scale farms.

4.3.1.2 Impacts of rice price-support programs on the demands for the variable factor inputs

To begin with, we will evaluate the impacts of changes in rice price on the demands for the three variable factor inputs, i.e., machinery, intermediate, and other inputs. Actually, the impacts expressed in terms of elasticities, are exactly the same as the demand elasticities of these three variable factor inputs with respect to the price of rice. We estimated the impacts for all observations of the six size classes for each year of the entire study 1956–97 period. The estimated impacts are shown in Figures 4.2, 4.3, and 4.4, respectively. Note here however that the estimates of the impacts for 1956 were omitted from the figure because of an unusual value obtained for size class (IV). Now, several findings are noteworthy from these figures.

First, as seen in Figure 4.2, the impacts of changes in the price of rice on the demand for machinery input were positive and had increasing trends in all six size classes for the study period 1956–97, although there were sharp changes in the amount of impact in size classes (III), (IV),

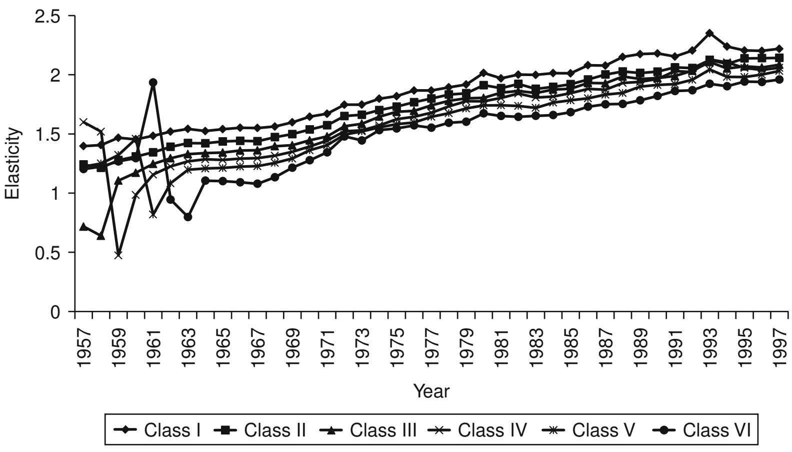

Figure 4.2 Impact of changes in the price of rice on the demand for machinery input for 1957–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (4.2).

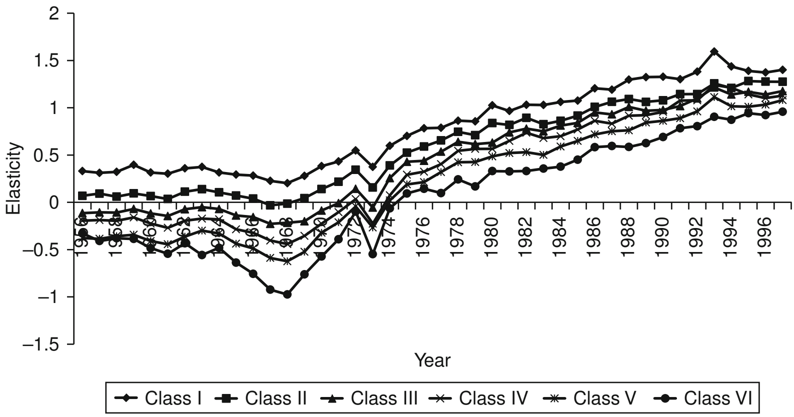

Figure 4.3 Impact of changes in the price of rice on the demand for intermediate input for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (4.2).

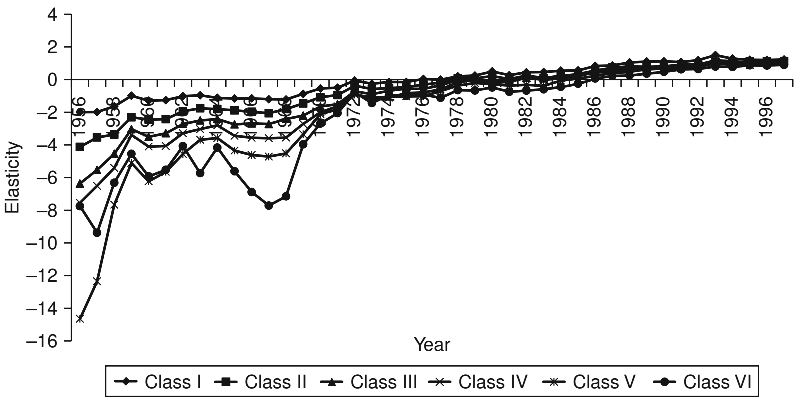

Figure 4.4 Impact of changes in the price of rice on the demand for other input for 1956–97: all size classes (Tohoku)

Note The impact for each size class was estimated using Equation (4.2).

(V), and (VI) for the 1957–64 period. In addition, it is clear that the smaller the size class, the greater the impact for the 1964–97 period. The elasticities in all six size classes were greater than unity on average in all six size classes for the 1964–97 period: farms in all six size classes were fairly responsive to changes in the price of rice for the demand for machinery input. This in turn implies that rice price-support programs helped to speed up “M innovations” for all six size classes during the last four decades of the 20th century.

Second, according to Figure 4.3, the impacts of changes in the price of rice on the demand for intermediate input were all positive in size classes (I) and (II) for the entire study period 1956–97. However, against our expectation, the impacts were negative in size classes (III), (IV), (V), and (VI) for the period 1956–74. At present, it is difficult for us to give a reasonable explanation for this phenomenon. However, for the period 1975–97, the impacts in all size classes were positive and had increasing trends as in the other size classes. Furthermore, it is very clear from Figure 4.3 that, between 1975 and 1997, the smaller the size class, the greater the impact. This finding implies that farms in all size classes were fairly responsive in the demand for intermediate input to increases in the price of rice during the 1975–97 period. It in turn implies that the rice price-support programs encouraged farms to utilize more and more intermediate inputs like chemical fertilizers, agri-chemicals, and seeds, which induced farmers to introduce advanced “bio-chemical (BC in short hereafter) innovations”, in particular, for the period 1975–97.

Third, again, against our expectation, the impact of changes in the price of rice on the demand for other input were negative for the period 1956–1977 in all size classes (see Figure 4.4). Although the impacts became positive but the magnitudes were very small in size classes (I) and (II) for the period 1978–97, the impacts in size classes (III), (IV), (V), and (VI) were still negative or close to zero for the period 1978–86. The impacts finally became positive overall between 1986 and the end of the 1990s. Recall here that other input consists of expenditure on farm buildings and cost of land improvement and water. It is rather easily imaginable that the impact of changes in rice price on these factor inputs may have been small since these items have a rather strong nature of fixed factor input, instead of the variable inputs mentioned elsewhere. However, it is difficult to give a reasonable interpretation on the strong negative impacts of rice price changes on other input, especially in larger-size classes.

Finally, we may say that the most intriguing and important feature in the present subsection is the finding from Figures 4.2 and 4.3 that, for the two variable factor inputs, i.e., machinery and intermediate inputs, the smaller the farm size, the greater the impact of increases in the price of rice. Indeed, the smallest size class (I) enjoyed the most advantageous fruit, given by increases in the price of rice due to the rice price-support programs. This in turn implies that the rice price-support programs encouraged strongly small-scale rice farms to apply more "M" and "BC" innovations to produce and increase the supply of rice, which may have played an important role in restricting land movements from small- to large-scale farms.

4.3.1.3 Impacts of rice price-support programs on the amount of variable profits

The impact of changes in the price of rice on the amount of variable profits were estimated in terms of elasticity using Equation (4.3) for all samples of the six size classes for the study period 1956–97 and are presented in Figure 4.5. As a matter of fact, the impact is equivalent to the output revenue-variable profit shares of rice production. At least, two findings are noteworthy from Figure 4.5.

First, according to Figure 4.5, the impact of changes in the price of rice in terms of elasticity were fairly large in all six size classes; from around 0.7 in 1956 (size classes (V) and (VI)) to around 2.21 in 1997 (size class (I)). Furthermore, there was an increasing trend in all size classes for the entire 1956–97 period, which indicates that rice price-support programs played an important role in increasing the variable profits of farms in all size classes.

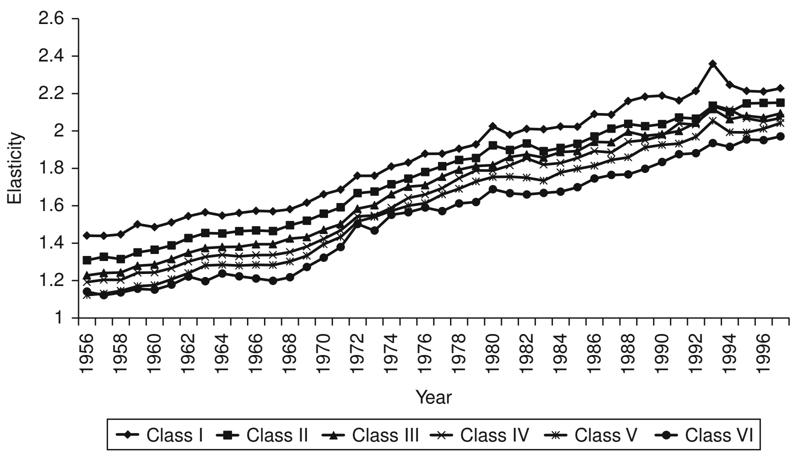

Figure 4.5 Impact of changes in the price of rice on the variable profits for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (4.3).

Second, we observe very clearly that the smaller the farm size, the greater the effects of increases in the price of rice on the variable profits for the entire period 1956–97: the smallest size class (I) enjoyed the greatest benefit from price increases. This in turn may have worked in the direction of limiting transfers of paddy lands from small-scale to large-scale farms for the entire study period 1956–97.

4.3.1.4 Impacts of rice price-support programs on the degrees of returns to scale

Using Equation (4.4), the impact of changes in the price of rice on the degrees of returns to scale (*RTS*) was estimated. The results are presented in Figure 4.6. At least two findings are noteworthy.

First, we observe that the impacts in terms of elasticity were negative in all six size classes. This can be interpreted as follows. An increase in the price of rice will induce farmers to produce more rice, indicating that the quantity of rice production will get closer to the minimum efficient output scale (*MEOS*) of the average cost curve. This will in turn lead to a reduction in the degree of returns to scale in rice production since the ratio of the average to marginal costs ($AC/MC = RTS$) will approach unity.

Second, it is clear from Figure 4.6 that, in absolute terms, the smaller the size class, the greater the impact of changes in the price of rice on *RTS*. This implies that, although the AC/MC ratios come closer to unity

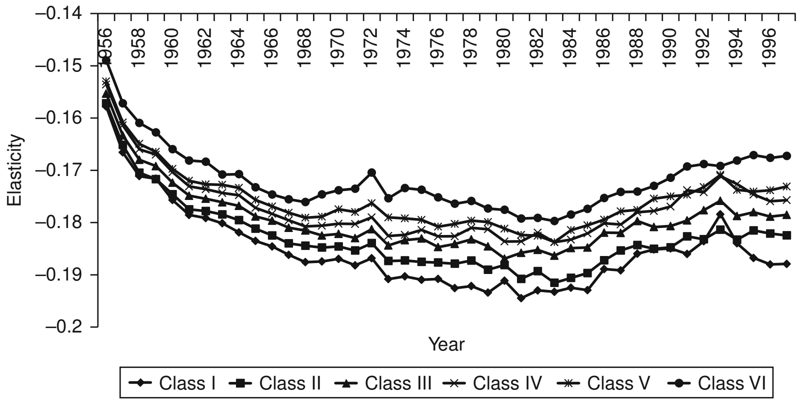

Figure 4.6 Impact of changes in the price of rice on the degrees of returns to scale for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (4.4).

in all six size classes, the speed of approaching the *MEOS* by smaller-scale farms is faster than that of larger-scale farms. This indicates that the differentials in the degrees of scale economies between smaller- and larger-scale farms may shrink, which will increase the possibility of transferring paddy lands from small- to large-scale farms.[3]

However, we should at this point recall that all the impacts of the rice price support programs on (i) the quantity of the rice supply, (ii) the quantities of the variable factor demands, (iii) the amount of variable profits, and (v) the shadow value of land (which will be interpreted immediately after this subsection) were restrictive in transferring paddy lands from small- to large-scale farms. As a result, with regard to paddy land movements, the sum of the negative effects on these four economic indicators totally overwhelmed the positive effect of the rice price support programs on (iv) the degrees of returns to scale.

4.3.1.5 Impacts of rice price-support programs on the shadow value of land

The impact of changes in the price of rice on the shadow value of land was estimated using Equation (4.5) for all samples in the six size classes for the study period 1956–97. The results are presented in Figure 4.7. Two important findings emerge.

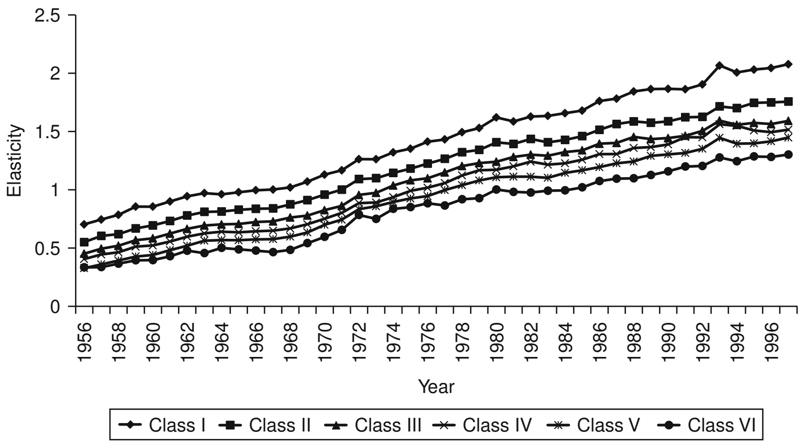

Figure 4.7 Impact of changes in the price of rice on the shadow value of paddy land for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (4.5).

To begin with, according to Figure 4.7, changes in the price of rice had a considerably strong and increasing impact on the shadow value of land in all six size classes for the entire study period 1956–97. Furthermore, the impact had a clear increasing trend in all size classes over the study period. The degrees of elasticity ranged from around 0.3 in 1956 (size class (VI)) to around 2.1 in 1997 (size class (I)). This implies that, for example, a one percent increase in rice price increased the shadow value of land by almost 2.1 percent in 1997, i.e., more than double.

In addition, we observe also very clearly that the smaller the size class, the greater the impact for the entire period. This finding again indicates that the rice price-support programs may have had a negative effect on paddy land transfers by raising the shadow relative value of small-scale farms, during the whole study period 1956–97.

4.4 Summary and concluding remarks

This chapter has estimated the single-product translog VP function, with labor and land being the quasi-fixed factor inputs for the rice sector in Tohoku for the period 1956–97. Based on the parameters reported in Table 3.1, we have estimated and evaluated the impacts of rice price-support on (i) the supply of rice, (ii) the demand for variable factor inputs, (iii) the amount of variable profit, (iv) the degrees of returns to scale, and (v) the shadow value of paddy land.

Before going further to summarize the empirical results, we would like to mention just one important finding related to the estimated shadow value of paddy land which has been considered to be a key factor for land movements from small- to large-scale farms for more efficient and productive rice farming.

We found through the empirical estimation of the shadow value of paddy lands that small-scale farms are willing to transfer their farmlands by renting them out to large-scale farms; at least, for the period 1974–97. As a result of this finding, we have put emphasis on treating the farm (exactly speaking, the "firm-household complex" [Maruyama, 1984]) as the "farm-household" instead of the "farm-firm". The "costs" of labor and land are basically counted as part of the costs for the "farm-firm". However, those "costs," which accrue to family-owned labor and land may be considered to be part of household income for the "farm-household". Thus, in order to examine the possibilities of land transfers from small- to large-scale farms, this narrowly defined "farm income" of the small-scale farm should be compared to the shadow value of land (or, "rent-bearing capacity") of the large-scale farm. When this norm was applied to our case, the shadow value of paddy land of the large-scale farm overwhelmed the "farm income" of the small-scale farm for the period from 1974 until the late-1990s. This indicates that many small-scale rice farms seem to have been ready to transfer their paddy lands to large-scale rice farms in the last quarter of the 20th century (in Tohoku, as well as Japan as a whole).

In reality (as shown in Table 1.1), however, the land movements in Tohoku were considerably inactive against our expectation based on the above empirical findings. We then hypothesized that government agricultural policies, in particular, such as the rice price-support, may have been intimately related to the lack of land transfers in Tohoku.

Consequently, we investigated quantitatively the impact of the rice price-support programs on the five economic factors: (i) rice supply, (ii) input demand (iii) profits, (iv) returns to scale, and (v) the shadow value of paddy land. We found in almost all examinations that the rice price-support programs yielded were most advantageous to small-scale farms. Based on these empirical findings, we may conjecture that the rice price-support programs may have caused the slow transfer of farmland from small- to large-scale farms during the last three to four decades of the 20th century in Tohoku.

We may conclude, based on these findings, that in order to drastically change the existing structure of small-scale inefficient farming to that of much larger-scale efficient farming, the government should reconsider its rice price-support programs and give stronger incentives to larger-scale farms.

5
Impact of the Set-Aside Programs on the Agricultural Structural Transformation of the Rice Sector

5.1 Introduction

As seen in the previous chapter, rice price-support programs since the early 1960s gave farmers in all size classes strong incentives to stick to producing rice on all paddy lands throughout Japan, indicating an enlarged supply of rice. On the other hand, the consumption of rice per person per year began to decrease simultaneously, not only due partly to the increased price of rice, but mainly due to a rapid "westernization" of food consumption patterns in Japan: bread instead of rice, meats, vegetables, and fruit. This happened because of an increase in income per capita thanks to overall rapid economic growth; in particular, in the nonagricultural sectors from around the mid-1950s to the early 1970s.

These economic conditions naturally caused an oversupply of rice and a big gap beween the consumer and producer prices of rice, which in turn resulted in a tremendous debt in the government budget for rice production. So, the government sold rice to consumers at a lower price than that levied by farmers, causing so-called "negative spreads" in the rice market. This resulted in a huge deficit every year, right after the introduction of price-support programs in the early 1960s; from around 500 billion to as much as 1 trillion yen every year for the period – roughly, 1962–1968.[1] The MAFF had to introduce a set-aside program in 1969 for the first time in the Japanese history of rice production.

Since then, the set-aside area has trended upwards, with some fluctuations over time as shown in Figure 1.4 of Chapter 1. The areas given up rice production because of the set-aside programs were around 500 thousand ha per year during the period of the early-1970s, then, gradually increased up to around 800 thousand ha during the late-1980s through the early-1990s, reaching almost 1 million ha during the late-1990s through to the early-2000s. This means that the areas of paddy fields by the enforcement of the set-aside programs almost doubled in the 33-year period. Due mainly to the set-aside programs, the total arable land area of paddy fields decreased from around 3.5 million ha in 1970 to around 2.5 million ha in 2003, i.e., a decrease of as large as one million ha over the 33 years. We will now look at the ratio of set-aside paddy field to the total area of arable paddy field in the same Figure 1.4. This ratio was less than 20 percent for the ten years of the 1970s, around 20 to 21 percent for the period 1980–86, jumped to 28 to 30 percent for the period 1987–1991, decreased somehow for the period 1992–97, but after then increased sharply to 37 to 40 percent for the period 1998–2003.

We also observe in Figure 1.4 the area changes in the set-aside paddy fields were transferred to production of other crops: wheat, soybeans, vegetables, and so forth. It appears that, except for the period 1974–78, the gap between the set-aside paddy area and transferred area became larger and larger as time passed. This finding may be confirmed by casually looking at the ratio of transferred to set-aside areas drawn in Figure 1.4. The ratio used to be around 90 percent for the period 1974–83, but since then it has steadily decreased from 1984 through to 2003, except for the two-year period 1996–1997 when some increases were observed. It became as low as 60 percent for the early-2000s. This may have caused a tremendous expansion of abandoned farmland all over Japan. It should be noted here that restoring given-up paddy fields to their original state may require a huge amount of re-investment. Therefore, we may infer from these observations that the set-aside programs for Japanese agriculture's most important product, i.e., rice, may have exerted great influence, not only on rice production, but also on production of all other agricultural products.

In this chapter as in Chapter 4 we will pay close attention to quantitative investigations of the impact of the government set-aside programs on various economic indicators which are intimately related to structural transformation in agricultural production. These economic indicators are exactly the same as in Chapter 4: i.e., (i) the supply of rice, (ii) the demands for variable factor inputs, (iii) the amount of variable profits, (iv) the degrees of returns to scale, and (v) the shadow value (equivalently, marginal productivity or "rent-bearing capacity") of paddy land.

To pursue this objective, we will employ the parameter estimates of the single-product translog VP function estimated in Chapter 3. Using these estimates, we will develop formulas to quantitatively investigate the impact of set-aside programs on the five economic indicators. Based on the estimated results, we may offer a brief conclusion at this point. That is, the set-aside programs may have brought out most serious difficulties in rice production, in the sense that such policies may have restricted the transfer of paddy lands from small- to large-scale farms for more efficient rice farming. The details of the evaluations follow in the next section.

It may be useful to review the previous studies which challenged us to investigate the impact of set-aside programs on Japanese rice production. Hasebe (1984) investigated the impact of the set-aside programs on land movement. Kusakari (1989) found that the "given-up income" due to the set-aside programs was greater on larger-scale farms than on smaller-scale farms. Ito (1993) examined the programs' impact on rice income and demand for rented land. Kondo (1991, 1992) investigated their effect on rice income and land rent. So, although these researchers have estimated the shadow value of paddy land for Japanese agriculture, none has empirically documented the impact of set-aside programs on the shadow value of paddy land, as well as the four other important economic indicators mentioned above.

So, this chapter in this sense may be considered the first attempt to present such influences in quantitative terms and is expected to offer policymakers useful information on how to ease land movements in the agricultural sector, e.g., either by modifying or by throwing away the set-aside programs.

The rest of this paper is organized as follows. Section two presents the VP function-based analytical framework. Section three explains the data and estimation procedure. Section four presents empirical results. Finally, section five provides a brief summary and conclusion.

5.2 Analytical framework

The major objective of this chapter is to quantitatively investigate the impact of the rice set-aside policies on the five economic indicators. In this section we will develop the appropriate formulas.

Recalling the features of the VP function employed in this chapter, one can compute the impact of all the exogenous variables of the VP function of this chapter, i.e., $H(P^{'}, \mathbf{w}^{'}, \mathbf{Z}, Z_R)$, on the five economic indicators. However, in the following subsections we will concentrate on the five key indicators.

Here, the impacts will be expressed in terms of elasticities, which easily capture the effects of changes in the quantity of land input (Z_B) on the five economic indicators.

However, we do not have any variable in our VP function which can directly capture the impact of set-asides on the five economic indicators. So, we will use the indirect method laid out in Chapter 4: we will assume that the effect of a decrease in paddy land (Z_B) is equivalent to that of a decrease in paddy land due to a set-aside. Accordingly, it is possible to capture the impacts of a reduction of paddy land, since the planted area (Z_B) is used as a quasi-fixed factor input in the VP function.

5.2.1 Impacts of changes in the planted area of paddy land on the five economic indicators

5.2.1.1 Impacts of changes in the planted area of paddy land on the supply of rice

First, the impact of changes in the planted area of paddy land (Z_B) on the supply of rice (Q) in terms of elasticities can be estimated by,

$$\frac{\partial \ln Q}{\partial \ln Z_B} = \varepsilon_{QB} = \frac{\phi_{QB}}{R_Q} + \frac{\partial \ln VP'}{\partial \ln Z_B}, \tag{5.1}$$

which is equivalent to the output supply elasticity with respect to land input (Z_B).

5.2.1.2 Impacts of changes in the planted area of paddy land on the demands for variable factor inputs

Second, the impact of changes in Z_B on the demands for the variable factor inputs ($X_k,\ k = M, I, O$) can be given by,

$$\frac{\partial \ln X_k}{\partial \ln Z_B} = \eta_{kB} = -\frac{\mu_{kB}}{R_k} + \frac{\partial \ln VP'}{\partial \ln Z_B}, \quad k = M, I, O, \tag{5.2}$$

which are equivalent to the variable factor demand elasticities with respect to Z_B.

5.2.1.3 Impacts of changes in the planted area of paddy land on the amount of variable profits

Third, the impacts of changes in Z_B on the amount of variable profits (VP') in terms of elasticity can be given by Equation (5.3) below,

$$\frac{\partial \ln VP'}{\partial \ln Z_B} = \beta_B + \phi_{QB} \ln P' + \sum_k \phi_{kB} \ln w'_k + \sum_h \delta_{hB} \ln Z_h + \mu_{BR} \ln Z_R, \quad k, n = M, I, O,\ h = L, B. \tag{5.3}$$

The term $\partial \ln VP^{'}/\partial \ln Z_B$ may be called as the "shadow land cost-variable profit share" of paddy land input (Z_B) which can be obtained using the estimated parameters of the *VP* function (3.4) in Chapter 3: refer to Equation (3.6).

5.2.1.4 Impacts of changes in the planted area of paddy land on the degrees of returns to scale

Fourth, the impacts of changes in Z_B on the degrees of returns to scale (*RTS*) in terms of elasticities can be obtained by,

$$\frac{\partial \ln(RTS)}{\partial \ln Z_B} = \frac{\sum_l \phi_{kl}}{RTS}, \quad k = M, I, O, \ l = L, B. \tag{5.4}$$

5.2.1.5 Impacts of changes in the planted area of paddy land on the shadow value of land

Finally, the impacts of changes in Z_B on the shadow value of land ($w_B^{S'}$) in terms of elasticities can be obtained by,

$$\frac{\partial \ln w_B^{S'}}{\partial \ln Z_B} = \frac{\partial \ln VP^{'}}{\partial \ln Z_B} - 1 + \frac{\partial\left(\frac{\partial \ln VP^{'}}{\partial \ln Z_B}\right)}{\partial \ln Z_B}\left(\frac{\partial \ln VP^{'}}{\partial \ln Z_B}\right)^{-1}$$

$$= \frac{\partial \ln VP^{'}}{\partial \ln Z_B} - 1 + \delta_{BB}\left(\frac{\partial \ln VP^{'}}{\partial \ln Z_B}\right)^{-1}. \tag{5.5}$$

All these impacts caused by changes in the planted area of paddy land (Z_B) on the output supply (Q) and variable factor input demands (X_k, $k = M, I, O$), the amount of variable profits ($VP^{'}$), the degrees of returns to scale (*RTS*), and the shadow value of land ($w_B^{'S}$) will be estimated for all observations for all six size classes for each year of the entire study period 1956–97 and they will be shown in the form of graphs.

5.3 Empirical results

5.3.1 Impact of the set-aside programs on the five economic indicators

We must admit, though, that this is an *indirect* procedure since it does not introduce the VP function model any variable which can capture *directly* the impacts of the set-aside programs. However, we believe that we can evaluate at least *indirectly* the impact of the set aside programs on the five economic indicators of rice production in post-war Japan by quantitatively investigating the impacts of changes in planted area of paddy land on the five economic indicators.

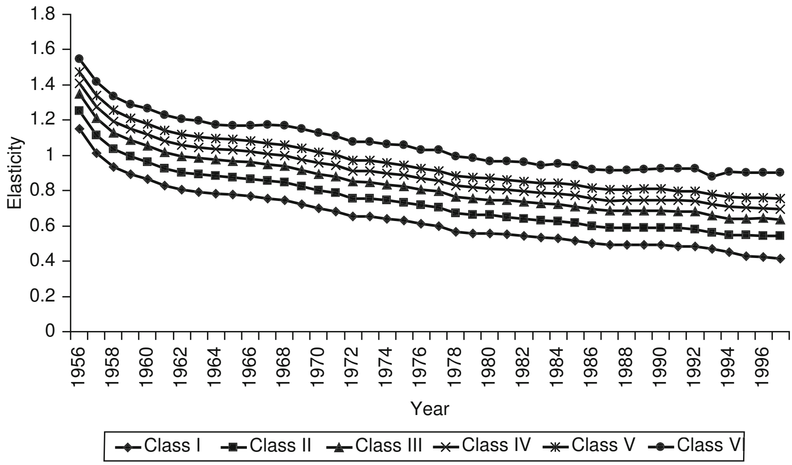

Figure 5.1 Impact of changes in the paddy planted area on the supply of rice for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (5.1).

5.3.1.1 Impacts of changes in the set-aside programs on the supply of rice

Now, we will evaluate the impacts of the set-aside programs on the quantity of rice supply by examining the impacts of changes in the planted area of paddy land (Z_B) on the supply of rice estimated using Equation (5.1). Figure 5.1 presents the estimates of the impact of changes in the planted area on the supply of rice. Several intriguing findings are worth mentioning based on this figure.

First, we will evaluate the impact of changes in Z_B on the supply of rice. According to Figure 5.1, it is clear that the larger the farm sizes, the larger the impacts of increases in the areas of paddy lands on the supply of rice. In particular, the largest size class (VI) had the largest impact of changes in Z_B for the entire period 1956–97; the magnitudes of impacts in terms of elasticity ranged from around 1.55 (in 1956) to around 0.92 (in 1997). This implies that a 10 per cent increase in the planted area of paddy land will increase the quantity of the supply of rice by around 9.2–15.5 percent.

Second, though the trends in all six size classes were consistently downward, larger sizes had greater impact on changes in paddy lands, and hence on the supply of rice for the entire study period 1956–97. This indicates that reductions in the planted area of paddy land due to the government set-aside programs will give the most severe negative impact on the supply of rice in the largest size class (VI); on the other hand, the smallest size class (I) farms will incur the least severe damage. It is not difficult to imagine that such severe set-aside programs, e.g., more than 20–30% set-asides every year since the 1980s, may have given strong negative incentives to, in particular, large-scale farmers who sought to engage in larger and more efficient farming. Based on such findings, we may assert that the set-aside programs implemented since 1969 may have had strong negative effects on transferring paddy lands from small- to large-scale farms during the period under question: which is to say, 1969–97.

5.3.1.2 Impacts of the set-aside programs on the demands for variable factor inputs

In this subsection, we will evaluate the impacts of changes in the planted area of paddy land (Z_B) on the demands for the variable factor inputs ($X_k,\ k = M, I, O$) estimated using Equation (5.2). As a matter of fact, the impacts expressed in terms of elasticity are exactly equivalent to the demand elasticities of the variable factor inputs with respect to land input. We estimated the impacts for all observations of the six size classes for each year of the entire 1956–97 period. The impacts expressed in terms of elasticity are shown in Figures 5.2, 5.3, and 5.4, respectively,

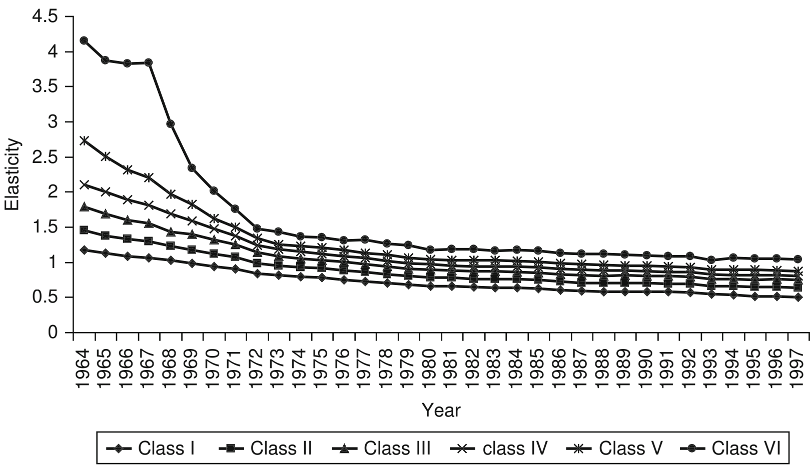

Figure 5.2 Impact of changes in the paddy planted area on the demand for machinery input for 1964–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (5.2).

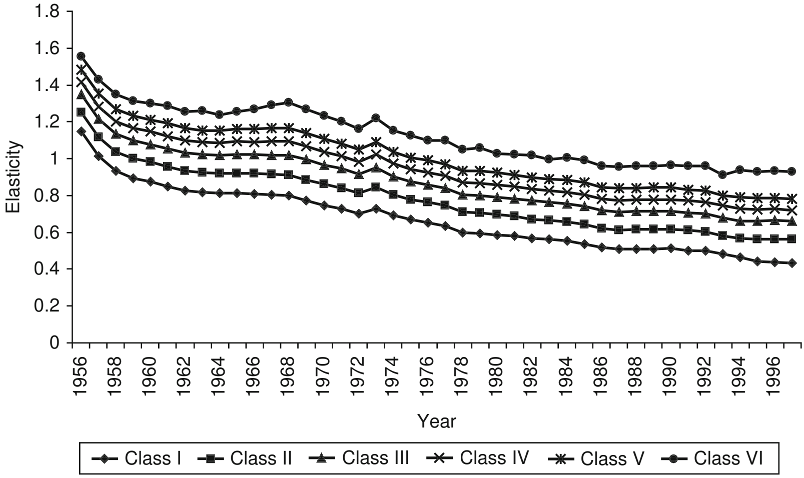

Figure 5.3 Impact of changes in the paddy planted area on the demand for intermediate input for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (5.2).

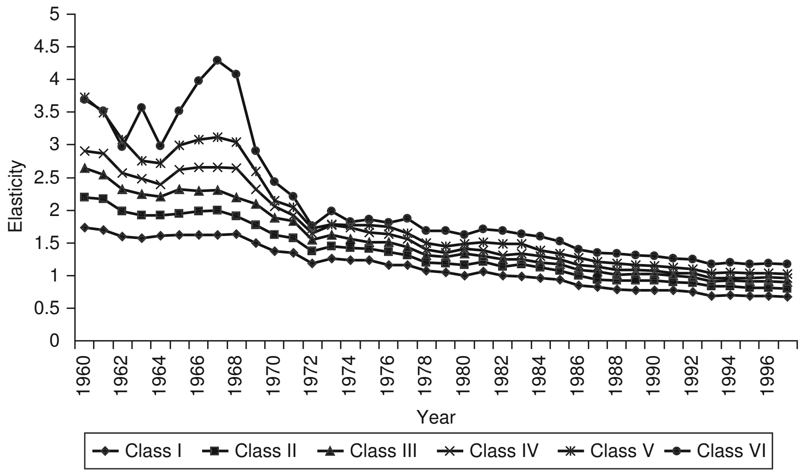

Figure 5.4 Impact of changes in the paddy planted area on the demand for other input for 1960–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (5.2).

for machinery, intermediate input, and other input. Several findings are noteworthy from these figures.

To begin with, according to Figure 5.2,[2] the impacts of changes in Z_B on the demand for machinery input X_M were positive and had consistent decreasing trends in all six size classes for the study period 1956–97.

According to Figure 5.2, the demand elasticities for machinery input X_M with respect to Z_B were rather high, in particular, in larger-scale farms, which indicates that enlargements of paddy lands required a lot of machinery input during first-stage smaller-scale mechanization – around the mid-1950s. As a large number of farms purchased smaller-scale machinery, the demand elasticities (or the impacts) with respect to land input sharply declined until 1973. Since then, the decreasing trends in all size classes became much milder towards the end of the 1990s. As a matter of fact, this period, i.e., from the early-1970s through the 1990s, is characterized by medium- and larger-scale mechanization, as mentioned earlier. Though much lower compared to those during the earlier period, the impacts of increases in paddy lands were fairly large; the elasticities of machinery demand with respect to paddy land input in the largest size class (VI) ranged from around 1.45 (in 1973) to around 1.1 (in 1997), while those even in the smallest size class (I) ranged from around 0.8 (in 1973) to around 0.5 (in 1997). In more detail, Figure 5.2 indicates that farms in all size classes were fairly responsive to changes in land input for the demands for machinery input. Furthermore, we observe clearly in Figure 5.2 that the larger the farm size, the larger the impact. This in turn implies that the set-aside programs which reduced substantially the planted areas for rice production may have restricted the speed of "mechanical (M) innovations" for all six size classes, in particular, for large-scale farms.

Second, Figure 5.3 shows that the impacts of changes in Z_B on the demand for intermediate input X_I were all positive for all six size classes for each year of the entire study period 1956–97. The impacts estimated using Equation (5.3) are equivalent to the demand elasticities of intermediate input with respect to land input (Z_B). According to Figure 5.3, the impacts in terms of elasticities were positive but had steady decreasing trends over time for the entire study period in all six size classes. This finding indicates that farms in all size classes had positive responses to an increase in land input in utilizing more intermediate input such as fertilizers, agri-chemicals, feed, and so forth to increase the quantity of the supply of rice.

In addition, it is very clear that the larger the size classes, the greater the impact of increases in paddy land on the demand for intermediate input; for example, the impact in the largest size class (VI) ranged from around 1.58 (in 1956) to around 0.95 (in 1997), while in the smallest size class (I), the impact ranged from around 1.15 (in 1956) to around 0.42 (in 1997), somewhat smaller compared to those in size class (VI). This finding may indicate that the set-aside programs which reduced the planted areas of rice limited the development and introduction of "BC" innovations for all six size classes; the negative effects on the introduction as well as application of BC-technologies were more serious against larger-scale than smaller-scale farms.

Third, the impacts of changes in Z_B on other input X_O are presented in Figure 5.4 for all observations of all six size classes. However, because of some unusual estimates in larger size classes (V) and (VI) for the 1956–59 period, the estimates of all six size classes for this period were dropped from this figure. Now, Figure 5.4 shows a similar picture as in the case of the demand for machinery input. That is, (i) the impacts were all positive in all six size classes for the study period 1960–1997; (ii) the impacts had decreasing trends in all six size classes; (iii) however, the magnitudes of the impacts in terms of elasticities were in general considerably larger than those for machinery and intermediate inputs; and (iv) the larger the farm sizes, the larger the impacts for the period 1960–97.

In sum, the impact of increases in the planted areas of paddy land on the demand for variable factor inputs – i.e., machinery, intermediate, and other inputs, estimated in terms of elasticity – were all positive in all six size classes for the entire study period 1956–97. Above all, we have found that the larger the size classe, the larger the impact. This means that the set-aside programs which forced farmers to reduce the planted areas of paddy lands had considerably strong negative impacts on promoting the M- and BC-innovations in rice production. In particular, the set-aside programs had strongest negative impacts on large-scale farms, meaning strong negative effects against the movements of promoting larger-scale and more efficient farming on larger-scale farms.

5.3.1.3 Impacts of the set-aside programs on the amount of variable profits

Using Equation (5.3), the impact of changes in paddy land Z_B on the nominal amount of variable profits VP' in terms of elasticities was estimated for each observation in each of all six size classes for each year of the study period 1956–97 and presented in Figure 5.5. As is clear from Equation (5.4), $\partial \ln VP' / \partial \ln Z_B = (\partial VP' / \partial Z_B) \times (Z_B / VP')$. This may

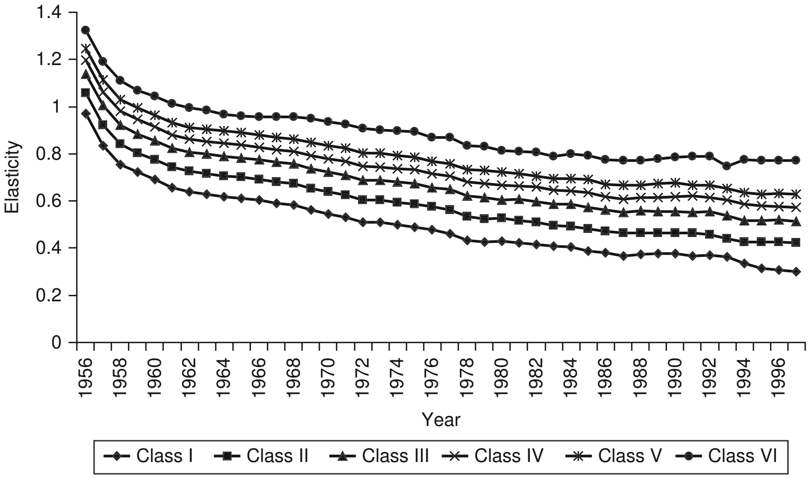

Figure 5.5 Impact of changes in the paddy planted area on the variable profits for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (5.3).

be called the "land shadow cost-variable profit share". Several intriguing findings emerge from Figure 5.5.

First of all, as seen in Figure 5.5, the impacts of Z_B on the amount of variable profits were positive in all six size classes for the entire 1956–97 period. More specifically, however, the impacts had steady decreasing trends in all six size classes; for example, the impacts in the smallest size class (I) ranged from around 0.95 (in 1956) to 0.3 (in 1997); on the other hand, the impacts in the largest size class (VI) ranged from around 1.33 (in 1956) to around 0.78 (in 1997). This finding in turn implies that reduction in the planted area for rice due to the set aside-programs will rather steadily reduce the amount of variable profits in all six size classes.

Next, as clearly seen in Figure 5.5, the larger the farm size, the larger the impact of increases in paddy land on the amount of variable profits. Conversely speaking, the larger the farm size, the greater the decrease in the amount of variable profits if the planted areas of paddy lands are reduced. From this logic, we may infer that the set-aside programs may have caused greater damage to larger-scale farms than to smaller-scale farms, which may have reduced the differentials in the amounts of variable profits among different size classes. This in turn played an important role in limiting transfers of paddy lands from small- to large-scale farms during the entire study period 1956–97.

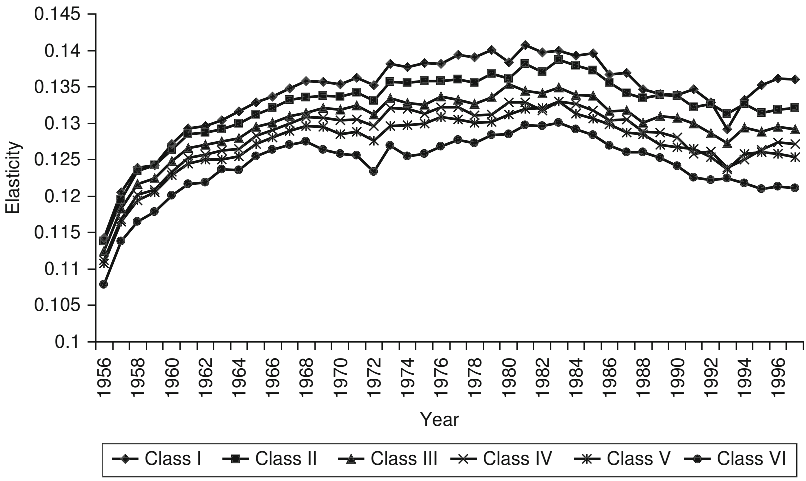

Figure 5.6 Impact of changes in the paddy planted area on the degrees of returns to scale for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (5.4).

5.3.1.4 Impacts of the set-aside programs on the degrees of returns to scale

The impacts of changes in the planted area of paddy lands (Z_B) on the degrees of returns to scale (*RTS*) was estimated in terms of elasticities using Equation (5.4) for all samples of all six size classes for each year of the entire study period 1956–97 and they are presented in Figure 5.6. At least, two important findings are noteworthy out of this figure.

First of all, with a glance at Figure 5.6, it is clear that the impact in all six size classes increased from 1956 to 1983. However, since 1983 this trend decreased, until 1993, and since then it increased trends towards the late-1990s, except for the largest size class (VI). This finding may indicate that the set-aside programs which reduced the planted areas of paddy lands decreased scale economies in all size classes for the entire study period 1956–97; though, having decreased until 1983, the impact subsequently increased.

Next, it is very clear from Figure 5.6 that the smaller the size, the larger the impact. This means that the introduction of the set-aside programs reduced scale economies in smaller-scale farms more sharply than for larger-scale farms, resulting in decreases in marginal scale economies between smaller- and larger-scale farms, which suggests that the set-aside programs may have promoted the transfer of paddy lands from smaller- to larger-scale farms during the study period, in particular, for the period 1969–97.[3]

Here again, however, we should recall that the impact of the set-aside programs on (i) the quantity of the rice supply, (ii) the quantities of the variable factor demands, (iii) the amount of variable profits, and (v) the shadow value of land (which will be interpreted immediately after this subsection) restricted the transfer of paddy lands from small- to large-scale farms. So, the total negative effects on these four economic indicators totally overwhelmed the positive effect of the set-aside programs on (iv) the degrees of returns to scale.

5.3.1.5 Impacts of the set-aside programs on the shadow value of land

The impacts of changes in the planted area of paddy lands Z_B on the shadow value of land $w_B^{\prime S}$ in terms of elasticity were estimated using (5.5) for all samples of all six size classes for each year of the entire study period 1965–97 and are presented in Figure 5.7. Before evaluating the impacts presented in this figure, we will look back upon the estimates of the shadow values of land presented in Figure 3.2 in Chapter 3. Recall that we observed in Figure 3.2 that (i) the larger the size classes, the larger the shadow values of land, (ii) the shadow values of land of larger size classes (II), (III), (IV), (V),and (VI) were much larger than the (government-regulated) "market" land rent, (iii) the shadow value of land even in the smallest size class (I) was much larger than the "market" land rent for the 1956–90 period and even since 1990 the shadow value of land was greater than the "market" land rent except for several years. Based on these findings, we may conclude that farms in all size classes did not utilize paddy land up to the "optimal" points to maximize the amount of variable profits. Keeping this conclusion in mind, we will now turn back to the results in Figure 5.7. Several intriguing findings are noteworthy from this figure.

To begin with, the impacts of increases in the planted area of paddy lands on the shadow values of paddy lands were positive in the largest size class (VI) for the entire study period 1956–97; positive for size class (V) for the period 1956–90; positive for the size class (IV) for the period 1956–1979; positive for size class (III) for the period 1956–1975; positive for size class (II) for the period 1956–68; and, positive for size class (I) for the period 1956–1960. Furthermore, it is very clear that the larger the size class, the larger the impact. This indicates that the set-aside programs reduced the shadow values of larger scale farms with greater extents than in the case of smaller size farms.

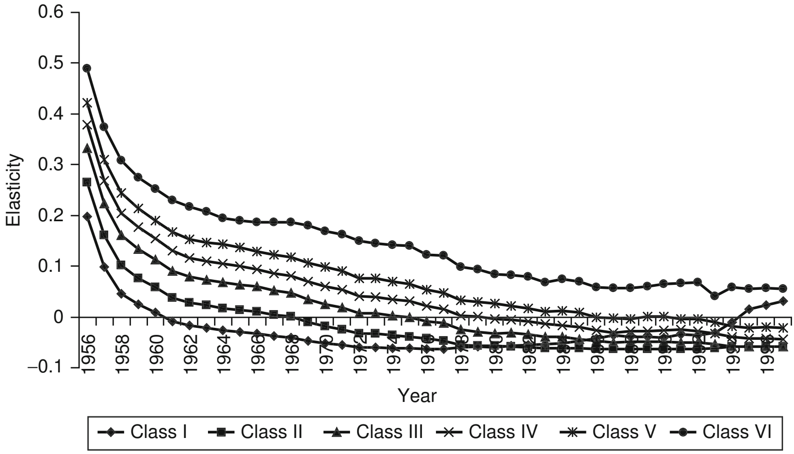

Figure 5.7 Impact of changes in the paddy planted area on the shadow of paddy land for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (5.5).

What then can we say from these findings? The above-observed findings indicate that the programs may have had negative effects on the shadow values of paddy lands in larger-scale farms for fairly long periods, with positive effects for smaller-scale farms for fairly long periods. This implies that the set-aside programs reduced the shadow value of paddy lands of larger-scale farms to much more than in smaller farms. This in turn may have restricted transfers from small- to large-scale farms during the study period 1956–97.

5.4 Summary and concluding remarks

Based on the translog VP function (3.4), we have estimated and evaluated the impact of rice set-aside policies on rice output and the demand for variable factor inputs, the amount of variable profits, the degrees of returns to scale, and the shadow value of paddy land.

Before going further to summarize the empirical results, we would like to mention just one important finding.

We found through the empirical estimation of the shadow value of paddy land that small-scale farms were willing to transfer their farmlands by renting them out to large-scale farms, at least, for the period

1974–97. In line with this finding, we treated the farm (exactly speaking, the "firm-household complex" [Maruyama, 1984]) as the "farm-household" instead of the "farm-firm". The "costs" of labor and land are basically counted as part of the costs for the "farm-firm". However, those "costs" accruing to the farm-owned family labor and land may be considered to be part of household income for the "farm-household". Thus, in order to examine the possibilities of land transfers from small- to large-scale farms, this narrowly defined "farm income" of the small-scale farm should be compared to the shadow value of land (or, "rent-bearing capacity") of large-scale farms. When this norm was applied to our case, the shadow value of paddy land on large-scale farms overwhelmed the "farm income" of small-scale farms, for the period from 1974 until the late-1990s. This indicates that many small-scale rice farms seem to have been ready to transfer their paddy lands to large-scale rice farms during at least the last quarter of the 20th century in Tohoku.

In reality (as shown in Table 1.1 of Chapter 1), however, land movement in Tohoku was found to be considerably inactive, against our expectations. We then hypothesized that government agricultural policies such as the rice set-aside programs, may have been intimately related to the lack of land transfers in Tohoku.

We then investigated quantitatively the impacts of the set aside programs on (i) the supply of rice, (ii) the demands for the variable factor inputs such as machinery, intermediate, and other inputs, (iii) the amount of variable profits, (iv) the degrees of returns to scale, and (v) the shadow value of paddy land. We found in all examinations – with the exception of the degrees of returns to scale – that the rice set-aside programs yielded most advantageous positive effects to small-scale farms. Based on these empirical findings, we may conjecture that the rice set-aside programs have indeed caused the lack of land transfers.

So, the government has to reconsider its set-aside programs and give stronger incentives to larger-scale farms to farm rice on much larger paddy lands.

6

The Impacts of Factor Inputs-Subsidies on the Agricultural Structural Transformation of the Rice Sector

6.1 Introduction

The major objective of this chapter is to quantitatively investigate the effects of factor input-subsidies on the urgent policy issue of transforming small-scale inefficient and low-productive rice farming into efficient and highly-productive rice farming on larger-scale paddy lands. In order to pursue this objective, we will quantitatively evaluate the impact of factor input-subsidy programs on the five key economic indicators of rice farming: (i) the quantity of the supply of rice, (ii) the demands for variable factor inputs such as machinery, intermediate, and other inputs, (iii) the amount of variable profits, (iv) the degrees of returns to scale, and (v) the shadow value of paddy land.

Again, the methodology used is basically the same as employed in Chapters 4 and 5. That is, we will utilize the estimated parameters of the single-product translog VP function defined in Chapter 3 to derive the formulas to quantitatively investigate the impact on the key five indicators. However, the formulas in this chapter will naturally be different from those used in Chapters 4 and 5.

At this point, we should note that there have been many kinds of subsidies for agriculture and forestry; about 70 or so. Thus, it is very difficult to identify which subsidies have been applied specifically to, say, machinery input, intermediate input such as fertilizers, agri-chemicals, and other input composed of expenditures on farm buildings and land improvement equipment for rice production. Fortunately, however, it seems to be clear that Finance for Agriculture, Forestry, and Fisheries has been offered to farmers to purchase machinery input. As for intermediate and other inputs, we have to conjecture that farmers may have utilized parts of other subsidies: for purchasing fertilizer, agri-chemicals, repairing farm buildings, and so on; i.e., the Farming Production Promotion, the Structural Reform of Paddy Farming, the Countermeasure of Agricultural Management, the Agricultural Infrastructure Construction and Improvement Programs, the Rural Area Improvement Programs, etc.[1]

Theoretically speaking, such subsidies associated with purchasing factor inputs may be considered equivalent to farmers lowering the prices of factor inputs such as machinery, fertilizers, agri-chemicals, farm equipment, etc., in real terms. Thus, the major objective of this chapter is to quantitatively estimate and evaluate the impact of reductions in the prices of variable factor inputs on the five key indicators, from the viewpoint of agricultural structural transformation for more productive and efficient rice farming post-war.

Our extensive survey finds that very few (or no) such studies have been executed in Japan.[2] This chapter, like Chapters 4 and 5, may be considered a first attempt to quantitatively present the impact of subsidies on agricultural structural transformation and offer policymakers useful information on how to ease land movements from small- to large-scale farms.

The rest of this chapter is organized as follows. Section two presents the procedures to estimate the impacts of factor inputs-subsidies on the five economic indicators based on the VP function framework introduced in Chapter 3. Section three presents empirical results. Finally, section four provides a brief summary and conclusion.[3]

6.2 Analytical framework

In this chapter, then, we will immediately derive the formulas to quantitatively investigate the impacts of factor inputs-subsidies on the above-mentioned five economic indicators resorting to the VP function system given by Equations (3.1) through (3.7).

6.2.1 Impacts of changes in the prices of the variable factor inputs on the five economic indicators

We will present only the final equation for estimating each impact, since the reader may easily derive the same formulas by following, with simple modifications, the procedures given in Chapters 4 and 5.

Now, we could unfortunately not obtain the *direct* effects of decreases in the prices of the variable factor inputs due to subsidies on the various economic indicators. This is because it was not always possible to compile all necessary data on the price indexes corresponding to the variable factor inputs defined in the VP function (3.1) in Chapter 3.[4] Note however that increases in factor inputs-subsidies by the government may have analogous effects due to decreases in the prices of variable factor inputs. Therefore, our procedure will first estimate the impacts of changes in the prices of the variable factor inputs ($w_M^{'}$, $w_I^{'}$, and $w_O^{'}$) on the above-mentioned five economic indicators and then, based on the estimated results, we will try to infer the impacts of decreases in the prices of the variable factor inputs due mainly to subsidy programs.

6.2.1.1 *Impacts of changes in the prices of the variable factor inputs on the supply of rice*

First, the impacts of changes in the nominal prices of the variable factor inputs ($w_M^{'}$, $w_I^{'}$, and $w_O^{'}$) on the output supply (Q) (ε_{Q_k}, $k = M, I, O$) can be given by,

$$\varepsilon_{Qk} = \frac{\gamma_{Qk}}{R_Q} - R_k, \quad k = M, I, O, \tag{6.1}$$

where R_k is the k-th variable factor input cost-variable profit share as given in the following Equation (6.2). Note here that these impacts expressed in terms of elasticities are equivalent to the elasticities of output (rice) supply with respect to the nominal prices of the variable factor inputs.

6.2.1.2 *Impacts of changes in the prices of the variable factor inputs on the demands for the variable factor inputs*

Second, the impacts of changes in the nominal prices of the variable factor inputs ($w_M{'}$, $w_I{'}$, and $w_O{'}$) on the demands for the variable factor inputs (X_M, X_I, and X_O) are again equivalent to the variable factor demand elasticities with respect to changes in the nominal prices of the variable factor inputs. Here, however, we will shed a special light on the own-price elasticities. Otherwise, it will be fairly complicated if we also try to evaluate the cross-price impacts.

Now, the impact of changes in the k-th factor price on the demand for the k-th factor input, i.e., the own-price demand elasticity of the k-th factor input, can be obtained by,

$$\eta_{kk} = -\frac{\gamma_{kk}}{R_k} - R_k - 1, \quad k = M, I, O, \tag{6.2}$$

where R_k is the k-th variable factor input cost-variable profit share.

6.2.1.3 Impacts of changes in the prices of the variable factor inputs on the amount of variable profits

Third, the impact of changes in the k-th factor price on the amount of variable profits (VP') in terms of elasticities can be obtained by,

$$\frac{\partial \ln VP'}{\partial \ln w'_k} = \alpha_k + \sum_n \gamma_{kn} \ln w'_n + \sum_l \phi_{kl} \ln Z_l + \mu_{kR} \ln Z_R, \tag{6.3}$$

$$k, n = M, I, O, \ l = L, B,$$

which is equivalent to the k-th variable factor input cost-variable profit share (R_k). Here, however, we are going to estimate the impacts given by Equation (6.3) using the estimated coefficients of the translog VP function (3.4) which are presented in Table 3.1 of Chapter 3, which are in general different from the actual k-th variable factor input cost-variable profit share used for the estimation of the system.

6.2.1.4 Impacts of changes in the prices of the variable factor inputs on the degrees of returns to scale (RTS)

Fourth, the impact of changes in the price of the k-th variable factor input on the degrees of returns to scale (RTS) in terms of elasticities can be obtained by,

$$\frac{\partial \ln RTS}{\partial \ln w'_k} = \frac{\sum_l \phi_{kl}}{RTS}, \ k = M, I, O, \ l = L, B, \tag{6.4}$$

where RTS is given by the following equation which is exactly the same as Equation (3.36) given in Chapter 3.

$$RTS = \sum_l \frac{\partial \ln VP'}{\partial \ln Z_l}, \quad l = L, B.$$

6.2.1.5 Impacts of changes in the prices of the variable factor inputs on the shadow value of paddy land

Finally, the impact of changes in the price of the k-th variable factor input on the shadow value of land ($w_B^{S'}$) in terms of elasticities can be obtained by,

$$\begin{aligned} \frac{\partial \ln w_B^{'S}}{\partial \ln w'_k} &= \frac{\partial \ln VP'}{\partial \ln w'_k} + \frac{\partial \left(\frac{\partial \ln VP'}{\partial \ln Z_B} \right)}{\partial \ln P'} \left(\frac{\partial \ln VP'}{\partial \ln Z_B} \right)^{-1} \\ &= \frac{\partial \ln VP'}{\partial \ln w'_k} + \phi_{kB} \left(\frac{\partial \ln VP'}{\partial \ln Z_B} \right)^{-1}, \quad k = M, I, O. \end{aligned} \tag{6.5}$$

As executed for evaluating the impacts of the rice price-support and set-aside programs on the five economic indicators in the previous chapters 4 and 5, all these impacts caused by changes in the prices of the variable factor inputs on (i) the quantity of the rice supply (Q), (ii) the variable factor demands ($X_k,\ k = M, I, O$), (iii) the amount of variable profits (VP'), (iv) the degrees of returns to scale (RTS), and (v) the shadow value of land ($w_B^{S'}$) will be estimated for all observations for all six size classes for each year of the entire study period 1956–97 and they will be shown in the form of graphs. In this way, one can visually capture differences in the magnitudes of the impacts among the different six size classes and changes in the impacts over time for the six different size classes.

6.3 Empirical results

6.3.1 Impacts of changes in the prices of the variable factor inputs on the five economic indicators

6.3.1.1 Impacts of changes in the prices of the variable factor inputs on the supply of rice

Using Equation (6.1), the impacts of changes in the prices of the variable factor inputs ($w_k', k = M, I, O$) on the supply of rice (Q) were estimated for all observations of the six size classes for each year of the entire study period 1956–97 and are presented in Figures 6.1, 6.2, and 6.3, respectively. Several findings are noteworthy.

To begin with, except for several years before 1960 in which we find positive elasticities in larger three size classes (IV, V, and VI), the impacts of changes in the price of machinery (w_M') on the supply of rice (Q), were all negative in all size classes for the study period 1956–97. In addition, the impacts in terms of elasticities increased over time in absolute terms from around 0.05 (size class (VI) in 1956) to around 0.72 (size class (I) in 1997). In other words, the supply of rice became more and more responsive to changes in the price of machinery over time in all six size classes. This in turn indicates that decreases in the price of machinery due to subsidies for machinery input may have increased the demand for machinery input, which may have lead to increases in the supply of rice. This may consequently have increased the amount of revenue during the study period 1956–97.

Furthermore, it is clear from Figure 6.1 that the smaller the size class, the greater the impacts of changes in the price of machinery input (w_M') on the supply of rice (Q) in absolute terms for the entire study period 1956–97. This finding may suggest that government subsidies which

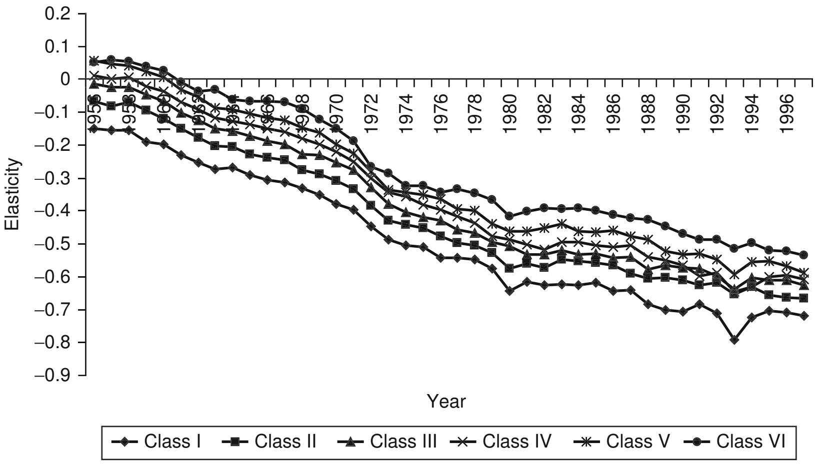

Figure 6.1 Impact of changes in the price of machinery on the supply of rice for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (6.1).

may have effects of reducing the price levels of machinery input will give stronger impacts on smaller- than larger-scale farms in increasing the demand for machinery input (X_M) and hence increasing the supply of rice (Q). In other words, this finding suggests that government subsidies for machinery input may have given stronger incentives to smaller-scale farms to stick to producing rice than to large-scale farms. This may have limited movements of paddy lands from small- to large-scale farms. This in turn may have restricted the transition to larger-scale and more efficient and productive rice farming during the second half of the 20th century.

Next, the impacts of changes in the price of intermediate input (w_I') on the supply of rice (Q) for all samples of all six size classes for each year of the study period 1956–97 are presented in Figure 6.2. Several intriguing findings are worth mentioning from this figure.

First of all, although the impacts expressed in terms of elasticities are very small (under 0.1), we obtained positive elasticities for changes in the price of intermediate input on the supply of rice from 1956 to around 1971–74 in larger size classes (III), (IV), (V), and (VI). An informal interpretation for this finding may be that in order to cover the increased expenditures on intermediate inputs (X_I) – such as fertilizers, agri-chemicals, seeds, and materials–, farms in these size classes might

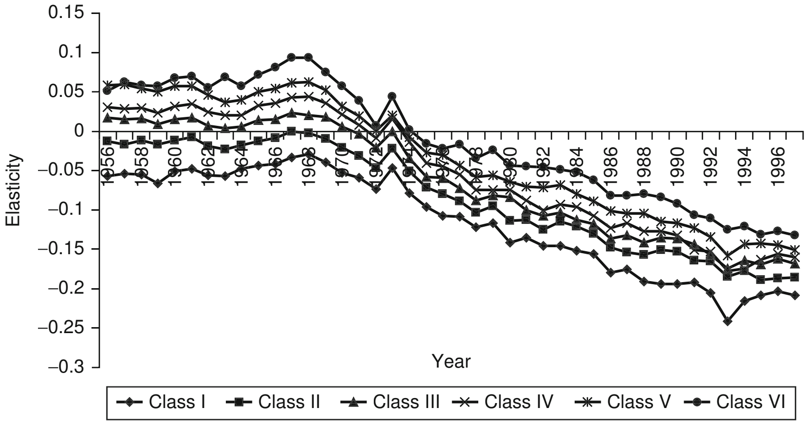

Figure 6.2 Impact of changes in the price of intermediate input on the supply of rice for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (6.1).

have behaved so as to increase the supply of rice (*Q*) during that period. On the contrary, the impacts for the smaller-size classes (I) and (II) were negative for the same period, which seems to be theoretically reasonable. As is clear from Figure 6.2, the impacts were found to be negative and increasing in absolute terms in all size classes after 1975 until 1997.

In addition, as in the case of the impact of changes in the price of machinery input on the supply of rice, it is clear that the smaller the size class, the larger the impacts of changes of the price of intermediate input on the supply of rice in absolute terms for the entire study period 1956–97. This indicates that decreases in the price of intermediate input thanks to subsidy increased the supply of rice more for smaller-scale farms than for large-scale farms. This mechanism may have worked in the direction of limiting transfers of paddy lands from small- to large-scale farms, which may have limited the development of larger-scale and more efficient rice farming in post-war Japan; more specifically, during the last three or four decades of the 20th century. Note here, however, from Figures 6.1 and 6.2, that the impact on the supply of rice with respect to changes in the price of intermediate input were in absolute terms much smaller than those with respect to changes in the price of machinery input for the whole period 1956–97.

Finally, the impact of changes in the price of other input (w_O') on the supply of rice (*Q*) is shown in Figure 6.3. Recall here that other input is

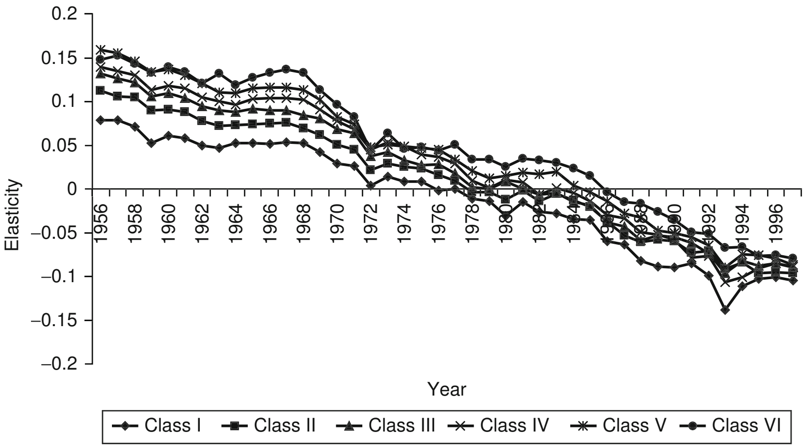

Figure 6.3 Impact of changes in the price of other input on the supply of rice for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (6.1).

composed of the expenditures on farm buildings and land improvement equipment and the cost of land improvement and water.

As in the case of the impacts with respect to intermediate input, we observe that the impacts of changes in the price of other input on the supply of rice were positive for fairly long periods in all size classes: 1956–77 for size classes (I) and (II); 1956–81 for size class (III); 1956–83 for size class (IV); 1956–84 for size class (V); and 1956–85 for size class (VI). Again, an informal interpretation is similar as in the case of the impacts with respect to changes in the price of intermediate input. That is, in order to cover the increased expenditures on other input (X_O), farms in all size classes may have tried to increase the supply of rice for more output revenue during those periods.

After those periods until 1997, the impacts were negative and trends increased in absolute terms in all six size classes. In addition, we observe that the smaller the size classes, the greater the impacts in absolute terms for that period. This indicates that, at latest, after 1985 until the late 1990s, decreases in the price of other input due to subsidies may have increased the supply of rice of smaller-scale farms than that of large-scale farms. This mechanism may have played a role in limiting transfers of paddy lands from small- to large-scale farms for larger-scale and more efficient and productive rice farming. Note, however, from Figures 6.1 and 6.3, that, as in the case of intermediate input, the impacts on the supply of rice with respect to changes in other input were in absolute terms much smaller than those with respect to changes in the price of machinery input.

At this point, we will recall that we have found that the smaller the size classes, the larger the impacts of changes in the price of rice on the supply of rice for the entire study period 1956–97 (Figure 4.1 in Chapter 4). This indicates that the rice price-support policies had a negative effect on transferring paddy lands from small- to large-scale farms.

Based on the findings with respect to changes in the prices of the variable factor inputs together with the output price for rice production, we may conclude that policies both for the rice price-support and for factor inputs-subsidies may have played important roles in limiting transfers of paddy lands from small- to large-scale farms. This in turn may have restricted the possibilities for larger-scale farming with higher productivity and efficiency in rice farming not only in Tohoku but also all over Japan during the second half of the 20th century.

6.3.1.2 Impacts of changes in the prices of the variable factor inputs on the demands for the variable factor inputs

The impacts of changes in the prices of the variable factor inputs ($w_k^{'}, k = M, I, O$) on the demand for the variable factor inputs for all observations of the six size classes for each year of the entire study period 1956–97 were estimated using Equation (6.2) and are presented in Figures 6.4, 6.5, and 6.6, respectively. Note that these impacts are equivalent to the own-price elasticities of demands for the three variable factor inputs obtained by Equation (3.31) in Chapter 3. Several findings are worth noting from these figures.

To begin with, the impacts of increases in the price of machinery ($w_M^{'}$) on the demand for machinery input (X_M) were all negative in all samples in all six size classes. This is consistent with the microeconomic theory.[5]

However, we found unusually large values of elasticity in absolute terms for the period 1957–1964, in particular, in larger-size classes (IV), (V), and (VI). Accordingly, we omitted those estimates from Figure 6.4.

Now, as clearly seen in this figure, the impacts, or equivalently, the own-price demand elasticities for machinery input, were extremely high in absolute terms in the larger three size classes (IV), (V), and (VI) for the 1965–1970 period. But since then, the elasticities in all size classes appear to have converged to around 2.0 in absolute terms in around 1974 and, since then until 1997, the own-price demand elasticities of

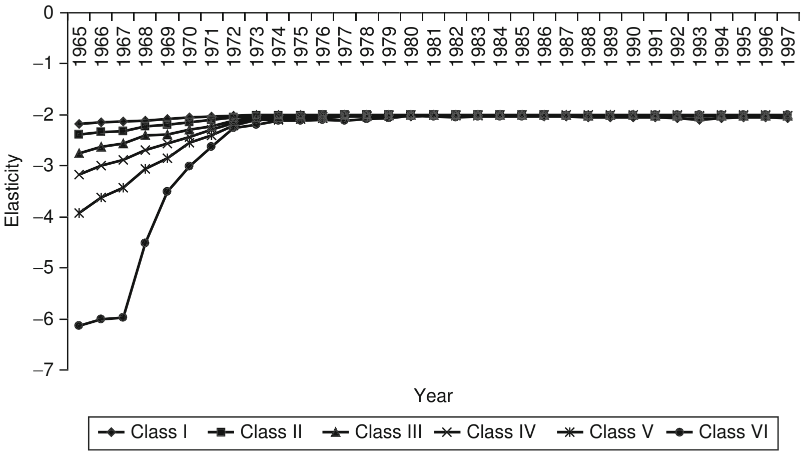

Figure 6.4 Impact of changes in the price of machinery on the demand for machinery input for 1965–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (6.2).

machinery were consistently around 2.0 in absolute terms in all size classes. Recall at this point that a transition from small-scale to medium- and larger-scale agricultural mechanization occurred from the late-1960s and the early-1970s towards the end of 1990s. Thus, one clear observation from Figure 6.4 is that farmers in all six size classes were very responsive to changes in the price of machinery when it comes to demanding machinery input for the entire study period 1956–97, the period of the transition of agricultural mechanization from small- to medium- and larger-scale machinery input. This in turn indicates that decreases in the machinery price due to subsidies for machinery input may have increased the demand for machinery input almost equally in all size classes, which may have played an important role in increasing the supply of rice in all size classes equally; in particular, since the early-1970s towards the end of 1990s.

Next, the impact of changes in the price of intermediate input (w_I') on the demand for intermediate input (X_I) for all six size classes for every year of the entire 1956–97 were estimated using Equation (6.2) and the results are presented in Figure 6.5. According to Figure 6.5, the impacts in all size classes were in general negative, which is consistent with the convexity condition except for some years in larger three size classes: for size class (IV), the period 1967–69 and 1973; for size class (V), the period

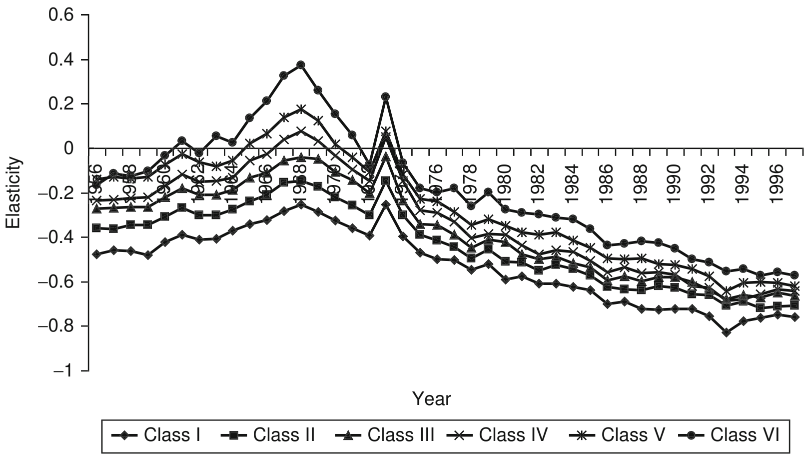

Figure 6.5 Impact of changes in the price of intermediate input on the demand for intermediate input for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (6.2).

1965–1970 and 1973; and for size class (VI), the period 1963–1971 and 1973. Needless to say, the convexity conditions were not satisfied for the years in these periods in the three larger-size classes (IV), (V), and (VI). Nevertheless, some interesting findings emerge from this figure.

First, the impacts of increases in the price of intermediate input had decreasing trends in absolute terms in all size classes for the period 1956–1968, but since then, the impacts had increasing trends in absolute terms in all size classes. This may indicate that after the introduction of the set-aside program in 1969, rice farmers in all size classes may have become more responsive to changes in the prices of intermediate input such as fertilizers and agri-chemicals to increase the yield per unit of planted lands. Note however that the impacts of changes in the price of intermediate input on the demand for intermediate input itself were much smaller in absolute terms than in the case of the impacts of changes in the price of machinery on the demand for machinery itself presented in Figure 6.4.

Second, as is clear in Figure 6.5, the smaller the size classes, the greater the impacts of changes in the price of intermediate input in absolute terms for the entire study period 1956–97. This may indicate that decreases in the price of intermediate input thanks to subsidies resulted in stronger demands for intermediate input in smaller-size classes than in larger-size classes. This may in turn indicate that smaller-scale farms

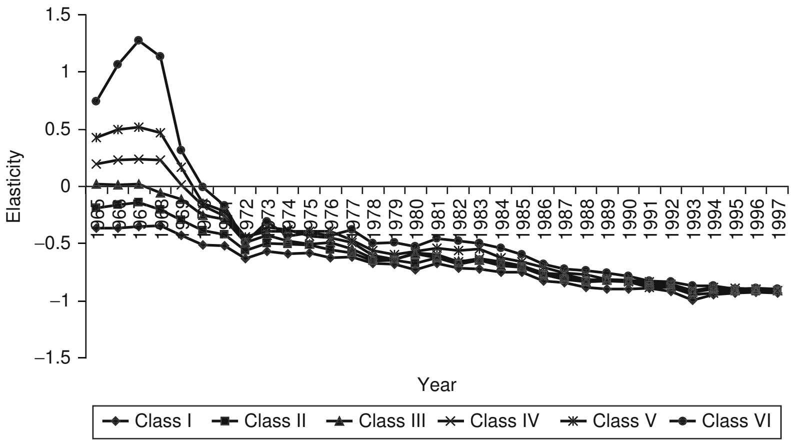

Figure 6.6 Impact of changes in the price of other input on the demand for other input 1965–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (6.2).

had stronger incentives to increase rice output and hence the amount of variable profits by increasing demands for intermediate input than did larger-scale farms. This may definitely have restricted transfers of paddy lands from small- to large-scale farms during the study period 1956–97.

Finally, the impact of changes in the price of other input (w_O') on the demand for other input (X_O) are equivalent to the own-price elasticity of demand for other input as in the cases of machinery and intermediate inputs as interpreted above. They were obtained using Equation (6.2) and are presented in Figure 6.6. In this case, the larger-scale (IV), (V), and (VI) farms did not satisfy the convexity conditions for the period 1956–69. On the other hand, however, smaller-size classes (I), (II), and (III) satisfied the convexity condition for the entire 1956–97 period. Accordingly, we decided to present the results in Figure 6.6 only for the period 1970–97, during which the convexity conditions were satisfied in all six size classes in order not to complicate the interpretations of the results. Some findings are noteworthy from Figure 6.6.

First, the own-price elasticities had steady increasing trends in absolute terms for the 1970–97 period in all six size classes. The elasticities (equivalently the impacts) range from around 0.1 (size class (VI) in 1970) to around 1.0 (size class (I) in 1993) in absolute terms, which are comparable with those of intermediate input.

Furthermore, it is fairly clear from Figure 6.6 that the smaller the size class, the greater the impact of changes in the price of other input on the demand for other input in absolute terms for the period 1970–97. This finding may suggest that subsidies which may have effects of reducing the price levels of other input will give stronger impacts on smaller-scale than on larger-scale farms in increasing the demand for other input and hence increasing the supply of rice. It may thus suggest that subsidies for other input may have given stronger incentives to smaller-scale farms to stick to producing rice than to larger-scale farms. This may have limited movement of paddy lands from small- to large-scale farms.

At this point, we will recall that we found that the smaller the size classes, the larger the impacts of changes in the price of rice on the demands for the variable factor inputs for the entire study period 1956–97 (Figures 6.1, 6.2, and 6.3 presented in this chapter). This indicates that the rice price-support policies had negative effects on transferring paddy lands from small- to large-scale farms.

In sum, we may conclude that government policies both for the rice price-support and for subsidies for variable factor inputs played important roles in restricting transfers of paddy lands from small- to large-scale farms during the last four decades of the 20th century. This in turn may have limited larger-scale farming not only in Tohoku but also all over Japan during the second half of the 20th century.

6.3.1.3 Impacts of changes in the prices of the variable factor inputs on the amount of variable profits

The impacts of changes in the prices of the variable factor inputs ($w_k^{'}$, $k = M, I, O$) on the amount of variable profits ($VP^{'}$) were estimated using Equation (6.3) for all observations of the six size classes for each year of the entire study period 1956–97 and are presented in Figures 6.7, 6.8, and 6.9, respectively. As mentioned earlier, they are equivalent to the *k*-th variable factor input cost-variable variable profit shares ($R_k, k = M, I, O$). Several findings are worth noting from these figures.

To begin with, the impacts of increases in the price of machinery ($w_M^{'}$) on the amount of variable profits ($VP^{'}$) were all negative in all samples in all six size classes except for several years in the late-1950s in the larger three size classes for which the impacts were positive: 1956–58 for size class (IV); 1956–60 for size class (V); and 1956–61 for size class (VI). At least, some findings are noteworthy from Figure 6.7.

Now, it is clear that the impacts of increases in the price of machinery on the amount of variable profits had decreasing trends for the entire study period 1956–97 in all size classes; the impacts ranged from

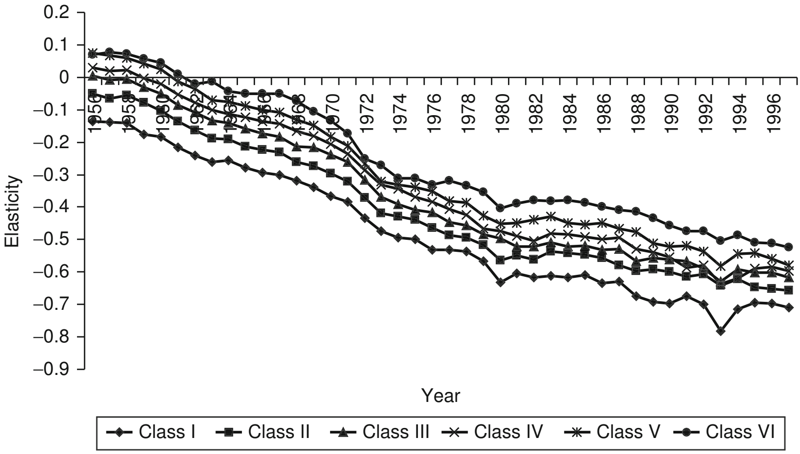

Figure 6.7 Impact of changes in the price of machinery input on the variable profits for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (6.3).

0.08 (size class (VI) in 1956) to −0.79 (size class (I) in 1993). Conversely speaking, decreases in the price of machinery input would have increased the amount of variable profits in all size classes. Furthermore, we observe very clearly from Figure 6.7 that the smaller the size classes, the greater the impacts in absolute terms for the entire period.

This may indicate that decreases in the price of machinery input thanks to subsidies will result in larger amount of variable profits in smaller-size classes than in larger-size classes. So, smaller-scale farms had stronger incentives to increase the amount of variable profits through rice production by increasing demand for machinery input, which may have caused a delay in transfers of paddy lands from small- to large-scale farms during the entire study period 1956–97.

Next, we observe in Figure 6.8 that the impacts of increases in the price of intermediate input ($w_I^{'}$) on the amount of variable profits ($VP^{'}$) were all negative in all samples in all six size classes for each year of the entire study period 1956–97. Conversely, this finding indicates that decreases in the price of intermediate input, such as fertilizers and agrichemicals, may have increased the amount of variable profits for all size classes. In addition, there are two more intriguing findings in Figure 6.8.

First, it is clear that increases in the price of intermediate input had an increasing impact between 1956 and 1968. The trend then decreased

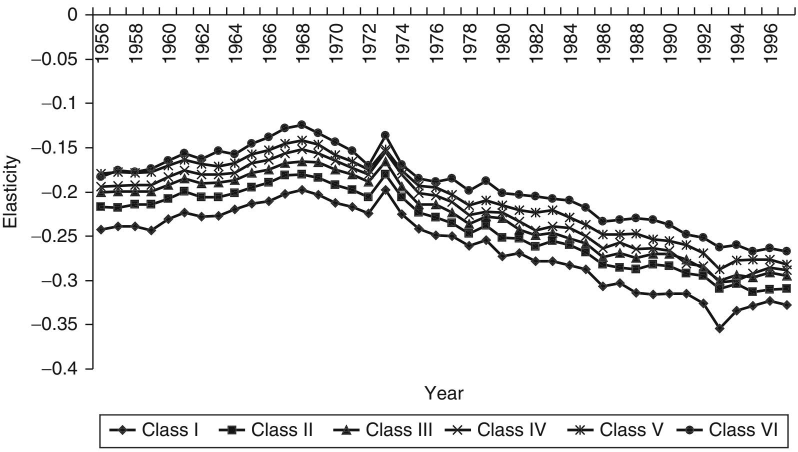

Figure 6.8 Impact of changes in the price of intermediate input on the variable profits for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (6.3).

for the period 1968–97, except for an increase in 1973 (the so-called "oil crisis" year), in all size classes; the impacts ranged from around −0.18 (size class (VI) in 1956) to −0.36 (size class (I) in 1993). Conversely speaking, decreases in the price of intermediate input due to subsidies may have played an important role in increasing the amount of variable profits in all size classes for the entire study period 1956–97, in particular, for the period 1968–1997, during which medium- and larger-scale mechanization proceeded at pace.

Second, we observe very clearly from Figure 6.8 that the smaller the size, the greater the impact in absolute terms. This may imply that decreases in the price of intermediate input due to subsidies led to more variable profits in smaller-size classes than in larger-size classes. This may in turn indicate that smaller-scale farms had stronger incentives to increase the amount of variable profit through increased rice production by increasing demand for intermediate input than did larger-scale farms. This would have limited transfers of paddy lands from small- to large-scale farms during the study period 1956–97, possibly discouraging agricultural structural transformation post-war.

Finally, Figure 6.9 shows that the impacts of increases in the price of other input (w_O') on the amount of variable profits (VP') were all negative in all observations in all six size classes for the entire study

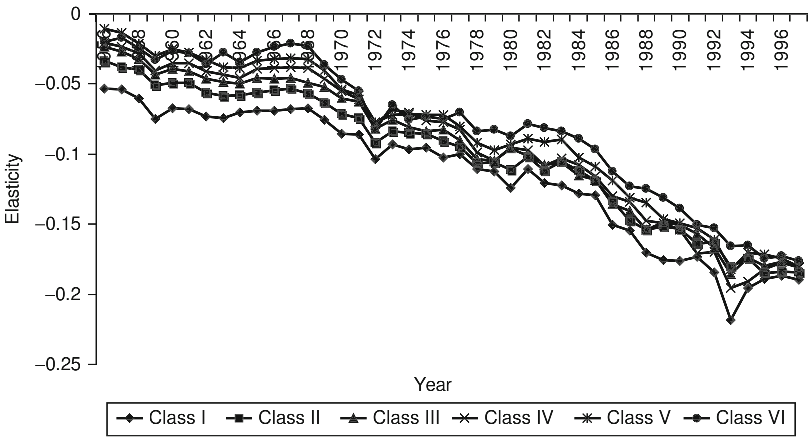

Figure 6.9 Impact of changes in the price of other input on the variable profits for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (6.3).

period 1956–97. Again, conversely speaking, this finding indicates that decreases in the price of other input may have increased the amount of variable profits in all size classes. Two more findings from Figure 6.9 are also intriguing.

First, it is clear that the impacts of increases in the price of other input on the amount of variable profits increased in absolute terms for each year of the whole period 1956–97 in all size classes; the impacts ranged from around 0.01 (size class (V) in 1956) to around 0.22 (size class (VI) in 1993) in absolute terms. Conversely speaking, we may infer that decreases in the price of other input may have helped to increase variable profits in all six size classes for the entire study period 1956–97.

Furthermore, we observe in Figure 6.9 that, in general, the smaller the size class, the greater the impact in absolute terms for the entire period. This indicates that decreases in the price of other input thanks to subsidies may have led to more variable profits in smaller-size classes than in larger-size classes. This may in turn indicate that smaller-scale farms had stronger incentives to increase the amount of variable profits thanks to rice production by increasing demand for other input than did larger-scale farms. We may conjecture here also that this may have limited transfers of paddy lands from small- to large-scale farms during the study period 1956–97 as in the cases of machinery and intermediate input exposed above.

At this point, we recall that we found that the smaller the size classes, the larger the impacts of changes in the price of rice on the amount of variable profits for the entire study period 1956–97 (refer to Figure 4.5 of Chapter 4). This indicates that the rice price-support policies had negative effects on transferring paddy lands from small- to large-scale farms.

Based on the findings with respect to changes in the prices of the variable factor inputs together with the output price for rice production, we may conclude that government policies both for the rice price-support and for subsidies for factor inputs may have restricted transfers of paddy lands from small- to large-scale farms. This in turn may have limited the possibilities for larger-scale rice farming with higher productivity and efficiency, not only in Tohoku but also all over Japan during the latter half of the 20th century.

6.3.1.4 Impacts of changes in the prices of the variable factor inputs on the degrees of returns to scale (RTS)

The impacts of changes in the prices of variable factor inputs ($w_k^{'}, k = M, I, O$) on the degrees of returns to scale (*RTS*) were estimated using Equation (6.4) for all observations of the six size classes for the entire study period 1956–97 and are presented in Figures 6.10, 6.11, and 6.12, respectively. Several findings are noteworthy.

First, according to Figures 6.10, 6.11, and 6.12, the impacts of increases in the prices of machinery ($w_M^{'}$), intermediate ($w_I^{'}$), and other ($w_O^{'}$) inputs increased the degrees of *RTS* in all six size classes for each year of the entire study period 1956–97. Second, the impacts of changes in $w_M^{'}$ were greater than those with respect to changes in $w_I^{'}$ and $w_O^{'}$ for the entire period. Third, we observe from Figures 6.10, 6.11, and 6.12 that in all three cases the impacts had increasing trends for the period 1956–81 and decreasing trends for the period 1981–97 in all size classes. Fourth, it is clear from the three figures that the smaller the size, the greater the impact with respect to increases in the prices of the three variable factor inputs for the entire study period 1956–97.

These findings may be interpreted as follows. Take, for example, an increase in the price of machinery ($w_M^{'}$). An increase in $w_M^{'}$ will induce farmers to reduce the demand for machinery input, which will have a negative impact on the production (or supply) of rice. This indicates that the quantity of rice production will decrease and will shift further away from the minimum efficient output scale (*MEOS*) towards the vertical axis of the figure of cost curves, at which the average cost reaches its minimum. This will in turn cause an increase in the degree of returns to

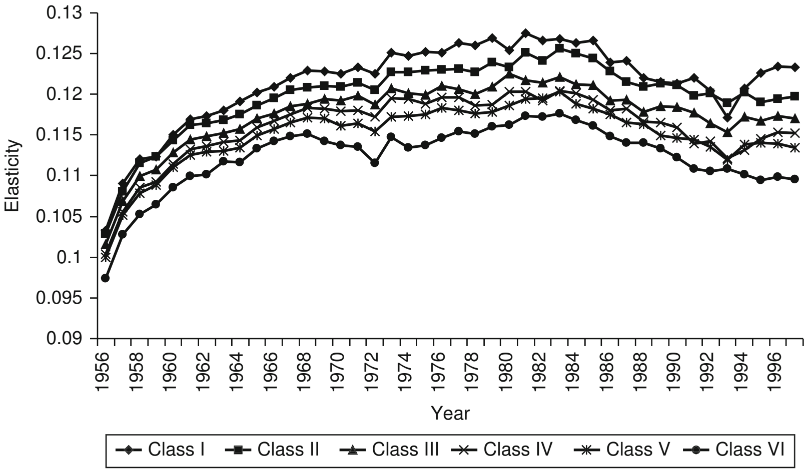

Figure 6.10 Impact of changes in the price of machinery on the degrees of returns to scale for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (6.4).

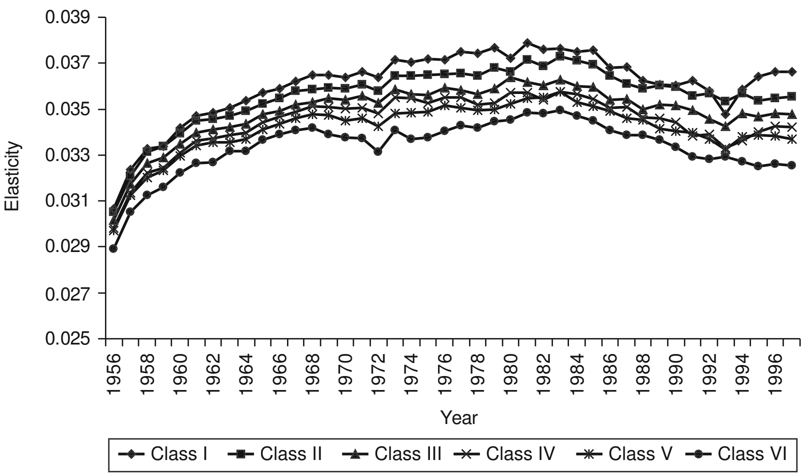

Figure 6.11 Impact of changes in the price of intermediate input on the degrees of returns to scale for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (6.4).

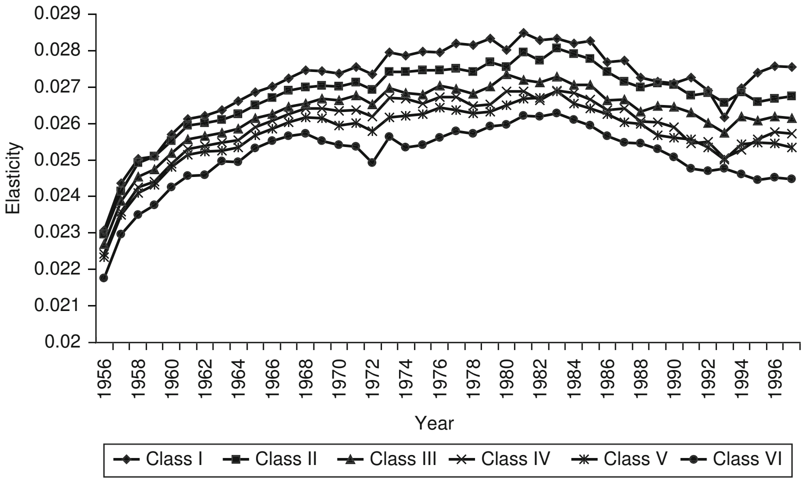

Figure 6.12 Impact of changes in the price of other input on the degrees of returns to scale for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (6.4).

scale (*RTS*) in rice production since the ratio of the average to marginal costs ($AC/MC = RTS$) will rise.[6] At this point, we should note that factor inputs-subsidies are in general equivalent to lowering the prices of factor inputs ($w_k^{'}$, $k = M, I, O$). This indicates that the converse logic will be applicable if real factor prices are reduced thanks to factor inputs-subsidies. That is, a decrease in the real price of machinery will increase the demand for machinery inputs, which may cause an increase in the quantity of the supply of rice. This in turn will lead to a decline in the degrees of the *RTS*.

We can now evaluate the observation in Figure 6.10 that the impact of increases in the price of machinery on the degrees of *RTS* was positive and increased for all size classes for the entire study period 1956–97, though the elasticities of the increases were very small, i.e., from around 0.022 in 1956 in size class (I) to around 0.028 in 1981 in size class (VI). Furthermore, the degrees of the impacts are greater as the farm size gets smaller.

Applying the above-mentioned logic, this observation in Figure 6.10 may indicate that the degrees of reduction in the *RTS* were greater the smaller the farm, due to decreases in the real price of machinery thanks to factor inputs-subsidies. This may in turn imply that factor inputs-subsidizing programs may have shrunk the degrees of returns to scale

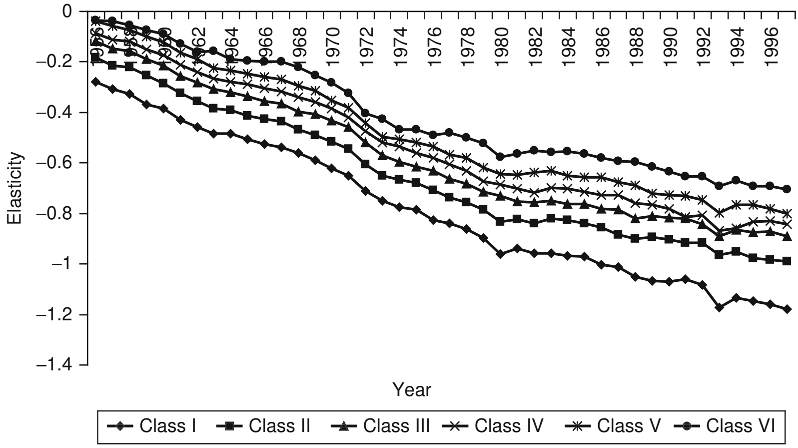

Figure 6.13 Impact of changes in the price of machinery input on the shadow value of land for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (6.5).

between small- and large-scale farms, wich may have played a positive role in promoting transfers of paddy lands from small- to large-scale farms, though the transfers were very small – see Figure 6.10.

Thus, we may conclude based on the above evaluations that the factor inputs-subsidizing programs may have shrunk the degrees of returns to scale between small- and large-scale farms, which may have worked in the direction in encouraging transfers of lands from small- to large-scale farms during the entire study period 1956–97.

However, we should here recall that all the impacts of the factor inputs-subsidizing programs on (i) the quantity of the rice supply, (ii) the quantities of the variable factor demands, (iii) the amount of variable profits, and (v) the shadow value of land (which will be interpreted immediately after this subsection) were restrictive in transferring paddy lands from small- to large-scale farms. As a result, regarding to paddy land movements, the sum of the negative effects on these four economic indicators totally overwhelmed the positive effect of the factor inputs-subsidizing programs on (iv) returns to scale.

Needless to say, analogous interpretations may be applicable to decreases in the real prices of intermediate and other inputs (w_I' and w_O') thanks to factor inputs-subsidies. We will not repeat the same interpretations for intermediate and other inputs to save space.

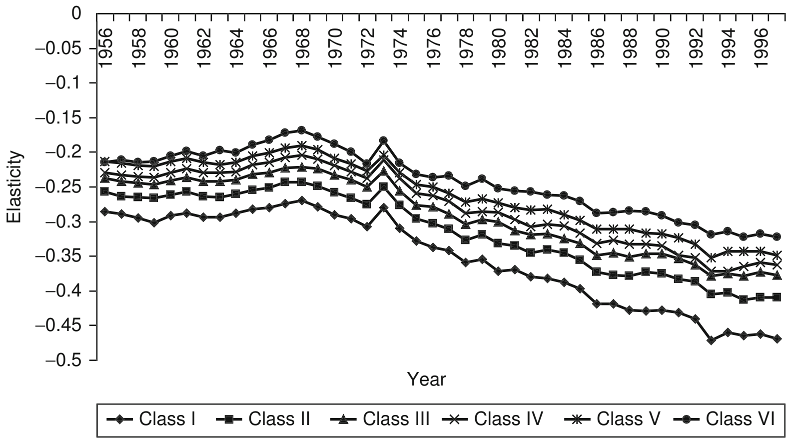

Figure 6.14 Impact of changes in the price of intermediate input on the shadow value of land for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (6.5).

6.3.1.5 Impacts of changes in the prices of the variable factor inputs on the shadow value of paddy land

The impacts of changes in the prices of variable factor inputs ($w_k^{'}, k = M, I, O$) on the shadow value of paddy land ($w_B^{'S}$) were estimated using Equation (6.5) for all observations of all six size classes for each year of the entire study period 1956–97 and are presented in Figures 6.13, 6.14, and 6.15, respectively. Several findings are worth interpreting based on these figures.

First, the impacts of changes in the price of machinery input ($w_M^{'}$) on the shadow value of paddy land ($w_B^{S'}$) were all negative and had increasing trends in absolute terms for the entire study period 1956–97 in all six size classes. Second, the impacts of changes in the price of intermediate input ($w_I^{'}$) on the shadow value of land ($w_B^{S'}$) were all negative. In this case, however, the impacts had slight increasing trends in absolute terms for the 1956–59 period, decreasing trends in absolute terms for the period 1959–68, and after then towards 1997 the impacts had increasing trends in absolute terms in all size classes. Third, as in the case of the impacts with respect to machinery input, the impacts of changes in the price of other input ($w_O^{'}$) on the shadow value of land ($w_B^{S'}$) were all negative and had increasing trends in absolute terms for the entire study period 1956–97 in all six size classes. Fourth, the impacts on the

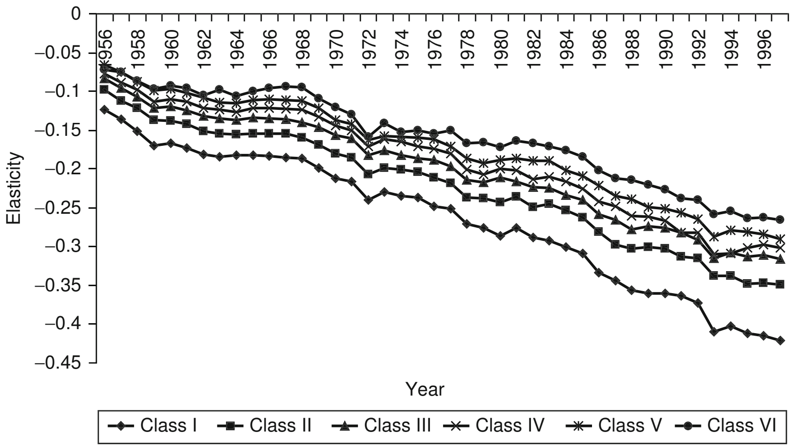

Figure 6.15 Impact of changes in the price of other input on the shadow value of land for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (6.5).

shadow value of land with respect to changes in the price of machinery input ($w_M^{'}$) were much larger than those with respect to changes in the prices of intermediate and other inputs ($w_I^{'}$ and $w_O^{'}$) in absolute terms for the whole period 1956–97. Finally, it can be observed clearly in Figures 6.13, 6.14, and 6.15 that the smaller the sizes of farms, the greater the impacts of changes in the variable factor prices ($w_M^{'}$, $w_I^{'}$, and $w_O^{'}$) in absolute terms for the entire study period 1956–97.

These findings may be interpreted as follows. Take, for example, an increase in the price of machinery ($w_M^{'}$). An increase in $w_M^{'}$ will induce farmers to reduce the demand for machinery input (X_M), which will have a negative impact on the output supply of rice (Q). This decline in rice production may result in a reduction in the shadow price of paddy land ($w_B^{S'}$). Furthermore, the extents of declines in rice production (Q) and hence the shadow values of paddy lands ($w_M^{'}$) in smaller-scale farms are bigger than those in larger-scale farms, which will help easing land movements from small- to large-scale farms. This interpretation may also be applied to the cases of the impacts of changes in the prices of intermediate and other inputs ($w_I^{'}$ and $w_O^{'}$) on the shadow values of paddy lands ($w_B^{S'}$).

On the other hand, factor inputs-subsidies will in general be equivalent to lowering the prices of factor inputs ($w_M^{'}$, $w_I^{'}$, and $w_O^{'}$). This indicates that the converse logic may be applicable if factor prices are reduced thanks to subsidy programs. This may imply that factor inputs-subsidizing programs may have reduced the differentials in the shadow values of paddy lands ($w_B^{S'}$) between small-scale and large-scale farms. This may have lead to discouraging transfers of paddy lands (X_B) from small- to large-scale farms during the study period 1956–97. This result is analogous to that of the price-support programs which may have restricted transfers of paddy lands from small- to large-scale farms during the study period as shown in Section 4.3.5 in Chapter 4.

6.4 Summary and concluding remarks

This chapter investigated and evaluated quantitatively the impacts of factor inputs-subsidizing programs on (i) the supply of rice, (ii) the demands for the variable factor inputs such as machinery, intermediate, and other inputs, (iii) the amount of variable profits, (iv) the degrees of returns to scale, and (v) the shadow value of paddy land. We found in almost all examinations, except with respect to returns to scale (*RTS*), that factor inputs-subsidies yielded advantageous results to smaller-scale farms rather than to larger-scale farms. Based on these empirical findings, we may conjecture that factor inputs-subsidizing programs may have restricted the transfer of paddy lands from smaller- to larger-scale farms during the last three to four decades of the 20th century in Tohoku.

So, in order to drastically change the existing structure of small-scale inefficient rice farming to much more efficient large operations, the government – in particular, the MAFF – must reshuffle the subsidies associated with factor inputs to incentivize highly-motivated larger-scale farms for more productive and efficient rice production.

7

The Impacts of Public Agricultural R&D and Extension (R&E) Programs on the Agricultural Structural Transformation of the Rice Sector

7.1 Introduction

The major objective of this chapter is to investigate the effects of public agricultural R&D and extension (R&E) capital stock, or, equivalently the stock of technological knowledge (R&E), on the urgent policy issue of transforming small and inefficient rice farms in to efficient and productive large operations. In order to pursue this objective, we are going to evaluate the impact of the stock of technological knowledge (R&E) on our five economic indicators.

The methodology for evaluating R&E is basically the same as employed in Chapters 4, 5, and 6; that is, the estimated parameters of the single-product translog VP function with labor and land being quasi-fixed factor inputs (Equation (3.4)) introduced in Chapter 3 will be used. However, the formulas to estimate R&E are naturally different from those used in Chapters 4, 5, and 6.

At this point, we will look at Figures 7.1 and 7.2 which present annual expenditure on R&E activities and the accumulated capital stock of R&E investments (or, equivalently, the stock of technological knowledge) for the rice sector, respectively.[1] They are deflated by the research expenditure deflator and expressed at 1985 prices. According to Figure 7.2, the stock of technological knowledge increased fairly sharply from the early-1970s through to the late-1980s, declined from the early-1980s until the early-1990s, then the rate of increase started increasing fairly fast from around 1992 until 1997. As shown in Figure 7.1, these movements reflect the rather sharp increase in research expenditures in the 1960s, the stagnation both in research and in extension expenditures since the early-1970s up to the late-1980s, and relatively sharp increases again from the late-1980s through to 1997. We have introduced the stock of technological knowledge as an exogenous variable into the VC and VP function models used in Chapters 2 and 3.

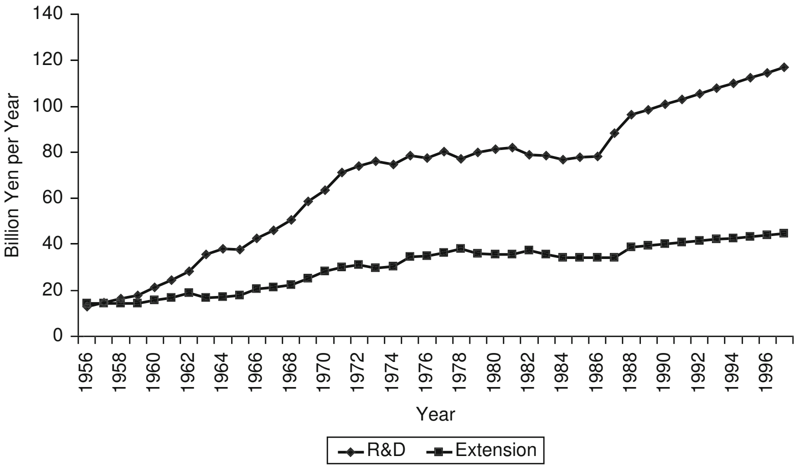

Figure 7.1 Agricultural public R&D and extension expenditures on rice production at 1985 prices: all Japan(Unit: Billion Yen)

Note: Figure 1.5 of Chapter 1 was copied here to save time to search for it.

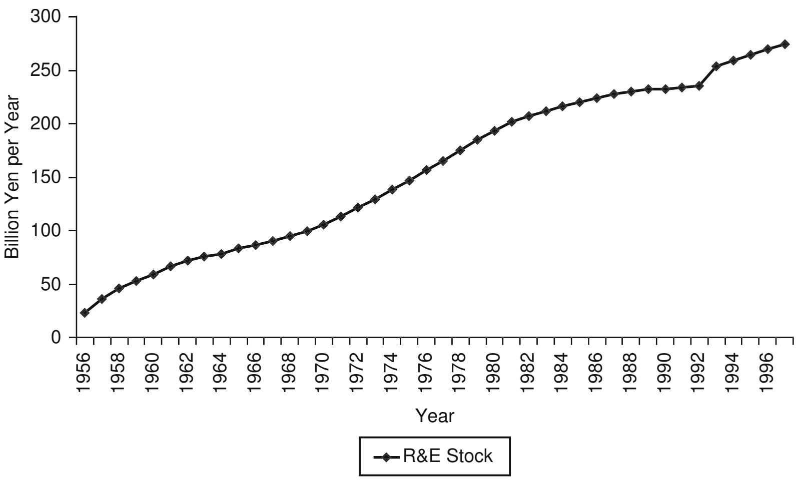

Figure 7.2 The stock of technological knowledge (or R&E stock) for rice production at 1985 prices: all Japan (Unit: Billion Yen)

Note: Figure 1.6 of Chapter 1 was copied here to save time to search for it.

Thus, the major objective of this chapter is to quantitatively estimate and evaluate the impact of changes in the stock of technological knowledge on the five economic indicators, from the viewpoint of structural transformation for more productive and efficient rice farming on larger paddy lands post-war.

As far as the present author's extensive survey goes, it is found that very few (or no) studies have been executed in Japan for empirical investigations of effects of the stock of technological knowledge (Z_R) on the agricultural structural transformation in Japanese rice farming.[2] This research may in this sense be claimed to be the first attempt to quantitatively present impacts of the stock of technological knowledge on agricultural structural transformation and may be expected to offer not only public agricultural research people but also effective and useful information to policymakers on how to ease land movements in the rice sector post-war.

At this point, a brief conclusion may be offered in advance. That is, against our expectation, public agricultural R&E programs had a seriously negative impact on rice farming: such programs restricted transfers of paddy lands from small- to large-scale farms.

The rest of this chapter is organized as follows. Section two presents the procedures to estimate the impact of technological knowledge on the five economic indicators, based on the translog VP function framework developed in Chapter 3. Section three presents empirical results. Finally, section four provides a brief summary and conclusion.[3]

7.2 Analytical framework

We will utilize the same translog VP function developed and employed in previous chapters.

We will also use the same formulas.

We will present only the final equations for estimating each of the five impacts, since the reader may easily derive the formulas.

7.2.1 Impacts of changes in the stock of technological knowledge (R&E) on the five economic indicators

7.2.1.1 Impacts of changes in R&E on the supply of rice

First, the impact of changes in the stock of technological knowledge (Z_R) on the output supply (Q) can be given by,

$$\varepsilon_{QZ_R} = \frac{\partial \ln VP'}{\partial \ln Z_R} - \frac{\sum_k \mu_{k_R}}{1+\sum_k R_k}, \quad k = M, I, O, \tag{7.1}$$

where R_k is the k-th variable factor input cost-variable profit share as given in Equation (3.5) in Chapter 3. Note here that these impacts expressed in terms of elasticities are equivalent to the elasticity of output (rice) supply with respect to the stock of technological knowledge (Z_R).

7.2.1.2 Impacts of changes in R&E on the demands for the variable factor inputs

Second, the impact of changes Z_R on the demands for the variable factor inputs (X_M, X_I, and X_O) are equivalent to the variable factor demand elasticities with respect to Z_R. The impacts can be obtained by the following Equation (7.2) using the estimated parameters of the translog VP function (3.4) presented in Chapter 3,

$$\eta_{kR} = \frac{\partial \ln VP'}{\partial \ln Z_R} - \frac{\mu_{k_R}}{R_k}, \quad k = M, I, O. \tag{7.2}$$

7.2.1.3 Impacts of changes in R&E on the amount of variable profits

Third, the impact of changes Z_R on the amount of variable profits (VP') in terms of elasticities can be obtained by,

$$\frac{\partial \ln VP'}{\partial \ln Z_R} = \beta_R + \sum_k \mu_{k_R} \ln w'_k + \sum_l \mu_{l_R} \ln Z_l, \tag{7.3}$$

$$k = M, I, O, \; l = L, B, R,$$

which is equivalent to the variable profit-technological knowledge stock(Z_R) elasticity. Here, however, we are going to estimate the impact given by Equation (7.3) using the estimated coefficients of the translog VP function (3.4).

7.2.1.4 Impacts of changes in the prices of the variable factor inputs on the degrees of returns to scale (RTS)

Fourth, the impact of changes Z_R on the degrees of returns to scale (RTS) in terms of elasticity can be obtained by,

$$\frac{\partial \ln RTS}{\partial \ln Z_R} = \frac{\sum_l \mu_{l_R}}{RTS}, \quad l = L, B. \tag{7.4}$$

where RTS is given by Equation (3.36) in Chapter 3 and copied here as,

$$RTS = \sum_l \frac{\partial \ln VP'}{\partial \ln Z_l}, \quad l = L, B. \tag{7.5}$$

7.2.1.5 Impacts of changes in R&E on the shadow value of paddy land

Finally, the impact of changes in Z_R on the shadow value of land ($w_B^{'S}$) in terms of elasticity can be obtained by,

$$\frac{\partial \ln w_B^{'S}}{\partial \ln Z_R} = \frac{\partial \ln VP'}{\partial \ln Z_R} + \frac{\partial\left(\frac{\partial \ln VP'}{\partial \ln Z_B}\right)}{\partial \ln Z_R}\left(\frac{\partial \ln VP'}{\partial \ln Z_B}\right)^{-1}$$
$$= \frac{\partial \ln VP'}{\partial \ln Z_R} + \mu_{B_R}\left(\frac{\partial \ln VP'}{\partial \ln Z_B}\right)^{-1}. \qquad (7.6)$$

All these impacts caused by changes in the stock of technological knowledge (Z_R) on (i) the output supply (Q), (ii) the variable factor demands (X_k, $k = M, I, O$), (iii) the amount of variable profits (VP'), (iv) the degrees of returns to scale (RTS), and (v) the shadow value of land ($w_B^{'S}$)will be estimated for all observations for all six size classes for each year of the entire study period 1956–97 and they will be shown in the form of graphs. In this way, one can visually capture not only differences in the magnitudes of the impacts among the different six size classes but also changes in the impacts over time for the six different size classes.

7.3 Empirical results

7.3.1 Impacts of changes in the stock of technological knowledge (R&E) on the five economic indicators

7.3.1.1 Impacts of changes in R&E on the supply of rice

Using Equation (7.1), the impact of changes in the stock of technological knowledge (Z_R) on the supply of rice (Q) was estimated for all observations of the six size classes for the entire study period 1956–97 and are presented in Figure 7.3. Several findings are noteworthy from this figure.

First, it is clear from Figure 7.3 that the smaller the farm sizes, the larger the impacts of changes in Z_R on the output supply of rice (Q). In particular, the smallest size class (I) had the largest impact of Z_R on Q for the entire study period 1956–97; the magnitudes of impacts in terms of elasticity ranged from around 0.48 in 1956 to around 0.72 in 1997, indicating that small-scale farms were fairly responsive to improved technologies developments in public agricultural experiment and extension institutions in rice production. On the other hand, the impacts in largest size class (VI) ranged from around 0.09 in 1956 to 0.30 in 1966

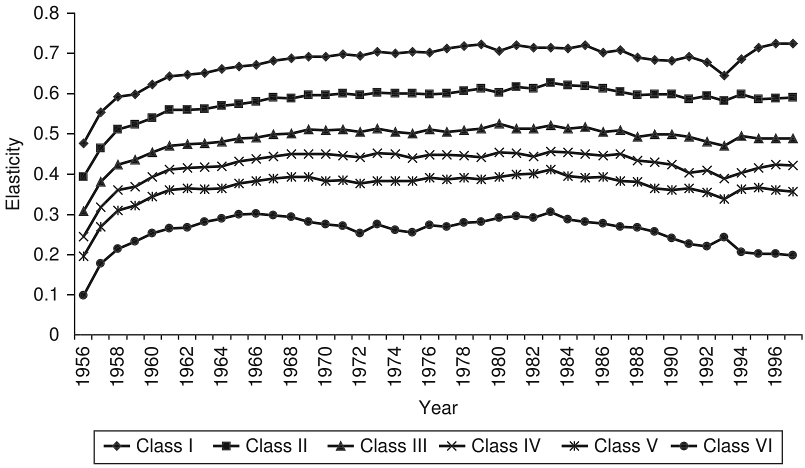

Figure 7.3 Impact of changes in the stock of technological knowledge on the supply of rice for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (7.1).

and since then had a stagnant or, in more specifically, decreasing trend towards the late-1990s.

Second, we find in Figure 7.3 another intriguing feature. That is, the impacts of Z_R on the supply of rice Q in all size classes had fairly sharp increasing trends from 1956 to the late 1960s; up to 1966 in size class (VI); up to 1969 in size classes (III) and (IV); up to 1973–79 period in size classes (I) and (II). Since those years towards the late-1990s, the impacts became stagnant in all size classes; the largest size class (VI) (and also second and third largest size classes (IV) and (V)) even had decreasing trends in the impacts for the period 1983–97. This finding may reflect that public R&E activities based on the rapid smaller-scale M- and BC-technological progress were prevalent and had strong progressive effects on the supply of rice in all size classes for the period from the mid-1950s to the late-1960s or to the early-1970s (before the "oil crisis" occurred in 1973). However, roughly speaking, after 1973, the impacts of public R&E activities on the supply of rice became stagnant in spite of the rapid introduction of medium-and larger-scale M-technologies in all size classes; in particular, the impact in the largest size class (VI) had a steady decreasing trend for the period 1983–97, while the impact in the smallest size class (I) had an increasing trend for the period 1993–1997.

In this subsection, we will evaluate the impacts of changes in the stock of technological knowledge (Z_R) on the demands for the variable factor inputs; machinery (X_M), intermediate input (X_I), and other inputs (X_O). As a matter of fact, the impacts expressed in terms of elasticities are exactly the same as the demand elasticities of the variable factor inputs ($X_k,\ k = M, I, O$) with respect to Z_R. We estimated the impacts for all observations of the six size classes for the entire 1956–97 period. The impacts of changes in Z_R on the demands for $X_k,\ k = M, I, O$ are shown in Figures 7.4, 7.5, and 7.6, respectively.

At this point, we will recall that we found that the smaller the size class, the larger the impact of changes in the price of rice on the supply of rice for the entire study period 1956–97 (Figure 4.1, Chapter 4). This indicates that the rice price-support policies had a negative effect on transferring paddy lands from small- to large-scale farms.

Based on these findings, we may now infer that increases in the stock of technological knowledge (Z_R) might have caused restrictions on transfers of paddy lands from small- to large-scale farms, because smaller-scale farms enjoyed more favorable effects in the supply of Q from increases in R_Z than did larger-scale farms. In Chapter 5 we found that the set-aside programs had significant negative impacts on rice production, especially on large-scale farms for the entire study period 1956–97. Unfortunately, public R&E activities seem to have had similar effects, restricting possibilities for larger-scale-more-efficient-and-productive rice farming on larger-scale paddy lands.

7.3.1.2 Impacts of changes in R&E on the demands for the variable factor inputs

In this subsection, we will evaluate the impacts of changes in the stock of technological knowledge (Z_R) on the demands for the variable factor inputs; machinery (X_M), intermediate (X_I), and other inputs (X_O). As a matter of fact, the impacts expressed in terms of elasticities are exactly the same as the demand elasticities of the variable factor inputs ($X_k,\ k = M, I, O$) with respect to Z_R. We estimated the impacts for all observations of the six size classes for the entire 1956–97 period. The impacts of changes in Z_R on the demands for $X_k,\ k = M, I, O$ are shown in Figures 7.4, 7.5, and 7.6, respectively. We should note, however, that because we obtained unusually large values of elasticities for larger size classes – in particular, the largest size class (VI) – for the period 1956–64, we dropped the estimates of all six size classes for this period, so Figure 7.4 looks much nicer, in the sense that we can observe much more clearly differences in the values of elasticities among different size

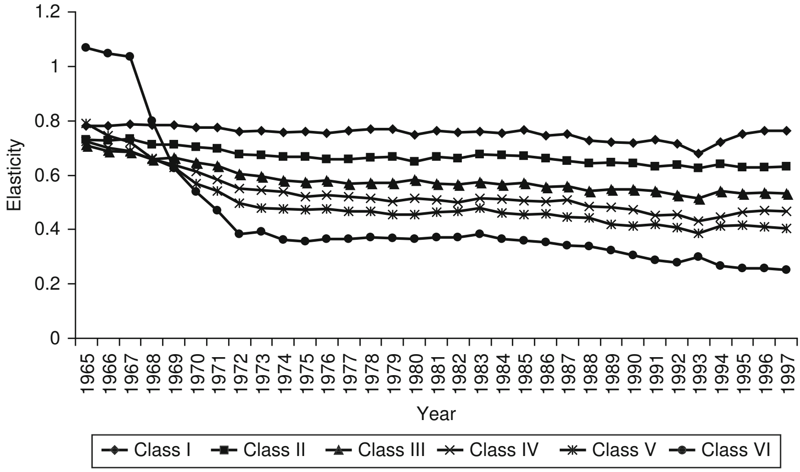

Figure 7.4 Impact of changes in the stock of technological knowledge on the demand for machinery input for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (7.2).

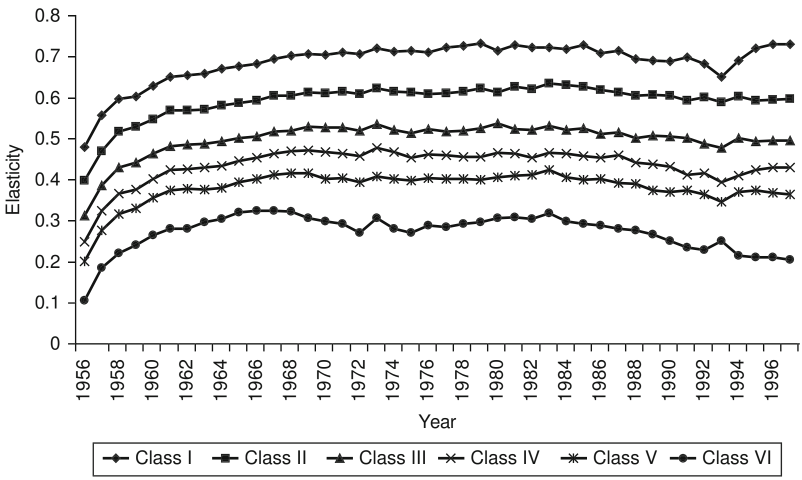

Figure 7.5 Impact of changes in the stock of technological knowledge on the demand for intermediate input for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (7.2).

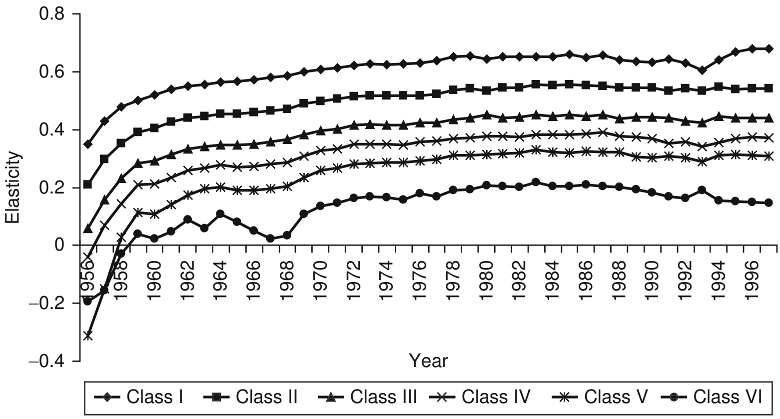

Figure 7.6 Impact of changes in the stock of technological knowledge on the demand for other input for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (7.2).

classes than in the case where the values of elasticities for the period 1956–64 are included. Several findings are noteworthy from these three figures.

First, according to Figure 7.4, the impacts of changes in the stock of technological knowledge (Z_R) on the demand for machinery input (X_M) were positive and had fairly steady slight decreasing trends in all six size classes for the period 1972–97, although there existed slight differences in the trends among six size classes; after 1993, in particular, the largest size class (VI) had a little sharper decreasing trend while the smallest size class (I) had a slight increasing trend. On the other hand, for the period before 1972, the impacts of changes in Z_R in larger size classes were very large, although they decreased sharply during the period 1956–72. This indicates that the "M-innovations" from smaller-scale to medium- and larger-scale machinery due to public R&E activities had stronger impacts on the demand for machinery input in larger-scale classes than in smaller-scale classes during the early stages of mechanization occurred during the 1950s and 1960s.

On the contrary, however, in smaller-scale classes (specifically, (I) and (II)), the impacts of Z_R on the demand for X_M were fairly consistent for the same period 1956–72, indicating that smaller-scale farms were consistently catching up with larger-scale farms for farm mechanization. As a result, the smaller the farm sizes, the greater the impacts of Z_R on

X_M. In particular, the smallest size class (I) had fairly high elasticities for the period 1965–97, around 0.78–0.79, while the impacts in the largest size class (VI) ranged only from around 0.38 in 1972 to around 0.25 in 1997. These findings imply that public R&E programs promoted "M-innovations" for all six size classes; the speed of mechanization in the smallest size class (I) was the highest for the period 1969–97.

Next, Figure 7.5 shows the impacts of changes in Z_R on the demand for intermediate input (X_I) among the six size classes. As in the case of the impact of Z_R on X_M, the impacts of changes in Z_R on X_I are equivalent to the demand elasticities of intermediate input X_I with respect to Z_R. A few intriguing findings emerge from Figure 7.5.

First of all, we may observe, at a glance, that the degrees and development of the impacts of Z_R on the demand for X_I are very similar to those of the impacts of Z_R on the supply of rice Q; the only minor difference appears to be that the degrees of impacts of Z_R on the demand for X_I are slightly larger than those of the impacts of Z_R on the supply of rice Q by around 0.01–0.02 on the average for the entire study period.

Second, according to Figure 7.5, it is clear that the smaller the farm sizes, the larger the impacts of changes in Z_R on the demand for X_I. In particular, the smallest size class (I) had the largest impacts of changes in Z_R on X_I for the entire period 1956–97; the magnitudes of impacts in terms of elasticity ranged from around 0.48 in 1956 to around 0.73 in 1997, indicating that small-scale farms were fairly responsive to improved technologies due to investments in R&E activities in the public agricultural experiment institutions and extension stations in rice production. On the other hand, the impacts in largest size class (VI) ranged only from around 0.10 in 1956 to 0.32 in 1966 and since then had a stagnant or decreasing trend towards the late-1990s.

Third, we find in Figure 7.5 another interesting feature. That is, the impacts of Z_R on the demand for X_I in all six size classes had increasing trends from 1956 to the late-1960s; up to 1966 in size class (VI); up to 1969 in size classes (III) and (IV); up to 1973–79 period in size classes (I) and (II). After those years towards the late-1990s, the impacts became stagnant in all size classes: the largest size class (VI) even had a steady decreasing trend of the impact. This finding may reflect that public R&E activities based on the rapid smaller-scale M- and BC-technological progress were prevalent and had strong progressive effects on the demand for intermediate input (X_I) in all size classes for the period from the mid-1950s to the late-1960s or to the early-1970s (before the "oil crisis" occurred in 1973). However, roughly speaking, after 1973, the impacts of public R&E activities on the demand for X_I

became stagnant in all size classes; in particular, the impact in the largest size class (VI) had a steady decreasing trend for the period 1983–97, while that in the smallest size class (I) had an increasing trend for the period 1993–1997.

Lastly, Figure 7.6 shows the impacts of Z_R on the demand for other input (X_O) in the six size classes. As in the case of the impact of Z_R on X_M, the impact of changes in Z_R on X_O is equivalent to the demand elasticity of other input X_O with respect to Z_R. A few intriguing findings emerge from Figure 7.6.

First of all, we may observe that, although larger size classes (IV), (V), and (VI) had negative values of the impacts during the late-1950s, the development of the impacts of Z_R on the demand for X_O are very similar to those of the impacts of Z_R on the demand for X_I: that is, increasing from 1956 to around 1983 but since then towards the late-1990s the movements of the impacts were stagnant in all six size classes. However, the degrees of impacts of Z_R on the demand for X_O were smaller than those of the impacts of Z_R on the demand for X_I by around 0.1 to 0.2 for all six size classes on an average except for the period 1956–1959 during which larger size classes had negative impacts for one, two, and three years for size classes (IV), (V), and (VI), respectively.

Second, according to Figure 7.6, it is clear that the smaller the farm sizes, the larger the impacts of changes in Z_R on the demand for X_O. In particular, the smallest size class (I) had the largest impacts of changes in Z_R on the demand for X_O for the entire period 1956–97; the magnitudes of the impacts in terms of elasticity ranged from around 0.35 in 1956 to around 0.68 in 1997, indicating that small-scale farms were fairly responsive in rice production to improved technologies due to investments in R&E activities in the public agricultural experiment and extension institutions. On the other hand, the impacts in the largest size class (VI) ranged from around −0.2 in 1956 to 0.21 in 1983 and since then had a stagnant or decreasing trend towards the late-1990s.

Third, we find in Figure 7.6 another intriguing feature. That is, the impacts of Z_R on the demand for X_O in all size classes had increasing trends from 1956 to around 1983 as mentioned above. After 1983 towards the late-1990s, the impacts became stagnant in all size classes; the largest size class (VI) even had a steady decreasing trend of the impact. This finding may reflect that public R&E activities based on the rapid smaller- to medium- and larger-scale M-and BC-technological progress were prevalent and had strong progressive effects on the demand for other input (X_O) in smaller size classes than in larger size classes for the period from the mid-1950s to the early-1980s. However, roughly speaking, after 1983, the impacts of public R&E activities on the demand for X_O became stagnant in all size classes; in particular, the impact in the largest size class (VI) had a steady decreasing trend for the period 1983–97, while that in the smallest size class (I) increased between 1993 and 1997.

In sum, the impacts of increases in the stock of technological knowledge (Z_R) on the demand for the variable factor inputs, i.e., machinery, intermediate, and other inputs estimated in terms of elasticities were all positive in all six size classes for the entire study period 1956–97 except for the case of the negative elasticities in size classes (IV), (V), and (VI) for a few years in the late-1950s in the case of other input. Above all, we have found that the smaller the size class, the larger the impact on demand for all variable factor inputs. This means that smaller-scale farms enjoyed greater effects in the demands for variable factor inputs due to changes in public R&E investments than did larger-scale farms. In particular, the public R&E programs had stronger positive impacts in smaller-scale farms than in larger-scale farms in the demand for variable factor inputs, indicating stronger positive effects in smaller-scale farms than in larger-scale farms in the production of rice. This in turn implies that public R&E investments had negative effects on land transfers from small- to large-scale farms in order to form larger-scale and more productive and efficient rice farming on larger-scale paddy lands.

At this point, we will recall that we found that the smaller the size classes, the larger the impacts of changes in the price of rice on the demands for the variable factor inputs for the entire study period 1956–97 (Figures 4.2, 4.3, and 4.4 in Chapter 4). This indicates that the rice price-support policies had negative (i.e., restrictive) effects on transferring paddy lands from small- to large-scale farms.

Based on our findings with respect to changes in the stock of technological knowledge, together with increases in the output price for rice production, we may conclude that government policies – both for rice price-supports and for public R&E activities – may have limited the transfer of paddy lands from small- to large-scale farms. This in turn may have restricted the possibilities for larger-scale farming with higher productivity and efficiency in rice production not only in Tohoku but also all over Japan during the latter half of the 20th century.

7.3.1.3 Impacts of changes in R&E on the amount of variable profits

The impacts of changes in the stock of technological knowledge (Z_R) on the amount of variable profits (VP') were estimated using Equation (7.3) for all observations of the six size classes for each year of the entire

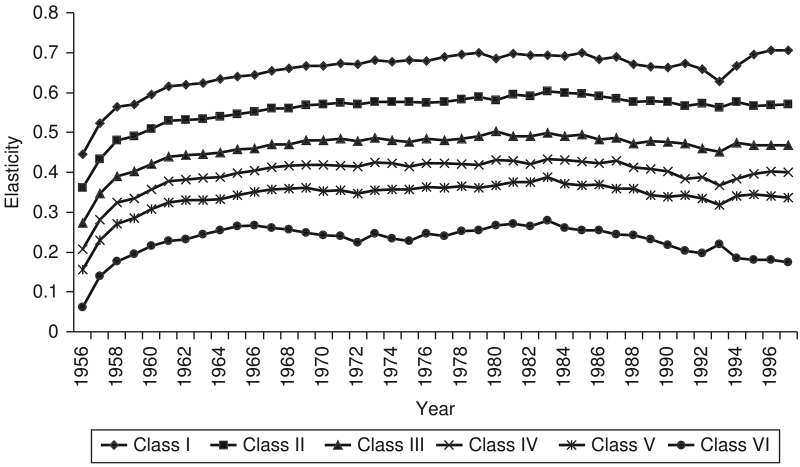

Figure 7.7 Impact of changes in the stock of technological knowledge on the variable profits for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (7.3).

study period 1956–97 and are presented in Figure 7.7. Some intriguing findings emerge from Figure 7.7.

To begin with, as was expected, the magnitudes and development are very similar to those of the impacts of increases in the stock of technological knowledge (Z_R) on the supply of output (Q) presented in Figure 7.2. At least two findings are noteworthy from Figure 7.7.

First, according to Figure 7.7, it is clear that the smaller the farm sizes, the larger the impacts of changes in Z_R on the amount of variable profits VP'. In particular, the smallest size class (I) had the largest impact of changes in Z_R on VP' for the entire period 1956–97; the magnitudes of impacts in terms of elasticity ranged from around 0.43 in 1956 to around 0.68 in 1997, indicating that small-scale farms were fairly responsive to improved technologies developed in public agricultural experiment and extension institutions in rice production. On the other hand, the impacts in the largest size class (VI) ranged from around 0.06 in 1956 to 0.24 in 1966 and since then had a stagnant or decreasing trend towards the late-1990s. We may conjecture, based on these results, that small-scale farms would have had weak incentives to transfer their paddy lands to large-scale farms.

Second, we found in Figure 7.7 another intriguing feature. That is, the impacts of changes in Z_R on the amount of variable profits VP'

in all size classes had increasing trends from 1956 to the mid-1980s; up to 1966 in size class (VI); up to 1969 in size classes (III), (IV), and (V); up to 1979–85 period in size classes (I) and (II). Since those years towards the late-1990s, the impacts became stagnant in all size classes; the largest size class (VI) (and the second largest size class (V)) even had decreasing trends in the impacts for the period 1983–97. This finding may reflect that public R&E activities associated with the rapid smaller-scale M- and BC-technological progress were prevalent and had strong progressive effects on increases in the amount of variable profits (VP') in all size classes for the period from the mid-1950s to around the period 1983–85. However, roughly speaking, after 1983, the impacts of public R&E activities (Z_R) on the amount of variable profits (VP') became stagnant in spite of the rapid introduction of medium- and larger-scale M-technologies in all size classes; in particular, the impact of changes in the largest size class (VI) had a steady decreasing trend for the period 1983–97, while that in the smallest size class (I) had an increasing trend for the period 1993–1997.

Based on these findings, we may infer that increased technological knowledge (Z_R) might have restricted the transfer of paddy lands from small- to large-scale farms because small-scale farms had more favorable benefits from public R&E activities than did large-scale farms.

At this point, again, we will recall that we found that the smaller the size class, the larger the impacts of changes in the price of rice on the supply of rice for the entire study period 1956–97 (refer to Figure 4.5 in Chapter 4). This indicates that the rice price-support policies had a negative effect on transferring paddy lands from small- to large-scale farms.

From these findings, we may conclude that policies, both for the support of rice prices and for R&E activities, may have limited the transfer of paddy lands from small- to large-scale farms. This in turn may have restricted the possibility of larger-scale rice farms with higher productivity and efficiency, not only in Tohoku but also all over Japan during the second half of the 20th century.

7.3.1.4 Impacts of changes in R&E on the degrees of returns to scale

Using Equation (7.4), the impact of changes in the stock of technological knowledge (Z_R) on the degree of returns to scale (RTS) was estimated for all observations of all six size classes for each year of the entire study period 1956–97. The results are presented in Figure 7.8. At least two findings are noteworthy based on this figure.

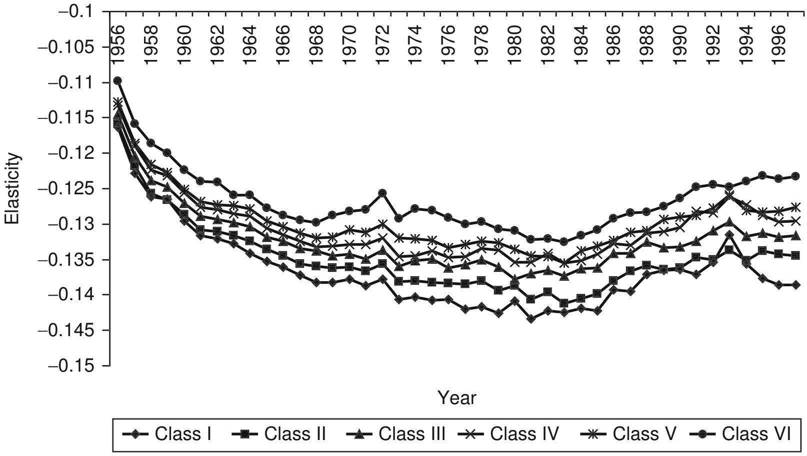

Figure 7.8 Impact of changes in the stock of technological knowledge on the degrees of returns to scale for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (7.4).

First, we observe that the impacts in terms of elasticities were negative in all six size classes. This can be interpreted as follows. An increase in the stock of technological knowledge (Z_R) will induce farmers to produce more rice, indicating that the amount of rice production will get closer to the minimum efficient scale (*MEOS*), at which the average cost reaches its minimum. This will in turn lead to a reduction in the degree of returns to scale in rice production since the ratio of the average to marginal costs ($RTS = AC/MC$) will approach to unity.

Second, it is clear from Figure 7.8 that, in absolute terms, the smaller the size classes, the greater the impacts of changes in Z_R on the degrees of *RTS*. This implies that although the AC/MC ratios came closer to unity in all size classes, the speeds of approaching to the *MEOS* by smaller-scale farms were faster than the speeds by larger-scale farms. This indicates that the differentials in the degrees of scale economies between small- and large-scale farms may have shrunk, which may have promoted the transfer paddy lands from small- to large-scale farms. We may thus conjecture that such a mechanism may have happened during the study period 1956–97, though the elasticities were fairly small, ranging from around −0.109 in 1956 in size class (VI) to around −0.148 in 1981 in size class (I).

Again, however, we should here recall that all the impacts of the public R&E programs on (i) the quantity of the rice supply, (ii) the quantities of the variable factor demands, (iii) the amount of variable profits, and (v) the shadow value of land (which will be interpreted immediately after this subsection) were restrictive in transferring paddy lands from small- to large-scale farms. As a result, regarding to paddy land movements, the sum of the strong negative effects on these four economic indicators totally overwhelmed the positive effect of the public R&E programs on (iv) the degrees of returns to scale.

7.3.1.5 Impacts of changes in R&E on the shadow value of paddy land

The impact of changes in the stock of technological knowledge (Z_R) on the shadow value of paddy land ($w_B^{S'}$) was estimated using Equation (7.6) for all observations of all six size classes for the entire study period 1956–97 and are presented in Figure 7.9. Several findings are worth interpreting based on this figure.

First, the impacts of changes in the stock of technological knowledge (Z_R) on the shadow value of paddy land ($w_B^{S'}$) increased for the period 1956–58 in all six size classes and since then until 1997 had stagnant or decreasing trends in all size classes except for the largest size class (VI).

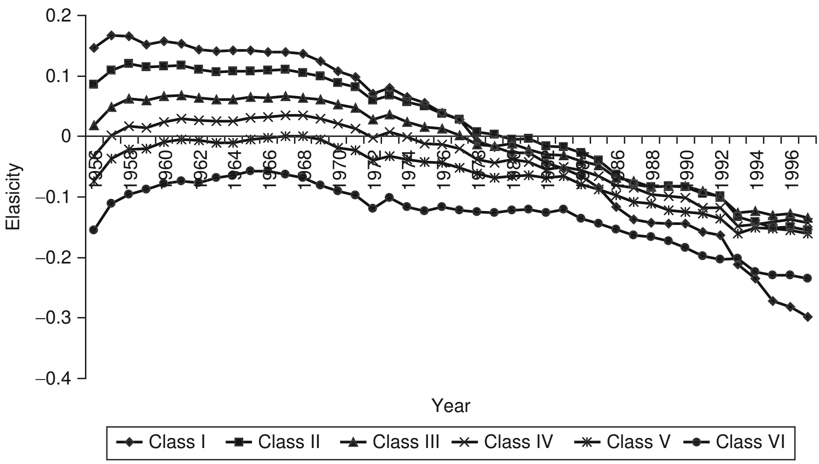

Figure 7.9 Impact of changes in the stock of technological knowledge on the shadow value of paddy land for 1956–97: all size classes (Tohoku)

Note: The impact for each size class was estimated using Equation (7.5).

This implies that the effects of R&E investments on raising $w_B^{S'}$ became weaker and weaker in all size classes for the period 1958–97 except for the largest size class (VI).

Second, in larger size classes (V) and (VI), the impacts were negative for the entire study period 1956–97. This indicates that public R&E activities worked in the direction of reducing the shadow values of paddy lands in size classes (V) and (VI) and such negative effects became stronger and stronger over time during the entire study period.

Third, the impacts in smaller size classes (I), (II), (III), and (IV) were in the beginning positive but became negative as time passed: from 1974 to 1997 for size class (IV); from 1978 to 1997 for size classes (I) and (III); and from 1982 to 1997 for size class (II). This finding indicates that, before those years, increases in Z_R had positive effects on the shadow values of land $w_B^{S'}$ in all four size classes except for 1956 in size class (IV). But, after those years towards the late-1990s, increases in Z_R had negative effects on the shadow values of land $w_B^{S'}$ in all four size classes.

Fourth, as clearly observed in Figure 7.9, the smaller the size classes, the greater the impacts for the whole period 1956–97, except for size class (I) for the period 1978–97 during which the negative effect increased most sharply in absolute terms.

These findings indicate that public R&E activities worked in the direction of shrinking the gaps of the shadow values of paddy lands between small- and large-scale farms during the entire study period 1956–97. This in turn suggests that increases in the stock of technological knowledge thanks to public R&E investments might have limited the transfer of paddy lands from small- to large-scale farms, which probably made agricultural structural transformation more difficult. This result is analogous to that of the price-support programs which may have restricted transfers of paddy lands from small- to large-scale farms during the study period as shown in Figure 4.7 of Chapter 4.

7.4 Summary and concluding remarks

This chapter has offered further results based on the estimates of the single-product translog VP function with labor and land being the quasi-fixed factor inputs for Tohoku for the period 1956–97 presented in Chapter 3. This chapter has evaluated the impacts of changes in the stock of technological knowledge (Z_R) on (1) the supply of rice, (ii) the demands for variable factor inputs, (iii) the amount of variable profits, (iv) the degrees of returns to scale, and (v) the shadow value of paddy land.

We have found in all examinations that public R&E investments yielded more favorable benefits to small-scale farms than to large-scale farms. Based on these empirical findings, we may conjecture that public R&E investments may have contributed to slowing down the speed of transfers of paddy lands from small- to large-scale farms during the last three to four decades of the 20th century in Tohoku.

We may conclude based on these findings that, in order to drastically change the existing structure of small-scale inefficient rice farming to that of much larger-scale efficient and productive rice farming, the government has to reconsider and reshuffle its application of various R&E activities so as to give much stronger incentives to larger-scale farms.

8
Summary and Conclusions

This book is composed of Part I and Part II. Part I focused on the macroscopic statistical observations and investigations of Japanese and Tohoku agriculture by looking, in particular, at changes in the quantities and prices of both outputs and inputs, transfers of farmland, agricultural budgets, and movements of public agricultural R&D and extension investments for improved crops and livestock for the second half of the 20th century; more specifically, the period 1956–97. Based on careful observations of these data, Part I shed a special light on quantitative investigation by analyzing econometrically the production structure of the rice sector, which is still the most important agricultural sector in Japan, although the share of production of rice in the total agricultural production has been steadily declining over time. Almost all farmers produce rice, it has deep roots in Japanese culture and offers beautiful scenic views in rural areas, with paddy fields doubling as dams against floods, and more. Therefore, it is academically intriguing and politically important to accurately capture the production structure of the rice sector through quantitative analyses; the behavior of rice supply, demands for factor inputs of production, rates and biases of technological change, and so on.

To be more specific, the major objective of Part I was to execute a comprehensive quantitative investigation on the technology structure of rice production. To do this, we introduced two different frameworks: the VC and VP functions – *duals* of the production function. The first approach introduced in Chapter 2 was the VC function framework: with labor and land were treated as quasi-fixed factor inputs and were developed and estimated for the second half of the 20th century, in particular, 1956–97 using a pooled cross section of time series data for Tohoku as a representative rice producing agricultural district in Japan. In this case, however, two different specifications of the VC function were distinguished because of the serious multicolinearity problem between the two variables which were introduced to capture the rates and biases of technological change; (a) a time index *t* to capture the overall technological change and (b) the public stock of technological knowledge estimated based on the expenditures on R&D and E activities in the governmental experiment and extension institutions. We named these two different VC function models Model (A) and Model (B).

In Chapter 3, as another approach to quantitatively investigate the production structure of the rice sector of Tohoku, the VP function model was introduced where labor and land are employed as the quasi-fixed factor inputs as in the case of the VC function approach. As with the VC function Model (B) in Chapter 2, we stuck to the stock of technological knowledge as a proxy for technological change since we were going to evaluate the impacts of the public R&E activities as an important agricultural policy. The major features of this chapter were to estimate (i) the own-price supply elasticity of rice, (ii) the demand and substitution elasticities of the variable factor inputs, (iii) the amount of variable profits, (iv) the degrees of returns to scale, and (v) the shadow price of paddy land. It must here be stressed that the estimation of these economic indicators based on the VP function model had another important role, as a preparation for the empirical estimation and evaluation of governmental agricultural policies, such as rice price-support, set-aside, factor input-subsidies, and R&E programs, on the above-mentioned five economic indicators.

The major findings of two Chapters 2 and 3 are summarized below.

In Chapter 2, the estimated parameters and economic indicators were in general very similar between the two VC function models except for the development of technological change. The input-saving “rate” of technological change based on Model (A) was fairly high during the mid-1950s through the early-1970s but since then stagnated until the late-1990s. On the contrary, the input-saving “rate” of technological change based on Model (B) was very low during the late-1950s but increased sharply until the early-1980s and after that turned out to be stagnant until the late-1990s.

Second, for the other economic indicators – such as factor demand and substitution elasticities, scale economies, and the technological change biases – the two VC function models yielded in general very similar and robust results. In particular, the degrees of scale economies were around 1.07 during the 1950s and 1960s and increased since then to around 1.13 in the late-1990s. Such movements may have been intimately related to the transition of small-scale to medium- and larger-scale mechanization of rice production during the study period 1956–97.

Third, the estimated shadow values of land for all six different size classes of Tohoku were in general greater than the land rent, which was regulated by the government for the entire study period 1956–97. So, the government-regulated land rent cannot be regarded as the "market" price of land. This in turn implies that approaches based on a TC function where all factor inputs are assumed to be at optimal level may cause serious biases in the results and hence in the derived policy implications.

Based on these findings, we may at this stage conclude as follows. To begin with, it may be correct to have introduced the VC function framework rather than the TC function framework in order to obtain more reliable and robust results in various important economic indicators. Above all, the existence and increasing trend of scale economies, as well as the large differentials in the shadow value of paddy lands between small-scale and large-scale farms, may indicate that small-scale farms were ready to transfer their paddy lands to large-scale farms. In reality, however, land movements were very slow during the study period 1956–97. Furthermore, it seems to be critical not only for farmers themselves but also for research and extension people to make more serious efforts to make rice farming in Japan more efficient and productive on larger-scale farms.

Part II focused on the quantitative investigation of the impact of four important policies on the five critical economic indicators, derived in Chapter 3 of Part I, with a view to examining the possibility of transforming the low-efficient and low-productive operations of rice production on small-scale paddy lands to much more-efficient and productive large-scale paddy lands.

More specifically, we estimated quantitatively and evaluated the impacts of (1) the rice price-support programs (Chapter 4), (2) the set-aside programs (Chapter 5), (3) the factor inputs-subsidy programs (Chapter 6), and (4) the public agricultural R&E programs (Chapter 7) on the above-mentioned five economic indicators for the entire study period 1956–97. One point we should emphasize here is that this study estimated all five economic indictors as well as the impacts of the policy variables on them for all samples of all six size classes for the entire study period 1956–97. In addition, all the impacts estimated were expressed in terms of elasticities and were presented in the form of graphs so that the reader can easily capture the magnitude of the effects of the policy instruments among different size classes of farms and their development for the entire study period 1956–97.

We found, through the empirical estimation of the shadow value of paddy lands for different size classes, that it was feasible for small-scale farms to transfer their land by renting it to large-scale farms; at least, for the period 1974–97. Behind this finding, we emphasized to treat the "firm-household complex" as the "farm-household" instead of the "farm-firm". The "costs" of labor and land are basically part of the "farm-firm's" costs. However, those "costs" accruing to the farm-owned family labor and land may be considered to be part of household income for the "farm-household". Thus, in order to examine the possibilities of land transfers from small- to large-scale farms, this narrowly defined "farm income" of the small-scale farm should be compared to the shadow value of large-scale farm land. When this norm was applied to our case, the shadow value of paddy land on large farms overwhelmed the "farm income" of small-scale farms between 1974 and the late-1990s. Many small-scale rice farms seem to have been ready to transfer their paddy lands to large-scale rice farms during the last quarter of the 20th century in Tohoku.

In reality, however, land movement in Tohoku was considerably inactive, against our expectations, according to the above empirical findings. So, we then hypothesized that government agricultural policies – in particular, rice price-support, set-aside, subsidies, and R&E activities – may have been intimately related to the lack of land transfers in Tohoku.

Accordingly, in Chapter 4 we quantified the impact of rice price-support and set-aside programs the five economic indicators based on the parameter estimates of the translog VP function specified in Chapter 3. We found in almost all cases that the price-support and set-aside programs yielded most positive effects on small-scale farms, rather than on large-scale farms. Based on these empirical findings, we may conjecture that the rice price-support and set-aside programs may have been responsible for the slow transfer of paddy lands from small- to large-scale farms during the last three to four decades of the 20th century in Tohoku.

Chapter 6 investigated the effects of factor input-subsidies on the five economic indicators as estimated similarly in Chapters 4 and 5. Theoretically speaking, government subsidies associated with purchasing variable factor inputs by farmers may be considered to be equivalent to lowering the prices of factor inputs such as machinery, intermediate, and other inputs. Thus, the major objective of Chapter 6 was to quantitatively estimate and evaluate the impacts of reductions in the prices of factor inputs on the five economic indicators listed above from the viewpoint of the possibility of agricultural structural transformation for more productive and efficient rice farming in post-war Japanese agriculture.

We found in almost all examinations, except for returns to scale, that factor input-subsidies were most favorable for small-scale farms. Based on these empirical findings, we may conjecture that factor inputs-subsidy programs may have restricted the transfer of paddy lands from small- to large-scale farms during roughly the last three to four decades of the 20th century in Tohoku.

Chapter 7 investigated the effects of public agricultural R&E activities on the five economic indicators again as estimated similarly in Chapters 4, 5, and 6. We found that public R&E investment also yielded most favorable benefits to small-scale farms rather than to large-scale farms. Based on these empirical findings, we may conjecture that public R&E investment may have slowed the transfer of paddy land from small- to large-scale farms.

We may finally conclude, based on the empirical findings of Chapters 4, 5, 6, and 7 that, in order to drastically change the existing structure of small-scale-inefficient-low-production rice farming to that of much larger-scale-efficient-highly-productive rice farming, the government – in particular, the MAFF – has to remodel and reconstruct its policy instruments – such as, price-support, set-aside, factor input-subsidies, and R&E programs – so as to give much stronger incentives to highly-motivated larger-scale farms for more productive and efficient rice farming.

Here, the author should mention some caveats.

First of all, the data used throughout this book has been only for the Tohoku agricultural district, which is the Northernmost region of Mainland Japan. As the author mentioned at the outset of this book, the author found after a tremendous numbers of estimations of the three models used in this book for altogether 11 agricultural districts that Tohoku could be the most representative for rice production in Japan, except for the Hokkaido district which has different size classifications. Although the author has very strong confidence in the results obtained in this book, one can of course challenge for better estimations by introducing different models: such as Generalized Cobb–Douglas, Generalized Leontief, Quadratic, and so on.

Second, when it comes to explaining the data used, the author wishes that he could have extended the observation periods to, say, 20 more years – from 1991 through to 2010. This might have given slightly different results from the ones obtained in this book, though the author believes that the basic findings obtained in this book are robust, reliable, and trustworthy, and hence basically still applicable for the first 20 years or so of the 21st Century.

Third, the author would at this point like to confess that he obtained very similar results for considerably many other agricultural districts than Tohoku. However, the author definitely chose Tohoku for the present research totally based on his strong shock and complicated emotional feelings. After such a horrible disaster he could only view the damaged area with heart-rending sympathy, and at the same time, through the eyes of an agricultural economist, see the big opportunity to totally reconstruct Tohoku agriculture as soon as possible. I would dare disclose my sincere thinking that this could be a big chance for rice production not only in Tohoku but also in Japan as a whole to restart rice farming with much larger paddy lands – 100–500 ha – by reconstructing the earthquake/Tsunami damaged lands. The Tohoku Agricultural District could be a pioneering agricultural district. I do hope there are still highly-motivated farmers and government people who are eager to create a new agriculture in Tohoku as well as in Japan as a whole.

Notes

The Objectives of Part I

1 Tohoku is one of the 13 agricultural districts in Japan which is composed of Hokakaido and Tofuken agricultural districts (Hokkaido and Tofuken, respectively, in short hereafter). Tofuken is here defined as Japan excluding Hokkaido. To be more specific, Tofuken is composed of the following 12 agricultural districts; from north to south, Hokkaido, Tohoku, Hokuriku, Kita-kanto, Tozan, Minami-Kanto (these three together, Kanto), Tokai, Kinki, Sanin, Sanyo (these two together, Chugoku), Shikoku, Kita-Kyushu, and Minami-Kyushu (these two together, Kyushu). To be more accurate, Tohoku is the northernmost agricultural district of Tofuken.

1 Changes in Post-war Japanese Agriculture, Problems Setting up, and the Analytical Framework

1. The details of the sources of data for public R&D and extension (R&E) expenditures and the procedure to obtain the R&E capital stock are presented in Appendix A of Chapter 2. Incidentally, we use the terms "the R&E capital stock" and "the stock of technological knowledge" interchangeably in this book.
2. The detailed expositions of the derivations and features of the VC functions will be presented in Chapter 2.
3. The terminologies "shadow price", "shadow value, and "marginal productivity" of farmland (or paddy land) are interchangeably used as equivalent throughout this book.
4. The references for this chapter are mainly statistics yearbooks which will also be used in the following chapters. Accordingly, they will be listed up in the "References" section in front of the "Index" section as the last part of this book.

2 Technology Structure of the Rice Sector of Japanese Agriculture: (I) A Translog Variable Cost (VC) Function Approach

1. The major sources of data used in these previous and the present studies are the *Kome oyobi Mugirui no Seisan-Hiyo Hokoku* [the *Survey Report on Production Costs of Rice, Wheat, and Barley*] (RCRWB in short hereafter) and the *Noson Bukka Chingin Chosa Hokoku* [the *Survey Report on Prices and Wages in Rural Villages*] (PWRV in short hereafter) published annually by the MAFF.
2. Oi (1962) explains in detail the logic of why it is more realistic to treat labor as a quasi-fixed factor input.
3. The Stevenson (1980)–Greene (1983) (S–G) type translog VC function was, needless to say, estimated both for Model (A) and for Model (B) which will be exposed below, the results were not satisfactory in terms of the curvature conditions. On the contrary, the ordinary translog VC function satisfied major conditions such as the curvature, monotonicity, goodness-of-fit conditions, so that this chapter decided to stick to the ordinary VC function models.
4. As exposed clearly in Appendix A of this chapter, we can fortunately obtain the wage rate per male-equivalent hour for all observations for all size classes. Generally speaking, family labor and temporary-hired labor engage in similar works. This may allow the assumption that the shadow price of family labor be imputed by the wage rate of temporary-hired labor.
5. More detailed explanations for the case of a multiple-product VC function Model (A) are presented in Kuroda (2008).
6. For more rigorous expositions of *extended* Hicks neutrality, refer to Blackorby, Lovell, and Thursby (1976), Blackorby, Primont, and Russell (1978), Halvorson and Smith (1984), and Antle and Capalbo (1988).
7. The superscripts A, M, and S in Equations (2.26) through (2.29) stand for AES, MES, and SES, respectively.
8. These "rates" are neither the generally defined rates of technological change nor the "rates" expressed in terms of generally defined "elasticities". Furthermore, CCS (1981) do not use a specific term for such a "rate" in their paper. Thus, we are going to call this "rate" as "a productivity index" ("index" in short).
9. Antle and Capalbo (1988) defined the biases in terms of percentage rates instead of elasticities.

10. Needless to say, we will apply the same procedure to Model (B).
11. Detailed expositions on technological change biases will be given in the next subsection.
12. Returns to scale can be estimated at the approximation points by $RTS = (1 - \beta_L - \beta_B)/\alpha_Q$ both for Model (A) and for Model (B).
13. Kuroda (2009) offers more detailed expositions of the ordinary and Stevenson (1980)–Greene (1983) (S–G) multiple-product TC function models used to construct Table 2.8 as well as the different features of the *AES*, *MES*, and *SES*. Note furthermore that both the ordinary and S–G models were estimated based on the pooled cross section of time series data obtained from the FHE for the period 1957–97 instead of the RCRWB.
14. Kako (1979a) and Chino (1984) obtained similar results but did not give any explanations on the findings.
15. We applied the same procedure to Model (B) (refer to Equation (2.43)) and obtained a very similar picture as in the case of Model (A). Thus, we will focus on the result obtained from Model (A) to save space.
16. As a matter of fact, we estimated the shadow values of labor for all observations in all size classes for the study period 1956–97. The results were that in each size class the estimated shadow value of labor and actual wage rate of temporary-hired labor were very close to each other for the entire 1956–97 period. This may be a natural consequence from the assumption with regard to labor input introduced in the present study.
17. Kusakari (1989) estimated the shadow values of paddy lands based on the parameter estimates of a variable profit function with labor and land being quasi-fixed factor inputs for rice production for the period 1958–86. He pooled data in two dimensions using the RCRWB as the major source of data; (i) Tohoku and Hokuriku both of which are representative rice producing districts in Japan; and (ii) the five size classes for the period 1958–86 excluding the smallest size class (I) (0.3–0.5 ha) in the present study.
18. Although the present author applied the Kulatilaka's method, the results were not satisfactory.
19. This assumption is based on the present author's personal interviews and discussions with extension people.

3 Technology Structure of the Rice Sector of Japanese Agriculture: (II) A Translog Variable Profit Function Approach

1. The terms "shadow price", "shadow value", and the "marginal productivity" of land (or paddy land) are used interchangeably in this chapter.
2. Detailed expositions on the treatment of labor as a quasi-fixed factor input are presented in Oi (1962).
3. Details of the variable definitions are presented in Appendices A and B of Chapters 2 and 3, respectively.
4. Instead of introducing this kind of device, the labor cost-variable profit share equation should ideally be treated as an endogenous equation in the system. However, if we do so, we face a serious problem that many samples, in particular, of smaller size classes have negative profits if labor costs together with the other variable factor costs are subtracted from total revenue. Since this chapter employs the translog specification, we have to give up too many observations particularly from smaller size classes in the econometric estimation of the system. Of course, we could try to apply a quadratic profit function model under such a situation.
5. As exposed clearly in Appendix A of Chapter 2, we can fortunately obtain the wage rate per male equivalent hour for all observations for all size classes. Generally speaking, family labor and temporary-hired labor engage in similar works. This may allow that the shadow price of family labor may be imputed by the wage rate of temporary-hired labor.
6. We have introduced similar test procedures for hypotheses in the case of the translog VC function employed in Chapter 2.
7. For a detailed discussion of *almost* homogeneous functions in the economics context, refer to Lau (1978).
8. Note that $\kappa > 0$ for a production function.
9. However, one has to be very careful to apply Sidhu and Baanante (1981) formulas because of some minor mathematical errors.
10. Actually, we estimated the shadow value of labor for all observations in all size classes for the study period 1956–97. The results were that in each size class the estimated shadow value of labor and actual wage rate of temporary-hired labor were fairly close to each other in all six size classes for the entire 1956–97 period, which may be a natural consequence from the assumption with regard to labor input introduced in this chapter.

11. As exposed in Appendices A and B of Chapters 2 and 3, respectively in detail, some modifications for variable definitions were carried out in order to take care of the discontinuity of data for the period 1991–97, in particular, the depreciations of capital stock such as machinery, large animals and plants, and farm buildings and structures. Due probably to these modifications of the data set, the estimated parameters have somehow changed from those of the previous similar study (Kuroda and Abdullah, 2003). In particular, all of the coefficients of the dummy variables of the present study were not statistically significant, and hence they were omitted from the final estimation.
12. Refer to Lau (1976) and Hazilla and Kopp (1986) for details on the curvature conditions.
13. Much more comprehensive evaluations of the rice price-support programs will be presented in Chapter 4.
14. He also obtained the long-run own-price supply elasticities for other crops; wheat (0.794), vegetables (0.198), fruit (0.128), cattle (0.576), milk (0.923), pigs (0.601), and eggs (0.175).
15. The effects of policy measures such as subsidies for factor inputs and set-aside programs will fully be evaluated in Chapters 5 and 6, respectively.
16. This result is contradictory to that obtained in Chapter 2 where the translog VC function with only land being a fixed factor input was estimated for the same study period 1956–97. As we observed in Subsection 2.5.3.3 of Chapter 2 of this book, although the magnitude of the differences were as small as around 0.01 in terms of elasticity, we obtained the result that the smaller the size classes, the greater the degrees of scale economies. The major reason for this contradiction may have come from the differences in the approaches employed in the two different Chapters 2 and 3; i.e., the VC and VP functions, respectively. To be more specific, for the VC function approach the quantity of the output level is assumed to be fixed, while for the VP function approach it is not fixed. Thus this difference coming from the different functional specifications may have caused the estimated results in the degrees of returns to scale though very minor. Although it is a very intriguing issue from the view points not only of the economic theories but also of the empirical estimations, we will not go further in this book to investigate such an issue. Instead, the point we should emphasize here is just to recognize the fact that there existed economies of scale in all six size classes for the entire

study period 1956–97 based on the estimation of *RTS* either by the translog VC or by the translog VP function models.

17. In fact, we can obtain the actual land rent for each size class from the RCRW for the study period 1956–97 and there are some differences in the estimated land rents among the six different size classes. As a matter of fact, we observe that the larger the size classes, the larger the "market" land rents. However, the differences are minor.
18. It has been popular among agricultural economists in Japan to define so-called "farm income" as

$$FI = \sum_i P_i' Q_i - (w_M' X_M + w_I' X_I + w_O' X_O).$$

It may be very clear that the sum of the last two terms in the parentheses of the above equation, i.e., $w_L' X_L^H + w_B' Z_B^R$, cannot be ignored as the values of hired labor and rented land become larger.

19. The term "rent-bearing capacity" has often been used by Kajii (1981), Shintani (1983), Kako (1984), Chino (1990), and Kondo (1998) to name only a few.

4 The Impacts of the Rice Price-Support Programs on the Structural Transformation of the Rice Sector

1. For empirical evidence of the existence of economies of scale in post-war Japanese rice production, see Kako (1983, 1984) and Chino (1984) to name only a few.
2. For details on the expositions of theory for land prices and technological change, see Herdt and Cochrane (1966) and Van Dijk, Smit, and Veerman (1986).
3. Since this interpretation may be a little confusing, it will be helpful for the reader to recall that we found in Figure 3.1 of Chapter 3 that the smaller the size classes, the greater the degrees of scale economies.

5 Impact of the Set-Aside Programs on the Agricultural Structural Transformation of the Rice Sector

1. To be more accurate for the history of the rice price-support programs, the MAFF set the producer price of rice to be higher than the consumer price of rice (so-called a "dual pricing system") by modifying

partly the “Staple Food Control Law” in 1952 (Terukuni, S. ed., 2003). However, the MAFF employed more serious rice price-support programs since the early-1960s.

2. Since the estimates of size classes (IV), (V), and (VI) were unusually large for the period 1956–63, the elasticities of all size classes were omitted from the figure. In this way, we can observe much more clearly the differences in the impacts among the six size classes, in particular, for the period 1972–97.
3. In order to understand the logic behind this interpretation, we should recall that we found in Figure 3.1 in Chapter 3 that the larger the farm sizes, the greater the degrees of scale economies.

6 The Impacts of Factor Inputs-Subsidies on the Agricultural Structural Transformation of the Rice Sector

1. The sources of data are the *Hojokin Soran* [the *Conspectus of Subsidies*] published annually by Nihon Densan Kikaku Inc. and the “Finance for Agriculture, Forestry, and Fisheries” reported in the *Norin Suisan-sho Tokei-hyo* [the *Statistical Yearbook of Ministry of Agriculture, Forestry, and Fisheries*] published annually by the MAFF. Furthermore, detailed descriptions with many statistical data and figures on agricultural budgets are presented in Ishihara (1997).
2. As a matter of fact, the same claim may be applicable on the international base not only for rice but also for agricultural products in general.
3. The section which explains the data and estimation procedure and an appendix which presents the definitions of the variables used for the VP function model is the same as those in Chapter 3. Thus, they were omitted in this chapter.
4. Indeed, it is far more complicated and awfully time-consuming to compile the necessary price data for the three variable factor inputs defined in the present study ($w_k^{'}$, $k = M, I, O$) than in the case of compiling data for price supports for rice.
5. Recall that the test result of the hypothesis of the convexity conditions with respect to the variable factor inputs (X_k, $k = M, I, O$) were satisfactory (Section 3.4.1, Chapter 3).
6. Since the VP function employed in this chapter is a short-run profit function, it is implicitly assumed here that both the AC and MC curves do not shift along with changes in the quantity of output (rice).

7 The Impacts of Public Agricultural R&D and Extension (R&E) Programs on the Agricultural Structural Transformation of the Rice Sector

1. We copied here Figures 1.5 and 1.6 in Chapter 1. Needless to say, the details of the sources of data for public R&E expenditures and the procedure to obtain the R&E capital stock are presented in Appendices A and B of Chapters 2 and 3, respectively. Incidentally, we use the terms "the R&E capital stock" and "the stock of technological knowledge" interchangeably in this chapter.
2. As a matter of fact, the same claim may be applicable on the international base not only for rice but also for agricultural products in general.
3. The section which explains the data and estimation procedure and an appendix which presents the definitions of the variables used for the VP function model are the same as those in Chapters 3 through to 6. Thus, they were omitted in this chapter to save space.

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