Essays on the Economics of Food Production and Consumption in Vietnam

A DISSERTATION
SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
OF THE UNIVERSITY OF MINNESOTA
BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

ADVISOR: PAUL W. GLEWWE

December 2008

ACKNOWLEDGMENTS

I wish to thank my adviser, Prof. Paul W. Glewwe for his intellectual support and his wonderful encouragement throughout the Ph.D. Program in Department of Applied Economics, University of Minnesota. Without his understanding and encouragement, this dissertation would not have been materialized. I would like to thank Prof. Kent D. Olson, who was my research supervisor in three years. I am grateful for his support and kindness in helping me at every stage of my research. Thanks are also to Prof. Philip Pardey, Prof. Terrance Hurley and Prof. Thomas J. Holmes for serving as my committee members, whose generous suggestions and comments were extremely invaluable to this dissertation. I am grateful to Prof. Benjamin Senauer for having read several chapters in my thesis and giving me invaluable comments and suggestions.

I am grateful to the Department of Applied Economics for its wonderful program and its financial and intellectual support during my Ph.D. program. I also wish to thank Carrie Turk of the World Bank, who provided extremely helpful suggestions and comments on chapter 6 in this thesis.

Finally, my thanks go to my beloved parents and brothers for their love and support, to my friends in the United States and in Vietnam, especially Dương, Lê, Hà, Phương, Quỳnh, Trang, for their understanding and encouragement. Without their support, it would have been impossible for me to finish the program.

Dedicated to my beloved parents,

my loving brothers,

and my wonderful friends: Hà, Phương, Quỳnh.

ABSTRACT

This study aims to provide an in-depth understanding of the economics of food production and consumption in Vietnam. Specifically, the study is comprised of five essays, covering several aspects of agriculture and food consumption in Vietnam.

The first essay studies agricultural productivity growth in Vietnam, using province-level data. It concludes that total factor productivity (TFP) growth in agriculture contributed greatly to Vietnam's agricultural success after it adopted reform policies. However, TFP growth has slowed in recent years, despite significant output growth.

The second essay examines the productive efficiency of rice farming households in Vietnam, using two methods, Data Envelopment Analysis (DEA) with bootstrap and Stochastic Frontier Analysis (SFA). It points out that there is variation in efficiency estimates across regions in Vietnam. Moreover, technical efficiency is significantly influenced by primary education and regional factors.

The third essay estimates household food demand parameters in Vietnam, based on a recent household survey conducted in 2006. The results indicate that that food consumption patterns in urban and rural areas, and across regions and income groups, are quite different. This implies that targeted food policies should be formulated based on the specific food demand patterns of those groups. Socio-economic factors such as household size and composition, as well as the age of the household's head and education, have sizeable and statistically significant effects on food consumption.

The fourth essay focuses undernutrition and food security in Vietnam. The income elasticity of calorie consumption is estimated using both parametric and non-parametric regressions. The finding of positive and significant calorie-expenditure elasticity implies that income growth can alleviate undernutrition

Finally, the fifth essay examines the impacts of rising food prices on poverty and welfare in Vietnam. Increases in food prices raise the real incomes of those selling food, but make net food purchasers worse off. Overall, the net impacts on an average Vietnamese household's welfare are positive. However, the benefits and costs are not evenly spread across the population, so some households are made better off while the others are worse off.

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CHAPTER 1: INTRODUCTION

After its reunification into a single country in 1975, Vietnam was one of the poorest countries in the world. During the period 1975-1985, there was little progress in the economy, and in 1985, its gross domestic product (GDP) per capita is estimated to be among the five lowest in the world (Glewwe 2004).

Yet, beginning in the late 1980s, Vietnam has been one of the fastest growing countries in Asia. Its annual economic growth is estimated to be 6.9 percent during 1988-94, 7.4 percent during 1994-2000 and 7.6 percent during 2000-07 (Glewwe 2004, and Vietnam General Statistics Office's data). As a result, GDP per capita has increased by 5-6 percent annually since 1988. In addition, the poverty rate has fallen sharply, from 58 percent in 1993 to only 16 percent in 2006. Thus, over 40 percent of the total population, the equivalent of more than 30 million people, were lifted out of poverty in just 13 years. From one of the poorest countries in the world, Vietnam has transformed itself into one of the most successful countries in the world in terms of economic growth and poverty reduction.

Agriculture is considered a basis of Vietnam's success. Many authors (Minot and Goletti 1998, Benjamin and Brandt 2004, Dang et al. 2006) argued that agricultural trade liberalization in late 1980s contributed greatly to raising both food production and rural households' welfare. From a net food consumer in the early 1980s, Vietnam became one important food exporters in the world in the 1990s. Vietnam is now one of the three largest rice exporters in the world. As a result of increasing income, domestic food consumption patterns have also changed in the past decade.

In this context, an in-depth understanding of the economics of food production and consumption in Vietnam is very important to enhance our understanding of the role of agriculture in increasing economic growth, reducing poverty and improving food security and nutrition in Vietnam. This is the purpose of this study.

This chapter is structured into three sections. Section 1.1 describes the objectives of the study. Section 1.2 is an overview of Vietnam's agricultural sector and of the Doi Moi (Renovation) policies that have transformed Vietnam from a centrally planned socialist system into a market-oriented economy. Section 1.3 describes the structure of the dissertation as well as the main contributions of each chapter.

1.1. Motivation and Objectives of this Study

This study is motivated by the lack of research on food production and consumption in Vietnam. Although agriculture as a whole has received some attention from researchers in Vietnam and abroad[1], there have been few attempts to study agricultural productivity, agricultural efficiency and food consumption patterns in Vietnam. For instance, to the knowledge of the author, there are no papers in any peer-reviewed journal on agricultural total factor productivity in Vietnam, and none on the estimation of food demand patterns or on the impact of food prices on poverty and/or nutrition. The main previous research on these issues include a International Food Policy Research Institute (IFPRI)'s research report by Minot and Goletti (2000)

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[1] Even research on agriculture is relatively modest. A search using the keywords "Agriculture" + "Vietnam" in IDEAS, an economic database composing of 250,000 working papers and 370,000 journal articles, yielded a total of only 29 economic research papers.

discussing food demand and the impact of rice prices on poverty, and a book chapter by Benjamin and Brandt (2004) that examines the impact of rice price changes on household welfare. The lack of empirical research on Vietnam's food production and consumption patterns is the major motivation for this study.

The broad objective of this study is to analyze various aspects of food production and consumption in Vietnam in order to provide useful insights for food policy as well as other policies aimed at improving agricultural growth and reducing poverty and undernutrition. The specific objectives of this study are:

1. Estimate agricultural productivity growth in Vietnam for the period 1985-2000.
2. Estimate the productive efficiency of household-based rice farming in Vietnam.
3. Estimate a household food demand system for Vietnam.
4. Determine how income can affect calorie and micronutrient intakes in Vietnam.
5. Assess the impact of income and food price changes on undernutrition in Vietnam.
6. Estimate the effects on household welfare and poverty from increases in food prices.

Thus, the results of this study are intended to contribute to a better understanding of some critical issues in Vietnam's food production and consumption. These results should be particularly useful in the formulation and implementation of food policy in Vietnam. For example, this study points out that agricultural productivity has slowing down in recent years, which should get greater attention from policy makers. The findings of this study are also helpful in the implementation of poverty reduction programs, health and nutrition programs, and social safety nets. In particular, the recent food crisis in 2007-08 is thought to have set back food security and nutritional status of hundreds of millions people in developing countries. In April, 2008, World Bank President Robert B. Zoellick stated that the rising food prices in 2008 might increase the number of malnourished people in the world by 44 million, reversing the achievements in worldwide poverty alleviation of the previous seven years. This study would contribute significantly to the debate on food crisis by analyzing the impacts of the surge in food prices on household welfare, poverty and nutrition in Vietnam.

1.2. The Doi Moi Process, Food Production and Consumption in Vietnam

In agriculture, Vietnam's reform process began in 1981 in response to a prolonged post-war crisis in its economy, especially in its agricultural sector. In 1981, the government introduced a policy that granted more autonomy to household producers in the form of output contracting, which was setting an output target level to households to fulfill. The initial success of that policy in agriculture, together with continued failures in the remaining State-owned agricultural and industrial sectors, led to the introduction of the Doi Moi (Renovation) in late 1986. In agriculture, a series of agricultural reforms were promulgated, effectively dismantling collective farms. In 1988, Resolution 10 was announced, granting households long-term use rights over land and freedom over many aspects of the production and marketing processes. Other reforms, including trade liberalization, soon followed, and the de-collectivization and liberalization in agriculture were *de facto* complete by 1990.

These Doi Moi market reforms have had profound effects on Vietnam's food production. Agricultural output grew steadily at a rate of 4.8 percent in 1989-1994, and at a 6.7 percent rate in 1995-99. Rice output increased at annual rate of 6.1 percent from 1987 to 2000. In 1989, for the first time in several decades, Vietnam exported rice, the dominant food staple consumed in Vietnam. Vietnam soon became one of the world's largest rice exporters. There has also been an impressive growth in rice yield, which grew at a rate of 3.3 percent from 1987 to 2000.

On the consumption side, there have also been major changes in the country's consumption patterns as household incomes increased. In 1993, rice and other food staples expenditure was 60 percent of total household food expenditure (Mishra and Ray 2006). In 2006, this study estimates that rice and other staples account for just 30 percent of total household food expenditure. In contrast, the expenditure share of meats increased from 11 percent of total food expenditure in 1993 to 21 percent in 2006. Benjamin and Brandt (2004) estimated that the average share of food away from home in Vietnam in 1993 constituted just one to two percent of household food expenditure in rural areas and from 6 to 10 percent in urban areas. In 2006, this study estimates that it was 7 percent in rural areas and 16 percent in urban areas.

1.3. Organization of the Study

This thesis is composed of seven chapters, covering the two major themes: the production and the consumption sides of the Vietnamese food economy. Chapters 2 and 3 study the food production aspect, whereas chapters 4, 5, and 6 examine the food consumption side. These five chapters can be considered as separate essays on food economics in Vietnam.

Chapter 2 is an analysis of Vietnam's agricultural productivity growth during the period 1985-2000. Studies of productivity growth are diverse, but many are based either on an index method or on a production function method, mostly using the Cobb-Douglass functional form. In my opinion, the Cobb-Douglas production function approach is inappropriate for estimating Vietnam's agricultural productivity since it assumes constant input share. Yet, evidence shows that the relative shares of inputs in Vietnam's agriculture have changed significantly since the market liberalization process that began in the mid-1980s. More specifically, farming in Vietnam has become more capital-intensive since 1980s. Among the index methods, the Malmquist index has a major practical advantage in that it can be estimated without price data, and price data are often missing, incomplete or unreliable in Vietnam. Moreover, the Malmquist index approach allows the decomposition of total factor productivity (TFP) growth into technical change and efficiency change. In Chapter 2, I use the Malmquist index approach and panel data for 60 provinces in Vietnam to examine changes in agricultural productivity and efficiency in Vietnam.

Chapter 3 presents a microeconomic analysis of agricultural production, using a sample of households to investigate the productive efficiency of rice farming in Vietnam. Differences among geographical regions in productive efficiency are highlighted. Chapter 3 also investigates the factors that influence farmers' productive efficiency. As the choice of the method may influence the results, this chapter applies both Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA). A recent improvement of the DEA method, DEA with bootstrapping, is also used in the chapter. Finally, a hypothetical Monte-Carlo simulation is conducted to check the robustness of estimates obtained from the DEA and SFA methods.

Chapters 4, 5 and 6 focus on food consumption. In chapter 4, I estimate the parameters for food demand in Vietnam, based on a recent household survey conducted in 2006. The most popular demand estimation model in the literature- the Almost Ideal Demand System (AIDS)-is used in this study. As the survey did not collect information on food prices, unit values are used instead of prices. The unit values are adjusted to reduce possible bias from quality effects and measurement errors. Finally, some demographic and community characteristics are included in the estimation to determine how those variables affect households' food demand.

Chapter 5 studies undernutrition and food security in Vietnam. Based on a cut-off calorie intake of 2100 calories per person per day, I calculate the prevalence of undernutrition in Vietnam. The income elasticity of calorie consumption is estimated, using parametric and non-parametric regressions, as well as the expenditure elasticities of proteins and micronutrient intakes. Finally, a simulation of income and price change shows the impacts of income growth and food price changes on the nutrition status of Vietnamese households.

Chapter 6 examines the impacts of rising food prices on poverty and welfare in Vietnam. Increases in the prices of food raise the real incomes of those selling food, but make net food purchasers worse off. Using simulated price changes of all food items and of rice alone, the chapter estimates the impact of food price changes on poverty and on average household welfare in rural and urban areas, and in different regions of the country. A simulation of the effects, calibrated to the price changes that occurred in 2007 and 2008 is also undertaken in this chapter.

Chapter 7 concludes the thesis. It discusses the main results as well as limitations and prospects for further studies on these issues.

CHAPTER 2: PRODUCTIVITY GROWTH IN VIETNAMESE AGRICULTURE: A MALMQUIST INDEX APPROACH

Abstract

This paper applies the Malmquist productivity index method to measure total factor productivity (TFP) growth in Vietnamese agriculture, using panel dataset that includes 60 provinces during the period from 1985 to 2000. The results indicate that most of the early output growth in Vietnamese agriculture (from 1985 to 1990) was attributable to TFP growth, in response to incentive reforms. During the period 1990-1995, the growth rate of TFP fell and Vietnam's agricultural growth was mainly attributable to a substantial increase in capital investment. In the last period, from 1995 to 2000, TFP growth increased again, though much lower than during the period from 1985 to 1990. Overall, TFP was estimated to grow at an annual average rate of 1.96 percent, contributing to 38 percent of Vietnam's agricultural growth. Yet, during the 1990s, TFP grew by only 1.2 percent and most of the country's agriculture output growth was attributable to an increase in the use of input. Therefore, reviving TFP growth will be a key factor for maintaining Vietnam's agricultural growth in the future. This study also shows the variation in TFP growth among provinces and regions within Vietnam. While the some regions achieved much success in increasing their output and TFP, other regions experienced decreases in TFP growth.

Keywords: Vietnam, agriculture, TFP, Malmquist, DEA, productivity.

2.1. Introduction

Ever since Vietnam launched its economic reforms in 1986, its economy has grown rapidly. From being a net importer of food during the early 1980s, Vietnam has now become one of the biggest rice exporters in the world. Agricultural output increased by 5.9 percent annually during the period 1988 to 2000, compared with 4.4 percent per year during the period 1975-1987. This growth in agricultural output has contributed greatly to improved household income in Vietnam, not least as about 70 percent of the Vietnamese population in 2000 was engaged in agricultural activities during this time period. In this context, a study on the productivity of agriculture in Vietnam as well as the impacts of market reforms on agricultural productivity is particularly important for understanding Vietnam's recent economic success.

This study attempts to measure TFP growth in Vietnamese agriculture using panel data from 60 provinces in Vietnam during the period from 1985 to 2000. During that period, there were two major policy reforms in agriculture. The first was Resolution 10 of Vietnam's Communist Party Politburo in 1988, which started the decollectivization process in 1988. The second major reform was the promulgation of Land Law in 1993, which gave secure land use rights to farmers and allowed households to transfer their land to other households.

There have been several attempts to estimate the productivity and efficiency of rice farming in Vietnam. Using a rice production function in conjunction with regional and provincial data, Tuong et al. (2006) reported that TFP grew by 0.77 percent per year during the 1976-1980 period, 3.52 percent during 1981-1987, and 3.24 percent during 1988-1994. Again based only on the rice economy, using regional data, Nghiem and

Coelli (2002) applied the Malmquist index method to investigate total factor productivity (TFP) growth in the period 1975-1997. They found that on average, TFP grew between 3.3 and 3.5 percent per annum in the Vietnamese rice economy, with the fastest growth occurring from 1981 to 1987. Thereafter, during the period 1987 to 1999, TFP grew by about 2.4 percent per annum. Kompas (2004) also estimated TFP growth in rice production in Vietnam using a stochastic frontier method. He estimated that annual TFP growth rate was 0.6 percent during 1976-1980, 2.7 percent during 1981-1987, 4.4 percent during 1988-1994 and 4.5 percent during 1995-99.

There is little empirical evidence on the productivity of the overall agricultural sector in Vietnam. An unpublished study by Nguyen and Goletti (2001) used Cobb-Douglass agricultural production function to estimate that annual TFP growth was 2.2 percent during 1985-1989 and 0.3 percent during 1990-1999. The lack of attention to analyzing agricultural productivity and efficiency in Vietnam is clearly a wide gap in recent research on Vietnam's economy. In comparison, there have been many papers on agricultural productivity in China, whose agricultural market reforms have been very similar to those in Vietnam. Studies focused on productivity performance in Chinese agriculture include Brümmer et al (2006), Caster and Estrin (2001), Fan (1991, 1997), Fan and Pardey (1997), Fleisher and Liu (1992), Huang (1998), Kalirajan et al. (1996), Lin (1992), Mao and Koo (1997), McMillan et al. (1989), Stavis (1991), Wang et al. (1996), Wen (1993), Wu et al. (2001). This paper is among the first to attempt to measure and assess agricultural productivity and efficiency in Vietnam.

Table 2.1 summarizes the results from previous studies on TFP growth in Vietnamese agriculture. Tuong et al. (2006) and Nguyen and Goletti (2001) used a production function while Kompas (2004) and Nghiem and Coelli (2002) applied frontier methods. The difference between Kompas (2004) and Nghiem and Coelli (2002) is that Kompas (2004) used a stochastic frontier method whereas Nghiem and Coelli applied a popular deterministic frontier method: the Malmquist index approach. The results from Tuong et al (2006), Kompas (2004), and Nghiem and Coelli (2002) showed that TFP growth in rice production was low during the immediate post-war period (1976-1981), but improved significantly during the 1980s. In the wake of the Doi Moi period (i.e. after 1988), the productivity trends vary across authors. Tuong et al. (2004), Nghiem and Coelli (2002) and Nguyen and Goletti (2001) reported a decline in TFP growth rate, while Kompas (2004) found an increase. In addition, the agricultural TFP growth rates in Nguyen and Goletti (2001) are much lower than comparative estimates of rice TFP in other studies.

Table 2.1: Previous Studies on TFP Growth in Vietnamese Agriculture

	Rice TFP growth (%)					**Agricultural TFP growth (%)**	
	Tuong et al.	*Kompas*	*Nghiem & Coelli*			*Nguyen & Goletti*	
Year			Year	TYW method	FC method		
1976-80	0.77	0.6	1976-81	2.7	1.8		
1981-87	3.52	2.74	1981-87	6.5	5.9	1985-89	2.16
1988-94	3.24	4.43	1987-97	2.4	2.4	1990-99	0.32
1995-99		4.46					
Method	Production function	Stochastic frontier	DEA: Three-year window (TYW) and Full Cumulative (FC)			Production function	

Source: Tuong et al. (2004), Kompas (2004), Nghiem and Coelli (2002), Nguyen and Goletti (2001).

This study uses the Malmquist index method to estimate Vietnam's agricultural productivity. The remainder of this chapter is organized as followed. Section 2.2

provides a brief description of Vietnam's agriculture and market reforms. Section 2.3 discusses the method and the data. Section 2.4 presents the results and discussion, and Section 2.5 provides concluding comments.

2.2. Vietnamese Agriculture and Market Reforms.

Agriculture is very important to the Vietnamese economy. In 2007, about 62 percent of Vietnamese labor was engaged in agricultural activities. Agricultural production constituted 23 percent of GDP during the period 2000-2004 (Dang et al. 2006) and 16 percent of its exports in 2004 (FAO 2004).

Following the reunification of the country in 1975, there was a crisis in Vietnam's agriculture sector, especially in the production of rice, the most important food crop in Vietnam. Although total agricultural output increased by an average of 4.5 percent annually during 1976-1980, there was a reduction in both the output and the average yield of rice, the most important crop in Vietnam, in the same period. Pingali and Vo-Tong (1992) estimated that rice output per capita in 1980 was 8 percent less than that in 1976, while rice yields were 7 percent lower (according to data in Nguyen (1995)). Consequently, during the late 1970s and early 1980s, Vietnam experimented chronic food shortages, indicative of the failures of the collectivized system of agriculture in place at that time.

In order to overcome this crisis, the Vietnamese government introduced several agricultural reforms in the early 1980s. In 1981, Vietnam began switching from a collectivized agricultural system to a household-oriented contract system. This system was similar to the household responsibility system launched in China in 1979. It allowed households to obtain short-term (three-year) use rights for their allocated plot of land, and at the same time, required them to meet output contracts with the state. The switch from a collectivized to a contract system of agriculture provided the initial stimulus to Vietnamese agriculture. The average rice yield increased by 34 percent from 1980 to 1985. However, agricultural output and input markets were still under strict state control, and farmers were required to sell all contracted outputs to, and buy all inputs from, the state at fixed prices. All output beyond the contracted amount could either be kept for owned consumption or sold to private traders.

Despite certain successes in the wake of this reform, the performance of Vietnamese agriculture was still mediocre before the *Doi Moi* (Renovation) policy reforms initiated in 1986. Rice output capita in 1986 was only 93 percent of per capita output in 1942 for Vietnam as a whole, 105 percent for the North and 79 percent for the South (Pingali and Vo-Tong 1992).

In December, 1986, the *Doi Moi* reform strategy was publicly launched at the Sixth Vietnamese Communist Party Congress. That strategy called for a complete renovation of the whole economy. The first priority of the *Doi Moi* policy was the industrial sector, giving more autonomy to state-owned enterprises. It took until 1988 before major policy changes in were introduced in agriculture. In April, 1988, Vietnam's Communist Party Politburo promulgated Resolution 10, which pertained to reforming the agricultural economy. Resolution 10 was a radical extension of the earlier policy (Resolution 100) in 1981. While Resolution 100 allowed farmers to have three-year use right on their allocated plots, Resolution 10 allowed them to have secure, long-term (15 year) contracts on the use of land and permitted them to make all decisions with regard to their farming activities. This policy resulted in the decollectivization of Vietnam agriculture, whereby state cooperatives shrank markedly in size and number, while farming households became the dominant mode of production in agriculture. In 1986, cooperative farmers account for over 99 percent of farmers in the Red River Delta in the North. In the South, in contrast, cooperative farmers only account for 6 percent of farmers in the Mekong River Delta. In early 1990s, there are very few cooperatives left in Vietnam.

In November 1988, the Government announced that except for tax obligations on agricultural output, farming households were free to sell their products in either to private traders or state companies. Private traders were guaranteed equal treatment with state trading companies. A two-tier price system that allowed government employees to buy rationed food at subsidized rates was abolished. The agricultural input markets were also liberalized in 1988. Thus, private traders were allowed to sell machinery, fertilizers and other input supplies to farmers. In 1989, further policy reforms were introduced to liberalize Vietnam's economy. Almost all prices controls were abolished, including controls on interest rate. The exchange rate system was shift from a fixed to a flexible market-oriented system. Finally, the government direct subsidies to state-owned enterprises were ended by 1989.

The combination of agricultural reforms such as Resolution 10 and trade liberation stimulated both agricultural production and agricultural exports. From 1985 to1989, agricultural output increased by 18 percent, rice output by 22 percent and rice yield by 18 percent. In 1989, Vietnam, which had been a net importer of rice for two decades, exported 1.5 million tons of rice (Dang et al. 2006).

During the 1990s, there was a further major policy reform in agriculture: the Land Law. Vietnam's Constitution states that all land is publicly owned, and the land rights were never clearly defined in laws, which makes it hard to secure a land use rights. The Land Law was passed in 1993. While all land is still publicly owned in law, it recognized the existence of land-use rights, enabling landholders to obtain legal land-use titles (colloquially called "the Red Book"). In agriculture, land use right terms are up to 20 years for annual crop land, and 50 years for perennial crop land. As a result, households established a secure legal right to their land, including the right to transfer, sell or bequeath their land. They can also use their land-use titles as collaterals to borrow loans.

In agriculture, the Land Law was intended to boost agricultural production by giving farmers incentives to increase their efficiency and productivity. However, the agricultural production and productivity consequences of the Land Law on agricultural production are unclear. Dang et al (2006) remarked that land markets have failed to develop strongly, and high land rental rates, as allowed by the Land Law, might prohibit new investment by farmers and reintroduce social stratification. Do and Iyer (2008) examined the 1993 Land Law and found that additional land rights led to increases in nonfarm activities and long-term farming, but the increases were not large. They found no significant impact on household consumption or on agricultural income. Ravallion and van de Walle (2008) note a pronounced rise in rural landlessness following the dismantling of the collectives and the introduction of the Land Law in 1993. However, they saw this as a positive factor, enabling farm household to take up new opportunities outside of agriculture. Hare (2008) assessed the impacts of land right certificates on agricultural production and found that the direct impact was rather small in the absence of supporting institutions. He pointed out that controlling for community characteristics; the impacts of land rights were insignificant.

In summary, Vietnam's major agricultural market reforms were implemented during 1980s and early 1990s. As a whole, Vietnam's market reforms on the economy in general and in agriculture, in particular, have induced remarkable changes in Vietnam. Table 2.2 reports annual changes in various indicators of Vietnamese agriculture during the period 1985-2000. Output increased at the slowest rate in the period 1985-1990 and at the highest rate during the period 1995-2000. The latter period also witnessed sharp increases in the use of machinery and fertilizer, as in the period 1990-1995, but the increase in labor was considerably smaller than during the period 1990-1995. Land productivity increased at the rate of 2.7 percent in the early 1990s and 2.5 percent in the late 1990s, slightly higher than in the late 1980s period (2.4 percent). Labor productivity improvement was low in the late 1980s period, at 1.25 percent, and slightly negative (-0.4 percent) in the 1990-95 period. The reason for negative labor productivity during this period is possibly due to the absorption of redundant labor from the restructured state-owned enterprises (SOEs) into the agricultural sector. As a result, agricultural labor increased remarkably during that period, at an annual rate of 6.2 percent[2]. In the period 1995-2000, the role of agriculture in absorbing redundant labor from other sectors diminished. In this period, labor productivity increased by 5.1

[2] Most of the increase occurred in 1991/92, when agricultural labor increased by 18% percent due to the fundamental SOE restructuring in 1991. The SOE sector shed about 750,000 workers in 1990 and 1991 alone (Dang et al. 2006). If year 1991/1992 were excluded, agricultural labor productivity would have increased by 1.4 percent annually during the period 1989-1993, slightly higher than the late 1980s period.

percent, while total agricultural labor increased by 1.1 percent, just about half of the growth rate in Vietnam's overall labor force.

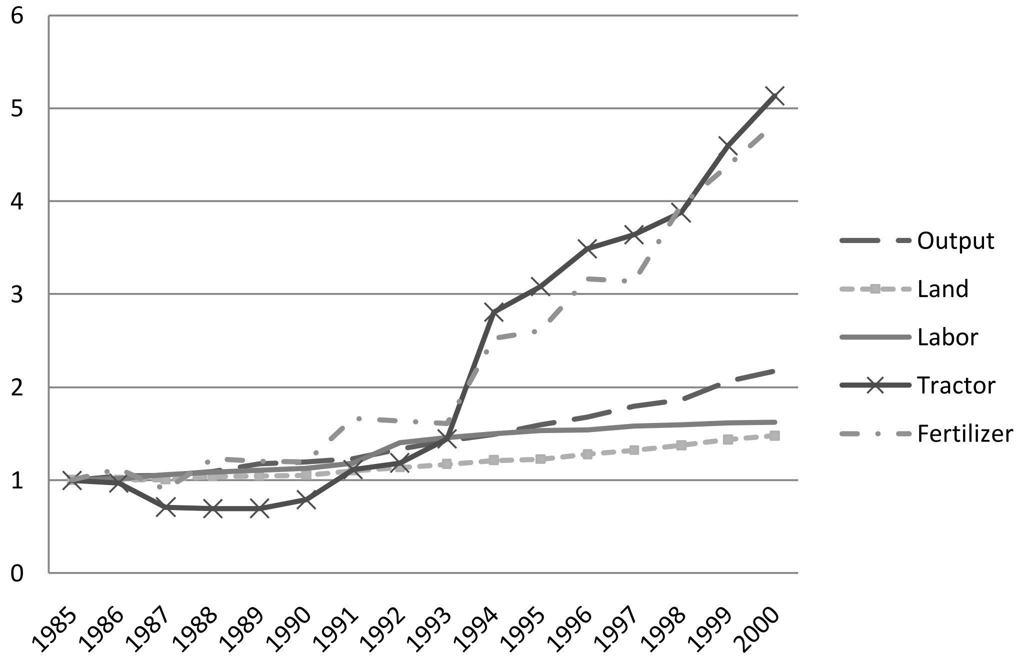
Growth in technology and machine use, as reflected by the growth in indices of tractors per labor and the amount of fertilizer consumption per hectare, are highest during the period 1990 to 1995, and lowest during the late 1980s. The index of tractors per labor actually decreased during the first reform period 1985-89, perhaps as a result of collectives being broken up and agricultural land being divided among households. However, during the 1990s, the number of machines used in agriculture increased substantially, while the use of draft animals contracted. Evidently, this reflects a change in the production technology in agriculture.

Table 2.2: Annual Growth Rates in Vietnamese Agriculture 1985-2000 (percent per year)

	1985-1990	1990-1995	1995-2000	1985-2000
Output (Gross value of output at 1994 prices)	3.37	5.73	6.18	5.18
Input				
Cultivated land (hectare)	0.97	2.99	3.72	2.60
Agricultural labor (laborer)	2.09	6.15	1.10	3.22
Tractors (unit)	-6.87	27.2	10.2	10.9
Threshing machines (unit)	2.61	17.5	21.5	13.9
Draft Animal (unit)	3.27	2.01	1.24	2.04
Fertilizer (ton)	3.71	15.6	12.3	10.5
Partial productivity				
Land productivity	2.38	2.74	2.46	2.58
Labor productivity	1.25	-0.42	5.08	1.96
Technology				
Tractor to labor ratio	-8.78	21.0	9.08	7.69
Fertilizer to land ratio	2.72	12.6	8.61	7.90

Source: Author's calculation from GSO (2000), Nguyen (2003), FAOSTAT

Figure 2.1: The Growth of Output and Inputs in Vietnamese Agriculture (1985=1.0)



Source: Author's calculation from GSO (2000), Nguyen (2003), FAOSTAT

2.3 Method and Data

2.3.1 Malmquist DEA Method

This paper applies the nonparametric output-oriented Malmquist data envelopment analysis (DEA) method to estimate total factor productivity (TFP) using panel data for 60 provinces during the period 1985-2000. Estimation of TFP using the Malmquist DEA method is preferable to using the Divisia-Tornqvist TFP indexing method because the latter approach requires data on prices of outputs and inputs, which are not available in Vietnamese agricultural data. Productivity change can occur either by improvement in efficiency (taken by more efficient utilization of inputs, given the state of technology), or by applying a better production technology. The Malmquist approach also allows the decomposition of TFP growth into an efficiency change component and a technical change component.

Färe et al. (1994) showed that a Malmquist productivity index can be calculated without price data. In their approach, an output distance function is defined on the output set *P(x)* as:

$$d(x,y) = \min\{\delta : (y/\delta) \in P(x)\}$$

The output distance function $d(x,y)$ will take a value larger than zero and less than or equal to 1 if the output vector *y* is an element of the feasible production set. If y is located on the boundary of the feasible production set, the output distance function will take a value of unity. Thus, a lower value of $d(x,y)$ is indicates that production is less efficient.

More generally, one can define a distance function $d_s^s(y_s, x_s)$ as the distance from period *s* observation to period *s* technology (y_s, x_s). Similarly, $d_t^s(y_t, x_t)$ is the distance period *s* observation to period *t* technology.

The output-oriented Malmquist TFP index measures the TFP change between two periods by calculating the distance functions of each data point to the relevant technology. Following Färe et al (1994), the Malmquist (output-oriented) TFP change index between period *s* (the base period) and period *t* under constant return to scale (CRS) is defined as

$$M_s^t(y_s, x_s, y_t, x_t) = \left[\frac{d_t^s(y_t, x_t)}{d_s^s(y_s, x_s)} \times \frac{d_t^t(y_t, x_t)}{d_s^t(y_s, x_s)}\right]^{1/2} \tag{2.1}$$

in which $d_t^s, d_s^s, d_t^t, d_s^t$ are distance functions under CRS, *s* and *t* are time periods, and *y*, *x* are output and input vector. More specifically, $d_t^s(y_t, x_t)$ is defined as the distance from period *t* observation to period *s* technology (Coelli and Rao 2005). The TFP change index in (2.1) is actually the geometric mean of two TFP change measure: the first is relative to period *s* technology, and the second is relative to period *t* technology. In all, a Malmquist index greater than unity indicates a TFP increase from *s* to *t*, while a Malmquist index less than unity indicates a TFP decrease.

Equation (2.1) can be arranged to show that the TFP change index is equivalent to the product of a technical efficiency change index and an index of technical change:

$$M_s^t(y_s, x_s, y_t, x_t) = \frac{d_t^t(y_t, x_t)}{d_s^s(y_s, x_s)} \left[\frac{d_t^s(y_t, x_t)}{d_t^t(y_t, x_t)} \times \frac{d_s^s(y_s, x_s)}{d_s^t(y_s, x_s)} \right]^{1/2} \tag{2.2}$$

One can effectively decompose the Malmquist index M_s^t in (2.2) into two terms: efficiency change (EC) and technical change (TC).

$$\textit{Efficiency change (EC):}\ EC_s^t = \frac{d_t^t(y_t, x_t)}{d_s^s(y_s, x_s)} \tag{2.3}$$

$$\textit{Technical change (TC):}\ TC_s^t = \left[\frac{d_t^s(y_t, x_t)}{d_t^t(y_t, x_t)} \times \frac{d_s^s(y_s, x_s)}{d_s^t(y_s, x_s)} \right]^{1/2} \tag{2.4}$$

The term EC denotes the change of efficiency level from period *s* to period *t*, which is equivalent to the ratio of the technical efficiency in period *t* to that in period *s*. The term TC reflects the change due the shift in technology from period *s* to period *t,* which is equivalent to the geometric mean of the shift in technology from period s to period t, evaluated at period *s* technology and at period *t* technology.

Furthermore, the efficiency change under CRS in (2.3) can be further decomposed into pure efficiency change (or efficiency change under variable returns to scale- RS) and scale efficiency change. Note that the EC in (2.3) is estimated under the assumption of constant returns to scale.

$$\textit{Pure efficiency change (PEC)}:\ PEC_s^t = \frac{d_{t-VRS}^t(y_t, x_t)}{d_{s-VRS}^s(y_s, x_s)} \tag{2.5}$$

and a *scale efficiency change (SEC)* component

$$SEC_s^t = \frac{d_t^t(y_t, x_t)/d_{t-VRS}^t(y_t, x_t)}{d_s^t(y_s, x_s)/d_{s-VRS}^t(y_s, x_s)} \tag{2.6}$$

where d_{VRS} denotes a distance function under variable returns to scale (VRS) assumption.

The distance function $\widehat{d}_s^t(y_s, x_s)$ is estimated for each household by the following linear programming problems under constant return to scale (CRS).

$$[\widehat{d}_s^t(y_s, x_s)]^{-1} = \max_{\theta,\lambda} \hat{\theta} \text{ such that} \tag{2.7}$$

$$\begin{aligned} &-\theta y_{is} + Y_t\lambda \geq 0, \\ &x_{is} - X_t\lambda \geq 0, \\ &\lambda \geq 0, \end{aligned}$$

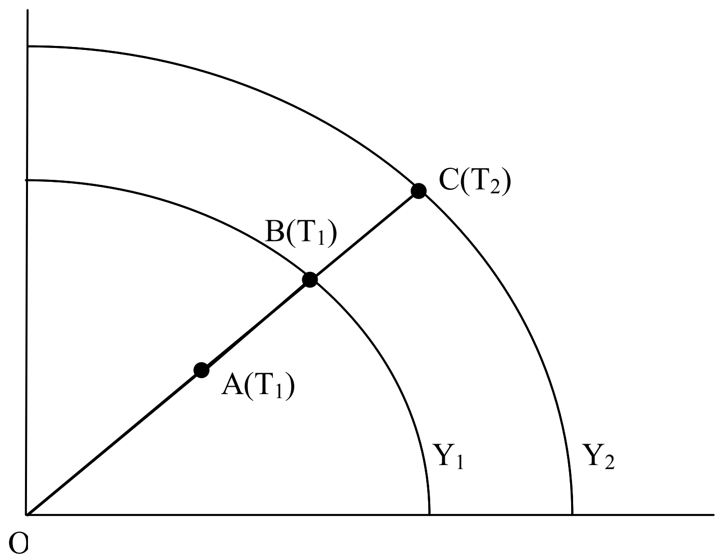
where $X_t = [x_{1t}, x_{1t,..} x_{nt}]$, and $Y_t = [y_{1t}, y_{2t, ..,} y_{nt}]$ are the input and output matrix of all units.

Replacing (2.7) with appropriate time period notations, one can calculate $\hat{d}_s^s(y_s, x_s), \widehat{d}_t^s(y_t, x_t), \widehat{d}_t^t(y_t, x_t)$.

The corresponding distance functions under VRS are obtained by adding the convex constraint $I1'\lambda = 1$ into (2.7).

Figure 2.2 illustrates a measure of productivity in the simplest case with one input X and one output Y. Points B, C, and D are on the production curves, while point A is below the curve, or technically inefficient. The distance from point A to point B reflects the inefficiency, because at point B, more output can be produced with the same amount of input as point A. The distance between point B and D reflect the change in productivity due to technical change. The shape of the curve Y_1 indicates a production technology with decreasing returns to scale, because at C, more of X is needed to produce each unit of Y than at B.

Figure 2.2: Productivity Change and Efficiency Change in 1- Output



It is assumed that A, B and C uses the same amount of input X to produces output. Points A and B use the same technology T_1, while point C uses a different technology Y2. The production frontiers are Y_1 for technology T_1 and Y_2 for technology T_2. Thus the distance AB reflects the inefficiency of point A compared to the frontier Y_1, while the distance BC reflects the technology change. If a firm moves from point A to point C, it needs to improve both its efficiency and its technology.

2.3.2 Bootstrapping the Malmquist Indices

Simar and Wilson (2000) proposed a bootstrap method to estimate confidence intervals for DEA efficiency scores of each decision-making unit. Simar and Wilson (1999) method to estimate confidence intervals for Malmquist indices, based on efficiency scores. The authors argue that the deterministic DEA scores as well as the Malmquist index are only estimates of the underlying, true frontiers. Therefore, the estimates obtained involved uncertainty due to sampling variation. The aim of the bootstrap is to estimate the population distribution, thus enabling the researchers to test hypotheses regarding the true parameter value.

Bootstrapping is based on the idea that by resampling the data with replacement, one can mimic the data-generating process characterizing the true data generation. The following algorithm describes the procedure for bootstrapping Malmquist indices.

i. First, calculate the Malmquist index by applying the DEA method for each decision-making unit (DMU) among *n* units, obtaining a set of $\{\hat{d}_o^t(y_t,x_t),\hat{d}_o^s(y_s,x_s),\hat{d}_o^t(y_s,x_s),\hat{d}_o^s(y_t,x_t)\}$ with *s, t* are time periods, and the DEA estimates $\hat{\theta}_1,...\hat{\theta}_n$. From these estimates of distance function, Malmquist indices including the Malmquist TFP change and its components are calculated: $\hat{M}_s^t,\hat{E}_s^t,\hat{T}_s^t,\hat{P}E_s^t,\hat{S}E_s^t$.

ii. Let $\beta_1^*,....\beta_n^*$ be a simple bootstrap sample from $\hat{\theta}_1,...\hat{\theta}_n$. Draw bootstrap estimates from the original sample of scores $\{\hat{\theta}_1,...\hat{\theta}_n\}$ using a bivariate smoothed representation of the probability density F

iii. For i=1,..., n, create a pseudo data set of (x_i^*, y_i^*) where $x_i^* = x_i$ and $y_i^* = (\hat{\theta}_i/\theta_i^*)\, y_i$ with x_i , y_i the original input and output vectors of the i^{th} unit, respectively.

iv. Solve the linear programming in (6) with the pseudo-data (x_i^*, y_i^*), one obtains the distance function estimates: $\tilde{d}_o^t(y_t,x_t),\tilde{d}_o^s(y_s,x_s),\tilde{d}_o^t(y_s,x_s),\tilde{d}_o^s(y_t,x_t)$. Use these distance functions to construct Malmquist indices $\tilde{M}_s^t,\tilde{E}_s^t,\tilde{T}_s^t,\tilde{P}E_s^t,\tilde{S}E_s^t$

v. Repeat step (ii) to (iv) for B times to yield B set of bootstrap estimates: $\{\widetilde{M}_s^t(b), \widetilde{E}_s^t(b), \widetilde{T}_s^t(b), \widetilde{PE}_s^t(b), \widetilde{SE}_s^t(b)\}_{b=1}^{B}$. In the empirical work, B is set to be 2000 to reduce the variability of the bootstrap confidence intervals. The number of bootstrap iterations should be more than 1000 if researchers are interested in confidence interval estimation. A smaller number of iterations would be enough if one only needs estimates for bias and standard deviation (see Efron and Tibshirani 1993).

vi. Construct the confidence intervals for the Malmquist indices. Since the distribution of $(\widetilde{M}_s^t - M_s^t)$ is unknown, we use the bootstrap values to finds a_α, b_α such that $\Pr ob(-b_\alpha \le \widetilde{M}_s^t - \hat{M}_s^t \le -a_\alpha) = 1-\alpha$. It involves sorting the value of $(\hat{\theta}_i^* - \hat{\theta}_i)$ for b =1,…, B in increasing order and deleting ($(\alpha/2)\times 100$ percent of the elements at either end of this sorted array and setting $-\hat{a}_\alpha$ and $-\hat{b}_\alpha$ at the two endpoints, with $\hat{a}_\alpha \le \hat{b}_\alpha$.

Thus, the bootstrap estimate of the (1-α) confidence interval for the Malmquist index is given by $\hat{M}_s^t - \hat{a}_\alpha \le M_s^t \le \hat{M}_s^t - \hat{b}_\alpha$

2.3.3 Data

This paper uses annual data for 60 provinces in Vietnam, which covers the whole country, except the newly formed province of Ba Ria -Vung Tau, during the period 1985-2000.[3] The data are collected by the General Statistics Office of Vietnam and published in its several agricultural statistics books (GSO 2000, Nguyen 1995,

[3] Provincial-level data are not fully available before 1985. Due to many changes in administrative division of provinces, only region-level data are comparable for the period 1975-85.

Nguyen 2003). The 60 provinces belong to eight regions. The biggest agricultural producers are the Mekong River Delta and the Red River Delta, while the smallest producer is the North West region, whose mountainous areas are unfavorable to agriculture. The variables used in the TFP analysis include one output in value and five inputs in quantity: land, labor, tractors, threshing machines and draft animals. Output is measured by total agricultural output value at 1994 prices. Land is measured as the total cultivated areas in each province. Labor is the number of agricultural laborers in each province. Draft animal variable is calculated as the total number of cattle and buffaloes in each province. Tractors and threshing machines are the number of tractors and threshing machines, respectively, in each province. Ideally, fertilizer should also be used as an input but only aggregated national data, and not province-level data, of fertilizer consumption are available.[4] Admittedly, the omission of fertilizer from the production function might lead to certain omitted variable bias, in particular, by overestimating TFP and efficiency estimates in provinces using more fertilizers and underestimating those using less fertilizers. Some authors tried to approximate the provincial fertilizer figures by one way or another. For example, Kompas (2004) estimated the province-level fertilizer data by multiplying the average amounts of fertilizer used (as in a certain survey in 1992) in the north 165.4 kg/ha and the south 193 kg/ha with the rice area in every province. This method is very doubtful since it assumes that the amount of fertilizer per hectare was the same for all provinces in the North/South, and that fertilizer intensity was unchanged throughout the time period. Using the national fertilizer consumption as a starting point, Nguyen and Goletti (2001)

[4] I tried to include fertilizer as an input based on national data, by assuming that each unit of agricultural land consumes the same amount of fertilizer consumption. The results, however, were unstable, and thereby were dropped from the analysis.

estimated the province-level data by assuming that the amount of fertilizer per hectare was positively related with crop yield. Yet, their method is arbitrary because it assumes that the rate of fertilizer over crop yield was the same in every province. I chose to drop fertilizer as an input, rather than approximate it from limited available data.

Sample means of these variables are presented in Table 2.3, where the period is divided into three sub-periods: the early reform period (1985-1989), the late reform period (1990-1994), and the post-reform period (1995-2000). Clearly, in the period 1995-2000, the number of machinery and draft animal inputs are much higher than in the previous periods.

Table 2.3: Mean Output and Inputs in Vietnam's Agriculture per Province per Year

	1985-89	1990-94	1995-2000	1985-2000
Agricultural output (billion VND at 1994 price)	919	1,140	1,586	1,238
Cultivated area (thousand hectares)	146	161	191	167
Labor (thousands)	276	346	410	348
Tractors (pieces)	434	767	2,065	1,151
Threshing Machines (pieces)	707	1,078	3,609	1,911
Draft Animal (units)	3,303	4,943	11,103	6,740

2.4. Results

2.4.1 Malmquist TFP Growth, Technical Change and Efficiency Change

The empirical results of the Malmquist DEA method, grouped by geographical regions, are presented in Table 2.4. Table 2.4 shows that the average TFP growth rate in Vietnam during the period from 1985 to 2000 was 1.96 percent. The growth rate was highest during the initial reform period 1985-1990, when it was 3.44 percent. In the early 1990s, the TFP growth rate fell down to 0.65 percent a year, but rose again to 1.81 percent annually during the late 1990s. These estimates of TFP growth are a little higher than Nguyen and Goletti (2001), who estimated that Vietnam's agricultural TFP increased by 2.16 percent in 1985-89, and by 0.32 percent in 1990-99. In a paper on TFP growth in agriculture based on 93 countries from 1980 to 2000, Coelli and Rao (2005) estimated that Vietnam's TFP growth in agriculture is 2 percent, very close to the estimate here for the period 1985-2000.

Estimates of TFP for rice farming by Tuong et al. (2006), Kompas (2004) and Nghiem and Coelli (2002) are higher than the estimates in this chapter for Vietnamese agriculture as a whole, which suggests that Vietnam's TFP growth has been higher in the rice sector than in other agricultural sectors. That is consistent with the finding that both the Mekong River Delta and the Red River Delta regions, which together produces two-thirds of Vietnam's rice supply and almost all rice exports, have relatively higher TFP growth rates than other regions: 4.2 percent for the Mekong River Delta and 2.0 percent for the Red River Delta.

The Central Highlands, which produce mostly industrial crops such as coffee and rubber, rather than food, is the second best region in productivity improvement, after the Mekong River Delta. Four regions have negative annual TFP growth: North East (-2.1 percent), North West (-6.6 percent), North Central Coast (-1.3 percent) and South Central Coast (-3.5 percent). The negative TFP growth rates in these regions were mainly caused by technical regress. These four regions are noted to have unfavorable weather and terrain for agriculture. In the North East, and particularly in the North West, the terrain is hilly and mountainous, and floods are common. In the North and South Central Coast, arable areas are narrow and limited, while storms and hurricanes occur every year. As a result, technological improvement in these regions is limited because it is too risky and less profitable to invest in technology in these regions. Moreover, extension support and Government investment in agricultural research and development are focused mostly in the main agricultural areas: the Mekong River Delta in the South and the Red River Delta in the North. In addition, most government agricultural universities and research institutes are located in the Mekong River Delta and the Red River Delta. Another possible reason is the limited non-farm job opportunities in these four regions, in contrast to the delta regions. Thus, most of the labor in these regions must be employed in the farm sector, making it more inefficient. Figure 2.4 shows that labor productivity reduced in these regions during the period 1990-95, possibly as a result of limited non-farm jobs. The closing of State-owned enterprises during that period also contributed considerably to the surge in agricultural laborers.

Among the factors that contribute TFP growth, technical change plays a more important role than efficiency change. Technical change grew at the rate of 1.3 percent, while efficiency change grew at 0.72 percent during the 1985 to 2000 period. The early reform period witnessed significant improvements in both technical change and efficiency change. Technical change grew at a rate of 2.13 percent and efficiency change at a rate of 1.48 percent during that period. In contrast, during the period from 1990 to 1995, technical change grew at a modest rate of 0.61 percent while efficiency change even reduced by 0.03 percent. The lay-off of many workers in State-owned enterprises and the liberalization of input markets during this period led to a considerable increase of farm inputs. As a result, farm efficiency and productivity were limited.

Among the regions, technical change growth rates were highest in the Mekong River Delta (3.7 percent) and the Red River Delta (1.3 percent) during the period from 1985 to 2000. Meanwhile, the North East, the North West, the North Central Coast and the South Central Coast had negative technical change rates. Efficiency change growth rates are the highest in the Central Highland, which is followed by the South East and the Mekong River Delta. Overall, the scale efficiency change growth rates are low, at less than 1 percent in most regions, except in the Central Highland.

Table 2.4: Regional Annual TFP Growth Rates (%)

	All	Red River Delta	North East	North West	North Central Coast	South Central Coast	Central Highland	South East	Mekong River Delta
TFP Growth									
1985-90	3.44	2.49	2.40	0.64	0.43	-1.07	4.59	2.87	6.08
1990-95	0.65	0.92	-3.02	-20.5	-5.37	-5.61	-0.50	1.96	4.03
1995-00	1.81	2.62	-5.76	-0.05	1.06	-3.70	7.27	2.90	2.51
1985-00	1.96	2.01	-2.13	-6.64	-1.29	-3.46	3.79	2.58	4.21
Technical Change									
1985-90	2.13	2.94	0.66	0.62	-2.37	-0.93	-0.80	-0.03	4.98
1990-95	0.61	2.08	-3.61	-16.5	-4.29	-4.90	-2.34	0.13	3.89
1995-00	1.15	0.19	-3.77	-1.53	0.08	-1.47	5.10	2.35	2.24
1985-00	1.30	1.73	-2.24	-5.81	-2.20	-2.43	0.65	0.82	3.70
Efficiency Change									
1985-90	1.48	-0.10	1.78	-0.01	2.98	-0.22	5.92	2.91	1.19
1990-95	-0.03	-1.04	0.23	-3.35	-1.24	-1.12	1.93	1.99	0.16
1995-00	0.70	2.42	-1.65	1.30	1.07	-2.12	2.13	0.62	0.29
1985-00	0.72	0.43	0.12	-0.69	0.94	-1.15	3.33	1.84	0.55
Pure Efficiency Change									
1985-90	0.34	-1.41	0.98	0.05	0.93	-0.90	3.38	2.18	0.26
1990-95	-0.34	-1.19	0.41	-2.13	-0.20	-1.59	0.50	-0.21	0.11
1995-00	0.51	2.36	-1.35	-0.23	-0.35	-2.18	2.18	0.75	0.13
1985-00	0.17	-0.08	0.02	-0.77	0.13	-1.55	2.02	0.91	0.17
Scale Efficiency Change									
1985-1990	1.17	1.45	0.62	-0.04	2.06	0.77	2.65	0.74	0.96
1990-1995	0.54	0.15	-0.32	-1.48	-1.25	0.48	1.58	2.12	0.08
1995-2000	0.12	0.09	-0.41	1.46	1.45	0.11	-0.05	-0.13	0.16
1985-2000	0.61	0.56	-0.04	-0.02	0.75	0.45	1.40	0.91	0.40

*Based on weighted average, with weights are provincial agricultural outputs.

Table 2.5 provides details on the TFP index and its decomposition for 60 provinces in Vietnam for the period 1985-2000. It indicates that the Southern provinces were more adaptive than the Northern provinces in improving their agricultural productivity and efficiency. Among 20 best-performing provinces, only four are in the North and the Center: Hai Phong, Ha Tay, Hai Duong, and Thua Thien-Hue; the rest are in the South. Most of the provinces of Mekong River Delta are noted for improving their productivity. Except Ben Tre, 11 of the 12 provinces in this region had positive TFP growth. Only two provinces in Mekong River Delta (Ben Tre and Ca Mau) are not in the top 20 best-performing provinces. The South East region and the Central Highlands, where major industrial crops and fruit crops are planted, are the second-best and third-best regions in terms of productivity growth. In the North, only Red River Delta, the second most important agricultural region in the country, performed well in terms of TFP. Ten among eleven provinces in this region has average annual positive TFP growth during the period. The other two regions in the North (North East and North West) have low TFP growth. North East and North West provinces also have lowest rankings in the country. Only one among 11 provinces in the North East and none of the three provinces in the North West has positive TFP growth.

Table 2.5: Provincial Productivity Indices and Their Decomposition

Province	TFP	EC	TC	PEC	SEC	TFP Rank
Red River Delta						***4***
Ha Noi	1.015	0.993	1.022	0.994	0.999	27
Hai Phong	1.039	1.006	1.033	1.005	1.000	6
Vinh Phuc	0.998	1.022	0.977	1.013	1.009	37
Ha Tay	1.028	1.007	1.021	0.994	1.013	15
Bac Ninh	1.020	0.993	1.028	0.992	1.001	24
Hai Duong	1.027	1.011	1.016	1.002	1.009	18
Hung Yen	1.026	1.000	1.026	1.000	1.000	21
Ha Nam	1.012	0.989	1.022	0.990	1.000	31
Nam Dinh	1.022	0.994	1.028	0.994	1.000	22
Thai Binh	1.005	1.000	1.005	1.000	1.000	34
Ninh Binh	1.004	1.010	0.994	0.983	1.028	35
North East						***7***
Ha Giang	0.967	1.003	0.965	1.001	1.002	45
Cao Bang	0.966	1.013	0.954	1.014	0.999	46
Lao Cai	0.941	0.996	0.945	1.000	0.996	53
Bac Kan	0.900	0.977	0.922	1.000	0.977	59
Lang Son	0.965	0.962	1.004	0.960	1.001	48
Tuyen Quang	1.004	1.025	0.979	1.020	1.005	36
Yen Bai	0.987	1.010	0.977	1.009	1.000	41
Thai Nguyen	0.931	0.985	0.945	0.991	0.994	54
Phu Tho	0.951	1.000	0.951	1.000	1.000	51
Bac Giang	0.989	0.982	1.008	0.987	0.994	39
Quang Ninh	0.966	1.004	0.962	0.995	1.009	47
North West						***8***
Lai Chau	0.926	0.977	0.949	0.976	1.000	55
Son La	0.955	1.000	0.955	1.000	1.000	50
Hoa Binh	0.893	0.978	0.913	0.983	0.995	60
North Central Coast						***5***
Thanh Hoa	0.975	0.999	0.976	1.000	0.999	44
Nghe An	0.978	1.014	0.965	1.000	1.014	43
Ha Tinh	0.950	0.982	0.968	0.990	0.992	52
Quang Binh	1.021	1.022	1.000	1.009	1.013	23
Quang Tri	1.014	1.028	0.986	1.013	1.014	28
Thua Thien	1.027	1.011	1.016	1.005	1.006	20
South Central Coast						***6***
Da Nang	0.924	1.000	0.924	1.000	1.000	56
Quang Nam	0.918	0.972	0.944	0.978	0.994	58
Quang Ngai	0.923	1.000	0.923	1.000	1.000	57
Binh Dinh	0.982	0.981	1.001	0.972	1.009	42

Table 2.5 (continued)

Phu Yen	0.995	0.985	1.011	0.972	1.013	38
Khanh Hoa	1.012	0.997	1.015	0.988	1.009	30
Central Highlands						***3***
Kontum	0.959	0.996	0.963	0.993	1.003	49
Gia Lai	1.014	1.016	0.998	1.018	0.999	29
Dac Lac	1.032	1.034	0.999	1.010	1.023	11
Lam Dong	1.063	1.040	1.022	1.026	1.014	2
South East						***2***
HCM City	1.028	1.008	1.020	1.000	1.008	17
Ninh Thuan	1.011	1.007	1.003	1.003	1.004	33
Binh Phuoc	1.031	1.036	0.995	1.024	1.012	13
Tay Ninh	1.031	1.035	0.995	1.016	1.019	14
Binh Duong	1.031	1.053	0.980	1.030	1.022	12
Dong Nai	1.011	1.000	1.011	1.000	1.000	32
Binh Thuan	1.016	1.027	0.989	1.008	1.019	25
Mekong River Delta						***1***
Long An	1.027	1.002	1.025	0.991	1.011	19
Dong Thap	1.051	1.004	1.046	1.004	1.000	3
An Giang	1.034	1.011	1.023	1.002	1.009	10
Tien Giang	1.036	1.000	1.036	1.000	1.000	8
Vinh Long	1.038	1.000	1.038	1.000	1.000	7
Ben Tre	0.988	1.000	0.988	1.000	1.000	40
Kien Giang	1.036	1.000	1.036	1.000	1.000	9
Can Tho	1.098	1.000	1.098	1.000	1.000	1
Tra Vinh	1.042	1.019	1.022	1.004	1.015	5
Soc Trang	1.028	1.011	1.017	1.002	1.009	16
Bac Lieu	1.049	1.024	1.025	1.025	0.999	4
Ca Mau	1.015	1.000	1.015	1.000	1.000	26

Note: The results are geometric averages of annual estimates. Rank of a region is determined based on average rank of the provinces in that region.

Figure 2.3 shows the trends in partial productivity indices and TFP. Two partial productivity indices are employed: the land productivity as a fraction of output over land, and the labor productivity. During the initial period 1985-1990, all these productivity indices rose, but TFP grew faster than both land productivity and labor productivity. In 1991, all these indices experienced negative growth, perhaps due to the major economic restructuring in the economy, in which many people were fired from the state sector. While both TFP and land productivity improved in 1992, labor productivity continued to decrease in 1992 but increased again from 1993. In 1994, there was a decrease in TFP. After 1994, all the productivity indices appeared to follow a rising trend. By 2000, labor productivity and TFP growth rates were almost identical during the period 1985-2000, while the growth rate of land productivity was higher.

Figure 2.3: Partial and Total Productivity Growth (cumulative)

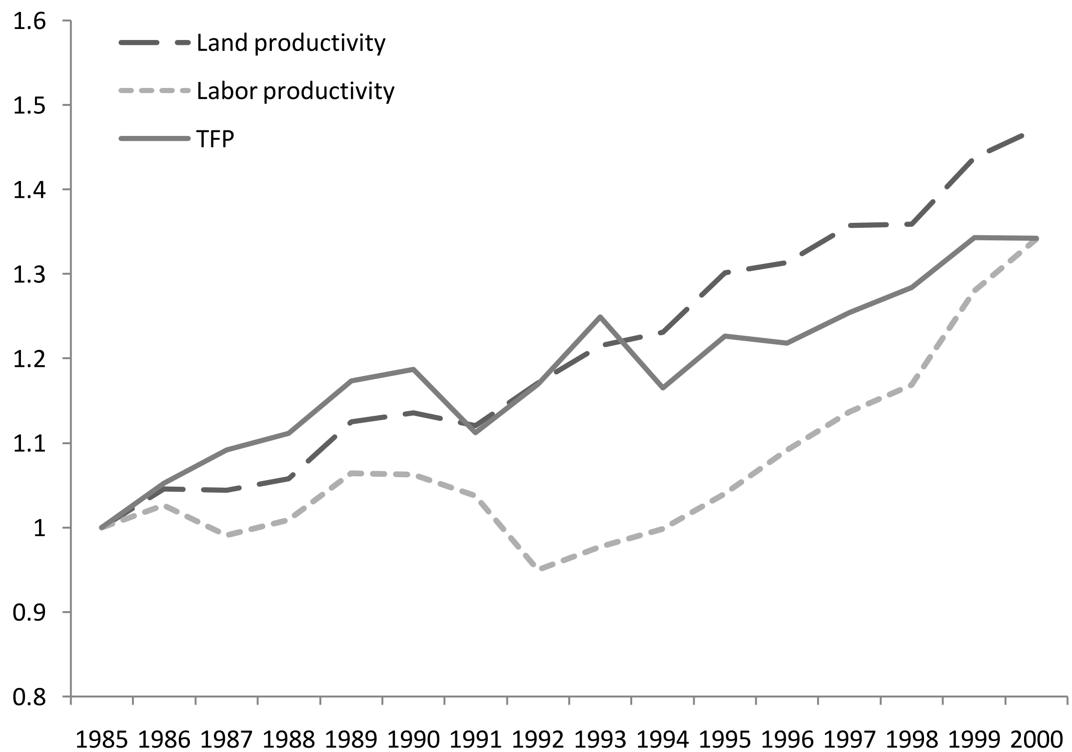


Figure 2.4: Partial and Total Productivity Growth in Eight Regions

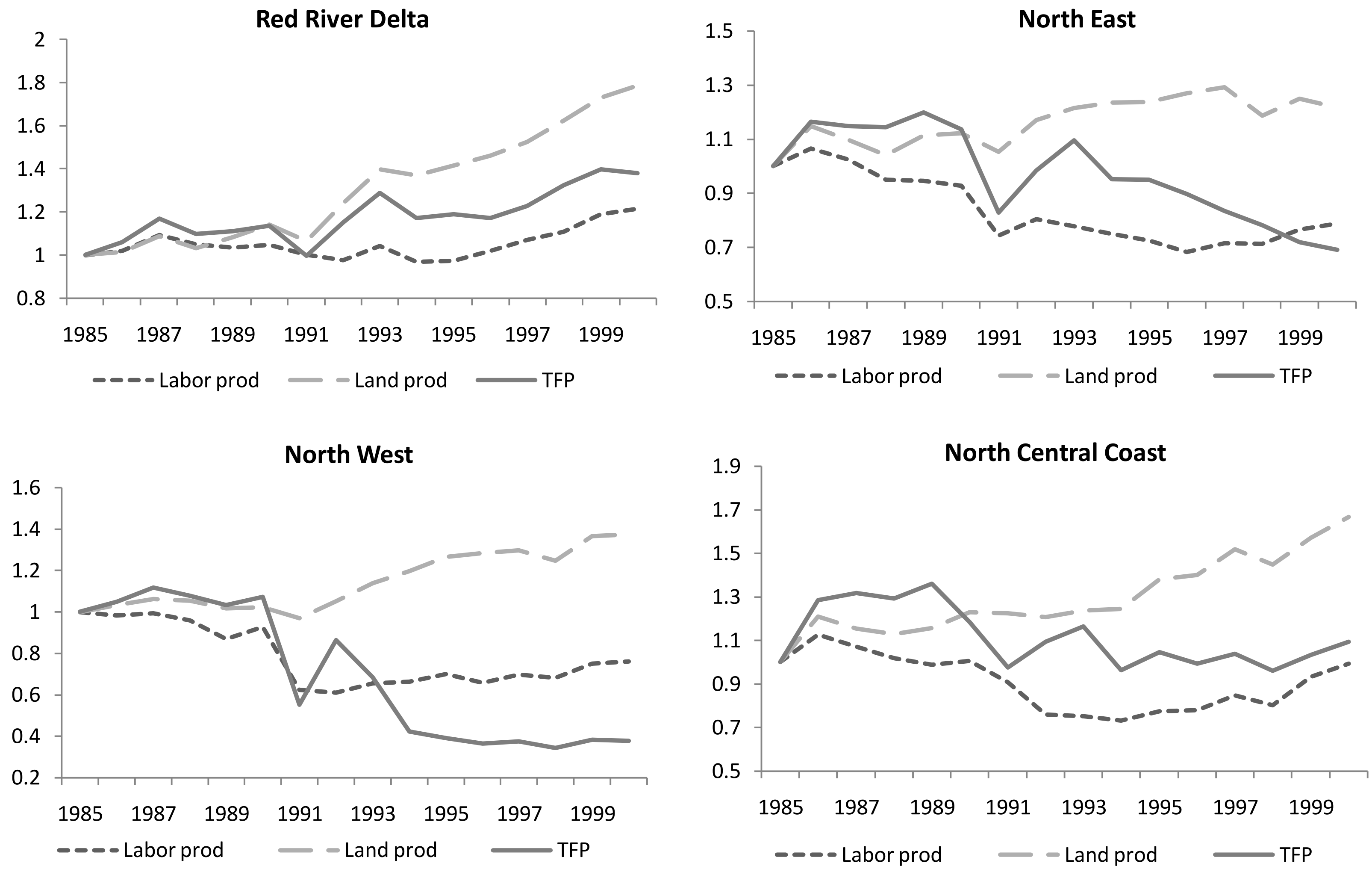
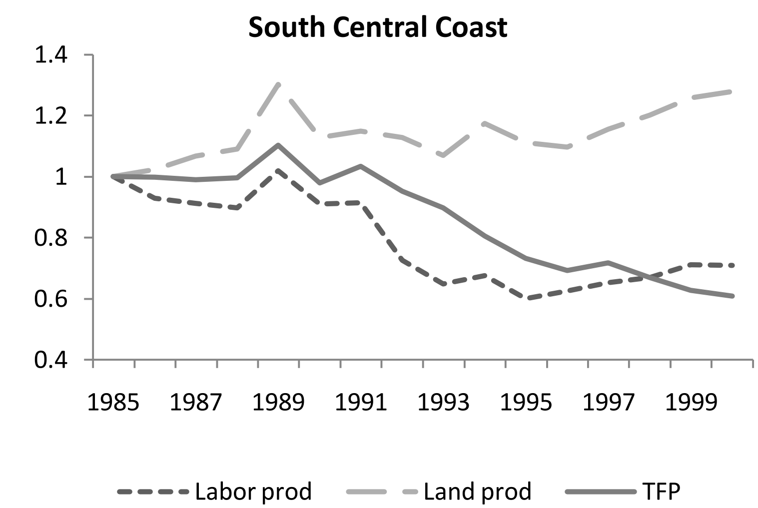
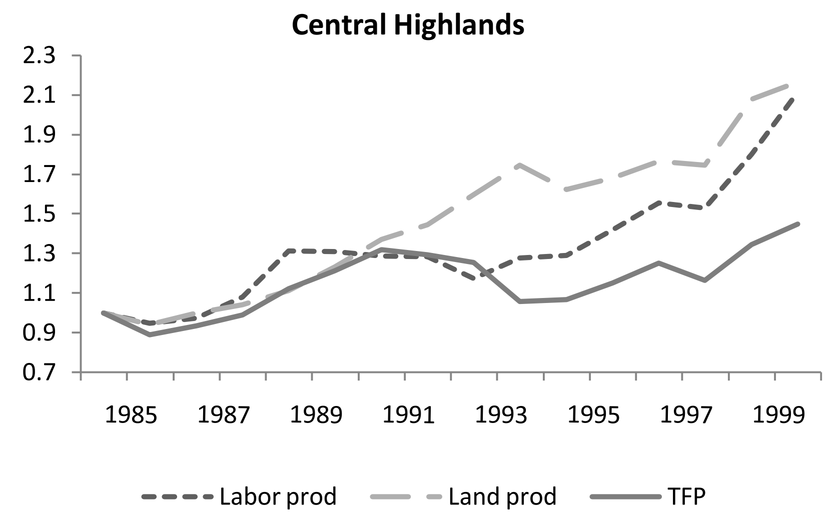
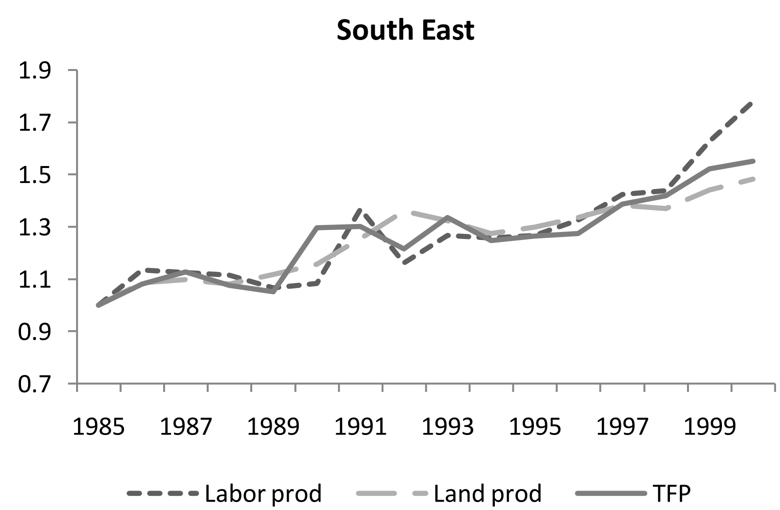


Figure 2.4 (continued)


South Central Coast
1.4
1.2
1
0.8
0.6
0.4
1985
1987
1989
1991
1993
1995
1997
1999
Labor prod
Land prod
TFP


Central Highlands
2.3
2.1
1.9
1.7
1.5
1.3
1.1
0.9
0.7
1985
1987
1989
1991
1993
1995
1997
1999
Labor prod
Land prod
TFP


South East
1.9
1.7
1.5
1.3
1.1
0.9
0.7
1985
1987
1989
1991
1993
1995
1997
1999
Labor prod
Land prod
TFP

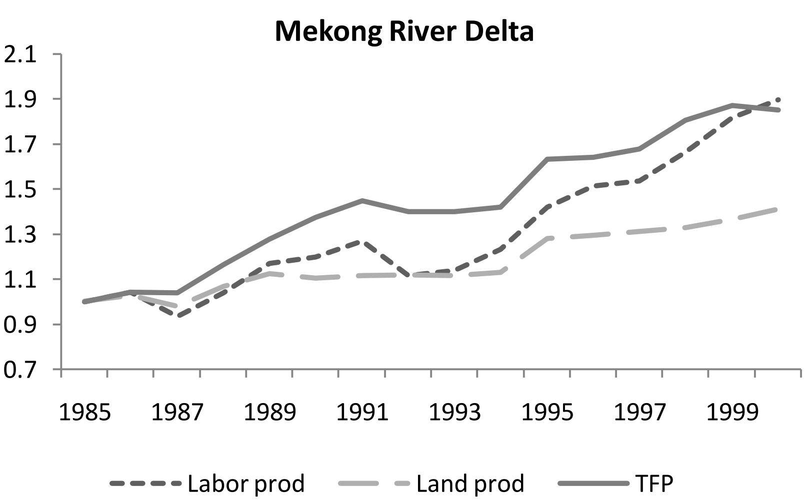

Mekong River Delta
2.1
1.9
1.7
1.5
1.3
1.1
0.9
0.7
1985
1987
1989
1991
1993
1995
1997
1999
Labor prod
Land prod
TFP

Figure 2.4 give trends in productivity indices for different regions. It shows that TFP and labor productivity generally follow similar trends. Both TFP and labor productivity increased in 4 regions (Red River Delta, Central Highlands, South East and Mekong River Delta) and decreased in the other 4 regions (North East, North West, North and South Central Coast). Yet, land productivity increased in all regions.

Table 2.6: Contribution of TFP and Inputs to Vietnamese Agricultural Growth (%)

	1985-1990	1990-1995	1995-2000	1985-2000
Output growth rates (%)	3.37	5.73	6.18	5.18
Contribution of TFP (%)	102.1	11.3	29.3	37.8
of which				
Technical change (%)	60.2	11.9	18.2	24.4
Efficiency change (%)	41.8	-0.6	11.1	13.5
Contribution of inputs (%)	-2.1	88.7	70.7	62.2

Table 2.6 summarizes the contribution of TFP and inputs to Vietnam's agricultural growth[5]. It shows that during the period 1985-2000, about 38 % of output growth can be attributed to TFP growth, of which 24% can be attributed to technical change and 14% to efficiency change.

However, the trend is not smooth over the period. In the period of initial reforms 1985-1990, the output and input markets were not fully liberalized while only reforms aimed at farmers' incentives were introduced. Output growth in this period was fully due to TFP growth, arguably due to better incentives for farmers. In fact, the contribution of inputs in this period was even negative at -2.1 percent, perhaps due to

[5] But note that the inputs exclude fertilizers and pesticides, which grew faster than outputs during the same time period. As a result, if these inputs are included, the contribution of TFP on output growth would be smaller and the contribution of inputs larger.

the decrease in machine use at the initial stage of the decollectivization process[6]. Output growth was caused by both technical change (60%) and efficiency change (42%) in this period. It implies that farmers responded positively to the incentive reforms by improving their efficiency and technology progress in this period, rather than increasing their inputs, mostly because until 1989, the input markets were strictly regulated by the Government.

In the second period 1990-95, the output and input markets were fully liberalized. The government considered agriculture as the sector to boost production and exports and to absorb redundant labor from the industrial sector. As the input market was liberalized, farmers invested heavily on their inputs, as revealed by the drastic increase in machinery use during this period. At the same time, SOE restructuring in the industrial sector led to sharp rise in agricultural labor. As a result, most of the output growth in this period (89%) was attributed to input increase. Only 11 percent of the output growth was due to TFP change. Moreover, TFP change in this period was wholly caused by technical change, while efficiency change reduced by 0.6 percent.

In the third period, 1995-2000, there was a slowdown in the growth rate of agricultural labor (at 1.1 percent annually, compared to 6.5 percent in the previous period). The annual increase in agricultural labor was much smaller than the annual increase in both population and total labor force (over 2 percent annually), signifying a gradual shift in the structure of the economy toward labor-intensive manufacturing sector. In 1995, agriculture (excluding forestry and fishery) contributed 23 percent of

[6] As the collectives were broken up and household-farming became dominant, many collectively-owned tractors and other machines were not used, as reflected by the decreases in the number of tractors used in this period.

Vietnam's GDP, but in 2000, it only contributed less than 20 percent, while the manufacturing share of GDP increased from 15 percent to 19 percent in the same period (Nguyen 2003). While the growth in labor supply slowed down, machine use continued to increase at a high rate (10 percent for tractors, 22 percent for threshing machines). Therefore, input growth contributed 71% of output growth, while TFP contributed 29% during the 1995 to 2000 period. Among TFP components, technical change contributed 18 percent of output growth, and efficiency change contributed 11 percent of output increase.

Compared to other countries, the contribution of TFP growth to agricultural output growth in Vietnam at 38 percent is higher that than in Thailand, a neighboring country with many similar characteristics. Poapongsakorn and Anuchitworawong (2006) reported a TFP contribution of 29 percent in Thailand's agricultural growth during 1981-2003. Tinakorn & Sussangkarn (1998) and Shintani (2002) (both cited by Poapongsakorn and Anuchitworawong 2006) estimated the contribution of TFP to agricultural growth during 1981-1995 at 25 percent and 35 percent, respectively.

2.4.2 Technical Efficiency of Vietnamese Agriculture

Table 2.7 summarizes the average estimates of technical efficiency in Vietnamese agriculture. The average technical efficiency estimate is 0.62 for the period from 1985 to 2000. Two major food-producing regions have the highest technical efficiency: Red River Delta (0.75) and Mekong River Delta (0.73). Red River Delta has a slightly higher efficiency estimate than Mekong River Delta. Perhaps, the reason lies in the fact the Red River Delta has limited available land and is more densely populated than the Mekong River Delta, requiring the farmers in the former region to farm more intensively. In fact, land productivity in the Red River Delta is 18% higher than that in the Mekong River Delta. In contrast, labor productivity in the Mekong River Delta is 50% higher than that in the Red River Delta.

The North West region has the lowest technical efficiency estimate (0.40), while the technical efficiency estimates of the North East and the North Central Coast are 0.54. Thus, the results indicate that the North East, North West and the North Central Coast have some serious problems with their agricultural production. They have low technical efficiency and low productivity growth over the period 1986-2000. Since these regions already have high poverty rates compared to the national level, especially in the North West, the need to improve agricultural production is a particular concern in these regions. On the other hand, the results indicate that there is much room for improving technical efficiency levels in these regions. For example, the results suggest that if the available inputs are used optimally, agricultural output in the North West can expand by 150% (=1/0.4-1) with given inputs and technology in the region. Therefore, improving technical efficiency in these regions may help to increase agricultural productivity and assist farming households to expand their income.

Both the Central Highlands and the South East have rather low technical efficiency estimates (0.55 and 0.59 respectively). Table 2.4 shows that these two regions have rather high productivity growth (3.8% and 2.6% respectively), and over 70% of the change in TFP is due to improvement of efficiency. But clearly, there is still substantial room for improvement of these two regions' efficiency in the coming years. Therefore, the potential for these regions' productivity growth is promising.

Table 2.7: Technical Efficiency of Vietnamese Agriculture

Province	Technical efficiency	*Rank*	Province	Technical efficiency	*Rank*
Country	**0.62**				
Red River Delta	**0.75**	**1**	**South Central Coast**	**0.63**	**3**
Thai Binh	0.98	1	Da Nang	0.70	20
Hung Yen	0.86	5	Phu Yen	0.69	21
Ha Tay	0.81	9	Quang Nam	0.64	26
Nam Dinh	0.81	10	Khanh Hoa	0.60	31
Hai Phong	0.80	11	Binh Dinh	0.58	35
Ha Noi	0.78	12	Quang Ngai	0.58	36
Hai Duong	0.78	13	**Central Highlands**	**0.55**	**5**
Ha Nam	0.70	19	Dac Lac	0.66	22
Ninh Binh	0.64	25	Lam Dong	0.66	23
Vinh Phuc	0.59	34	Kontum	0.45	53
Bac Ninh	0.53	43	Gia Lai	0.44	54
North East	**0.54**	**7**	**South East**	**0.59**	**4**
Bac Giang	0.89	4	HCM City	0.86	6
Phu Tho	0.61	29	Dong Nai	0.75	14
Quang Ninh	0.57	37	Ninh Thuan	0.72	18
Thai Nguyen	0.56	39	Tay Ninh	0.54	42
Lang Son	0.56	40	Binh Thuan	0.46	52
Yen Bai	0.51	45	Binh Duong	0.43	55
Tuyen Quang	0.50	46	Binh Phuoc	0.36	59
Cao Bang	0.48	48	**Mekong River Delta**	**0.73**	**2**
Bac Kan	0.47	50	Tien Giang	0.92	2
Lao Cai	0.38	57	Vinh Long	0.92	3
Ha Giang	0.36	58	An Giang	0.83	7
North West	**0.40**	**8**	Ben Tre	0.83	8
Hoa Binh	0.49	47	Can Tho	0.73	15
Son La	0.41	56	Tra Vinh	0.73	16
Lai Chau	0.30	60	Dong Thap	0.72	17
North Central Coast	**0.54**	**6**	Kien Giang	0.66	24
Nghe An	0.61	28	Soc Trang	0.62	27
Thanh Hoa	0.60	33	Bac Lieu	0.60	30
Ha Tinh	0.56	41	Long An	0.60	32
Thua Thien	0.52	44	Ca Mau	0.57	38
Quang Tri	0.48	49			
Quang Binh	0.46	51			

2.4.3 Bootstrapping the Malmquist Indices

The above analysis is concerned with point estimates of Malmquist indices. However, the point estimates of Malmquist indices cannot answer the question if a province's TFP growth is significantly different from zero or not. In other words, one cannot say a province's TFP growth in a given year is statistical significant. By bootstrapping, one can establish the confidence intervals for Malmquist index and test the results statistically. Therefore, it is possible to determine if a province's Malmquist index in a given year is significantly different from zero.

Table 2.8 presents the percentages of observation (province/year) with positive, negative and zero TFP growth rates. Without bootstrapping, there are 504 observation with positive TFP growth and 396 with negative TFP growth in Vietnam. By bootstrapping the Malmquist TFP index at 95% confidence interval, there remain 368 observations with positive TFP growth; 286 with negative TFP growth and 246 observations with zero TFP growth. In percentage terms, the bootstrap correct the initial estimates by changing the percentage of observations with positive TFP growth from 56% to 41%, negative TFP growth from 44% to 32% and zero TFP growth from 0% to 27%.

For instance, in the South East, without bootstrapping, one may draw a conclusion that 65% of the provinces in the region exhibits positive TFP growth, which is the second-highest percentage, after Mekong River Delta. However, after bootstrapping, only 37 percent of provinces in the region have statistically significant positive TFP growth, and this region would only rank 6th in terms of the percentages of provinces with positive TFP growth.

Bootstrapping also allows one to test the reliability of our point estimates. Table 2.9 presents the confidence interval widths of the Malmquist productivity index, efficiency change index and technical change index. The estimates of the widths for TFP are rather 'tight', an average ò 0.09, thus giving the point estimates certain credibility. The confidence level widths for efficiency change and technical change are larger. So, more caveats are necessary in explaining the point estimates of efficiency change and technical change.

Table 2.8: Percentages of Observations with Positive, Negative and Zero TFP growth

	Positive TFP growth		**Negative TFP growth**		**Zero TFP growth**	
	No bootstrap	Bootstrap	No bootstrap	Bootstrap	No bootstrap	Bootstrap
All country	*56.0*	*40.9*	*44.0*	*31.8*	*0*	*27.3*
Red River Delta	61.8	49.7	38.2	21.8	0	28.5
North East	44.8	32.1	55.2	42.4	0	25.5
North West	44.4	28.9	55.6	51.1	0	20.0
North Central Coast	51.1	42.2	48.9	38.9	0	18.9
South Central Coast	34.4	27.8	65.6	48.9	0	23.3
Central Highlands	61.7	53.3	38.3	33.3	0	13.3
South East	64.8	37.1	35.2	19.0	0	43.8
Mekong R. Delta	70.0	47.8	30.0	21.1	0	31.1
Total observations	504	368	396	286	0	246

Table 2.9: The Widths of 95 Percent Confidence Interval in Bootstrapped Malmquist Estimates

	TFP width	EC width	TC with
1985/86	0.07	0.31	0.29
1986/87	0.09	0.23	0.23
1987/88	0.05	0.28	0.27
1988/89	0.06	0.30	0.29
1989/90	0.09	0.35	0.32
1990/91	0.11	0.35	0.29
1991/92	0.12	0.29	0.28
1992/93	0.11	0.31	0.26
1993/94	0.14	0.36	0.26
1994/95	0.07	0.26	0.24
1995/96	0.07	0.23	0.21
1996/97	0.07	0.23	0.21
1997/98	0.15	0.24	0.18
1998/99	0.07	0.21	0.19
1999/00	0.15	0.25	0.18
Red River Delta	0.08	0.22	0.20
North East	0.11	0.32	0.27
North West	0.14	0.34	0.29
North Central Coast	0.09	0.26	0.23
South Central Coast	0.08	0.30	0.26
Central Highlands	0.09	0.28	0.24
South East	0.10	0.29	0.25
Mekong River Delta	0.09	0.27	0.26
All country	**0.09**	**0.28**	**0.25**

2.5. Summary and Conclusion

This study has examined total factor productivity of Vietnamese agriculture during the period 1985-2000. During this period, Vietnam has achieved substantial success in agriculture, with an admirable annual growth rate of 5.2 percent. The reform policies carried out in the agriculture as well as in the economy as a whole have fundamentally changed the technology used in agriculture, by substituting machines for human and animal labor. In this context, the growth accounting approach used by Nguyen and Goletti (2001) is inappropriate since it assumes constant shares of inputs and a specific functional form for the production function. The Malmquist index approach is an attractive alternative, especially in the situations like in Vietnam, where certain data such as prices of labor and capital are missing, contradictory or unreliable. By using the Malmquist index approach, one can also decompose TFP growth into technical progress and efficiency improvement to determine the most importance sources leading to agricultural growth.

This study indicates that most of the early growth in Vietnamese agriculture during the first reform period, from 1985 to 1990, was due to TFP growth, in response to incentive reforms that were part of Vietnam's Doi Moi policy. During the second reform period, from 1990 to 1995, the growth rate of TFP slowed down and Vietnam's agricultural growth was mainly caused by a large increase in capital investment. In the last period (1995-2000), however, TFP growth increased again, though at a much smaller rate than during the 1985-1990 period. Overall, the average TFP growth rate during the whole period is estimated to be 1.96 percent per year, which accounts for 38% of Vietnam's agricultural growth. Although this growth rate is high compared to those in other developing countries,[7] it is not steady, high in the late 1980s but low in the early 1990s. In the 1990s decade, TFP grew by only 1.2 percent and most of

[7]For example, in Fulginiti and Perrin (1998), the mean agricultural TFP growth of 18 developing countries during 1961-1985 is negative, at -1.6%. Coelli and Rao (2005)'s mean agricultural TFP growth of 93 countries during 1980-2000 is 0.5%

Vietnam's agriculture growth was caused by increased inputs. Sustaining TFP growth will be a key factor in maintaining Vietnam's agricultural growth in the future because long-term growth relies on productivity growth, rather than input growth.

This study also points out different patterns in TFP growth across provinces and regions. While the Mekong River Delta and the Central Highland have achieved much success in increasing their outputs and TFP, there are some regions which experienced decreases in TFP growth. The situation was particularly severe for the North West, where TFP growth declined by 6.7 percent annually during the whole period. It is clear that the success of Vietnamese agricultural growth was not spread evenly. As agriculture is still the major source of employment and income for a large population in Vietnam, investing in improving productivity and efficiency in farming should be a priority to achieve long-term economic growth and success in rural poverty alleviation.

Finally, it is important to point out this study's limitations. First, some important variables such as fertilizers and buildings are left out due to insufficient data, which may lead to some bias in TFP estimates. Second, also due to limited data, the "quality" aspects of certain inputs such as labor and land are ignored. If possible, these input variables should be adjusted for their quality. Third, the "labor" variable is measured as the number of agricultural laborers, yet the number of labor hours (which is not available) might be a better proxy for labor. Fourth, using several outputs instead of one aggregate output in the estimation may reveal the transformation of Vietnamese agricultural production and productivity more clearly.

CHAPTER 3: EFFICIENCY OF RICE FARMING HOUSEHOLDS IN VIETNAM: A DEA WITH BOOTSTRAP AND STOCHASTIC FRONTIER APPLICATION

Abstract

This study uses household survey data of rice farming households in Vietnam to estimate the technical efficiency using two different methods, the Data Envelopment Analysis (DEA) and the stochastic frontier approach. A bootstrap method is used to obtain the statistical precision of the DEA estimator. Bootstrap methods have not commonly been used in empirical analysis despite being an important statistical tool for estimating the precision of estimated parameters. In this chapter, technical efficiency is modeled as a function of household and production factors. The results from the deterministic, semi-parametric and parametric approaches indicate that, among other things, technical efficiency is significantly influenced by primary education and by location. In addition, scale efficiency analysis indicates that many farms in Vietnam are operating at a less than optimal scale of operation, especially in the Central region.

Keywords: Data Envelopment Analysis (DEA), stochastic frontier, efficiency, rice, bootstrap, Vietnam.

3.1. Introduction

Agriculture is the most important sector in the Vietnamese economy, accounting for 21.8 percent of gross domestic product in Vietnam (World Bank 2006) and employing 67.3 percent of the working population[8]. In agriculture, rice is the most important crop in Vietnam. It is planted on about 84 percent of Vietnam's agricultural land and constitutes more than 85 percent of Vietnam's food grain production.

Since the Doi Moi policy reforms were launched in December, 1986, the government has liberalized both the rice market and the markets for agricultural inputs. The government has also promoted cultivation of high-yielding varieties. Since then, rice production and export has steadily increased. Rice production increased from 15.1 million tons in 1987 to 32.6 million tons in 2000, a growth rate of 6.1 percent per year, while rice yields increased from 2.70 tons/ha in 1987 to 4.25 tons/ha in 2000, a growth rate of 3.3 percent per year (IRRI 2006). Figure 3.1 presents trend for rice production, rice area and rice yield over the past 20 years. Since the launch of the Doi Moi policies, rice production, rice area and rice yield have increased significantly, although since 2000, the growth of rice area has slowed and even been slightly negative.

Vietnam has been a major rice exporter since 1989, and it is currently among the top three largest rice exporters in the world, exporting as much as 5.2 million tons in 2005, equivalent to 18.2 percent of the total world rice trade in that year (FAO 2006). Recently, modern rice technology has been widely disseminated. The adoption rate of

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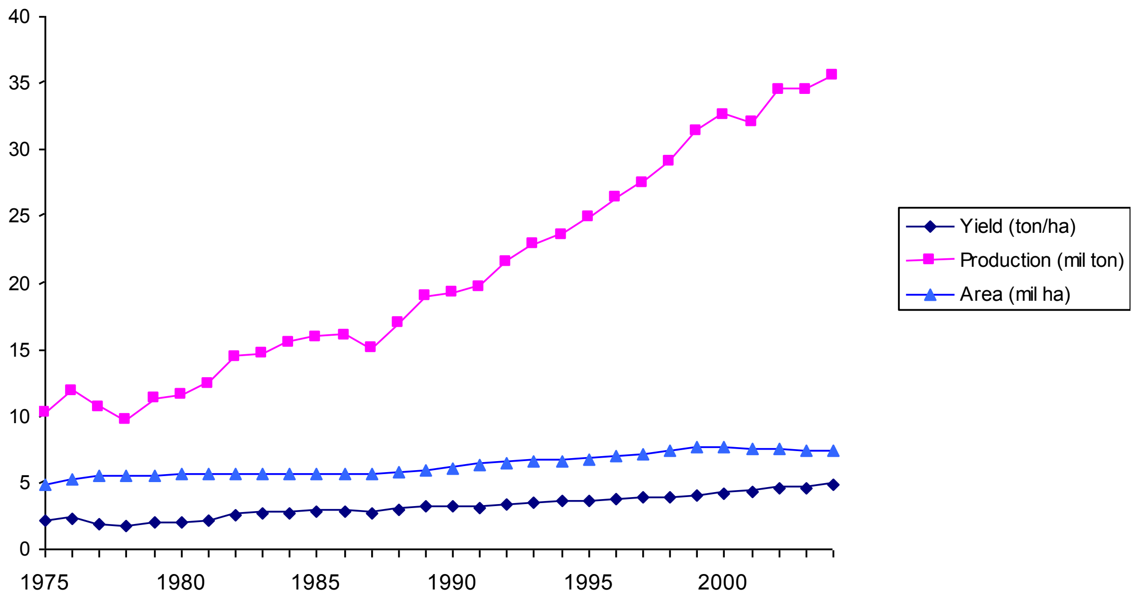
[8] Calculated by the author based on International Rice Research Institute (IRRI)'s World Rice Statistics data.

fertilizer-responsive, high-yielding modern rice varieties increased from 17% in 1980 to nearly 90% in 2000 (Tran and Kajisa 2006).

Figure 3.1: Rice Production, Yield and Area in Vietnam 1975-2004



Source: Author calculated from IRRI 2006

Given the importance of rice production in Vietnam, it is unclear why there have been so few studies on the efficiency of Vietnamese rice farms. This chapter is the first study to estimate farm-level technical and scale efficiency in rice production in Vietnam, and factors influencing that technical efficiency by applying several recently developed methods. This chapter should be useful for those interested in Vietnam's rice production, and more generally it contributes to the empirical work on efficiency, notably by applying bootstrap procedures to establish the statistical properties of DEA technical efficiency.

The structure of this chapter is as follows. Section 3.2 describes the analytical framework. Section 3.3 summarizes the methods and data. Section 3.4 presents the results. Section 3.5 is a hypothetical Monte-Carlo simulation to check the robustness of efficiency estimates from different methods. Finally, section 3.6 concludes the study.

3.2 Analytical Framework

Following seminal work of Farrell (1957) and others, economic efficiency is typically decomposed into three types: technical, allocative and scale efficiency[9]. Technical efficiency (TE) measures the firm's ability to use the best practices and available technology in the most effective way. Allocative efficiency (AE) is dependent on prices and measures the firm's ability to make optimal decisions on product mix and resource allocation. Combining measures of technical and allocative efficiency yields a measure of economic efficiency. Scale efficiency measures the optimality of the firm's size.

Efficiency can be estimated by either parametric or nonparametric method. Parametric measurement includes specifying and estimating a stochastic production frontier or stochastic cost frontier. In this method, the output (or cost) is assumed as a function of inputs (or output), inefficiency and random error. The main strength of the stochastic frontier function approach (SFA) is its incorporation of stochastic error, and therefore permitting hypothetical testing. The disadvantage of this approach is the imposition of an explicit functional form and a distributional assumption of the error term. Therefore, parameter estimates obtained using the stochastic frontier method is sensitive to the parametric form chosen.

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[9] Farrell (1957) used the term "price inefficiency" instead of "allocative efficiency"

On the other hand, the non-parametric approach used in the data envelopment analysis (DEA) has the advantage of making no prior parametric restrictions on the technology; therefore it is less sensitive to model misspecification. The DEA method is also not subject to assumptions on the distribution of the error term and imposes minimal assumptions on production behavior. Furthermore, estimation using the DEA method is based on a piecewise production frontier, making the estimated frontier close to real activity. However, because DEA is a deterministic approach, all deviations from the frontier are considers are considered inefficiencies, making it sensitive to measurement errors and noisy data. Furthermore, DEA is known to be sensitive to outliers.

There have been many studies on efficiency in agriculture in developing countries, the majority of which used the stochastic frontier approach. Thiam et al. (2001) summarizes 51 estimates of technical efficiency (TE) in agriculture in developing countries from 32 papers that were published before 1999. They include 27 stochastic frontier approach (SFA), six deterministic frontier, and two DEA studies. However, the application of DEA method to has gradually increased. Bravo-Ureta et al. (2006) summarized 167 published papers on efficiency in agriculture that were published between January 1979 and June 2005. Of these 167 papers, 42 used DEA method, 32 used deterministic frontier method, and 117 used stochastic frontier method[10]. Thus, among the studies that published since 2000, 19 studies used DEA, 6 studies used deterministic frontier and 38 studies used stochastic frontier. The use of DEA has now been widely regarded as an alternative to stochastic frontier method. Recent applications of the DEA method on the estimation and explanation of agricultural efficiency in

[10] Some papers reported estimates from different methods.

developing countries include Dhungana et al. (2004) on Nepal rice farms, Krasachat (2003) on Thailand rice farms, Chavas et al. (2005) on Gambia farms, and Shafiq and Rehman (2000) on Pakistan farms. There are several studies that use both DEA and stochastic frontier methods such as Sharma et al (1999), Wadud (2003) and Wadud and White (2000).

There are only a few papers that calculate the efficiency and determine the factors affecting efficiency in Vietnam's agriculture. They include Tran et al. (1993) on state rubber farms (who used the stochastic frontier method) and Rio and Shively (2005) on coffee farms (using the DEA method). Most past studies on the efficiency of rice production in Vietnam used only simple measures such as yield per hectare, which is not a measure of efficiency but productivity. However, some studies focus on total factor productivity (TFP) growth. For example, Nghiem and Coelli (2002) used region-level panel data on rice production in Vietnam to investigate TFP growth in Vietnam since its reunification in 1975. They found an average annual TFP growth of between 3.3 and 3.5 percent during the period. Kompass (2004) estimated TFP growth in the same period and found TFP growth rates of 0.6, 2.74, 4.43 and 4.46 percent during the periods 1976-80, 1981-87, 1988-94 and 1995-99, respectively.

Kompas (2004) is also the only known attempt to calculate average technical efficiency for rice sector in Vietnam, using a stochastic production frontier approach based on a region-level panel data. In his study, the average technical efficiency for the whole country was 0.65 in 1999 and about 0.78 for the principal rice-growing areas (Red River Delta and Mekong River Delta). Among other factors, farm size, tractor use and a dummy variable for the principal rice areas are found to be positively associated with higher technical efficiency. However, by using regional data, that study cannot give useful information on the efficiency at farm level as well as on the determinants affecting farm efficiency. To date, there have been no studies on the efficiency of rice farms that use farm-level data yet.

Given the advantages and disadvantages of both the DEA and SFA methods, it may be helpful to use and compare them on the same data set. In addition, establishing the statistical properties of the DEA estimator is useful for carefully interpreting its results. Recent advances in the DEA literature include using bootstrap to establish the confidence interval of technical efficiency (see Simar and Wilson 2000). The bootstrap method in Simar and Wilson (2000) has been applied empirically in several studies of farm efficiency in developed countries. For example, Brummer (2001) uses it to establish the confidence interval of technical efficiency for private farms in Slovenia; Latruffe et al. (2005) apply the method for crop and livestock farms in Poland; Ortner et al (2006) for dairy farms in Austria; and Olson and Vu (2007) for farms in Minnesota, USA.

The objectives of this paper are to: (1) use DEA methods to estimate technical and scale efficiency of rice farming households in Vietnam; (2) use a semi-parametric bootstrapping procedure based on Simar and Wilson (2000) to establish the statistical properties of technical efficiency of rice farming households in Vietnam; (3) use stochastic frontier methods to estimate technical efficiency and compare it with the results from DEA methods; (4) use estimates from both DEA and SFA in the second stage to determine the factors influencing these estimates..

3.3. Methods and Data

3.3.1. Deterministic Nonparametric Method: Data Envelopment Analysis

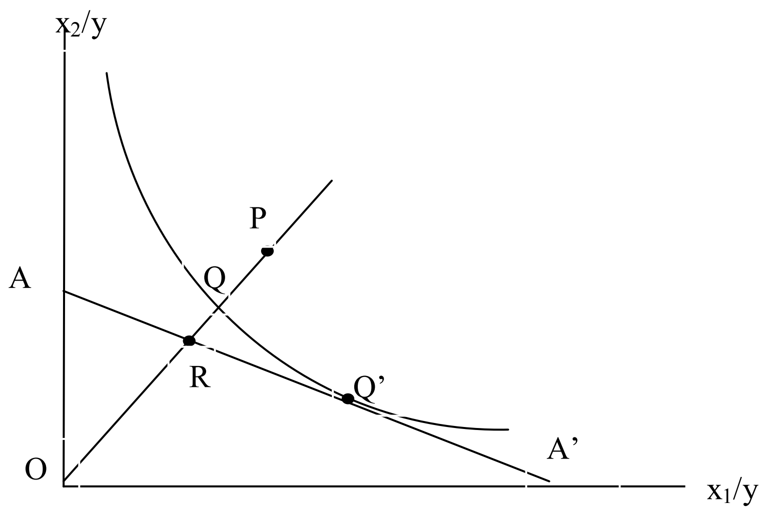
As a nonparametric approach, DEA (Charnes et al 1978, Färe et al 1994) is used to derive technical and scale efficiency. DEA methods can be applied using either an output-based or an input-based approach, depending on whether they use an input distance function or an output distance function. In the input-based approach, the idea is to measure the farm's efficiencies by comparing its actual inputs with the minimum inputs needed to produces its actual bundle of outputs. In contrast, the output-based approach is to compare the actual outputs with the maximal outputs from actual inputs. Except under constant return to scale, these two approaches yield different measurements of efficiency (Färe et al 1994). Thus, if the farm's purpose is to maximize its revenue, the output-based approach is a more appropriate approach. On the other hand, the input-based approach is more appropriate if the farm's purpose is to minimize its costs.

This chapter first uses DEA methods to estimate input-based technical and scale efficiency as well as output-based technical efficiency. The input-based technical efficiency under variable returns to scale (VRS) is the focus of this study because in smallholding agriculture such as Vietnam, farmers have more controls over their inputs than outputs. Based on the smoothed bootstrap procedure for DEA estimators proposed by Simar and Wilson (1998, 2000), the chapter estimates the bias and the confidence interval of the input-based technical efficiency with VRS, using the FEAR package developed by Wilson (2005) for the R platform.

Input-based Technical and Scale Efficiency

Figure 3.1 illustrates the concept of technical and scale efficiency in the case of two inputs (x_1, x_2) and one output (y) under constant returns to scale (see Coelli 1996). Point P is technically inefficient because the farm can move to point Q and reduce its inputs. The distance QP reflects the technical inefficiency of the farm. It is often expressed in percentage terms as OQ/OP.

Figure 3.1: Input-Oriented Technical and Allocative Efficiency



In figure 3.1, the input prices are expressed by the line AA'. Point Q is technically efficient but is allocatively inefficient, while point Q' is both allocatively and technically efficient. The allocative efficiency is expressed as the fraction OR/OQ.

Mathematically, for the j^{th} farm out of n farms, input-based technical efficiency (TE) under constant return to scale (CRS) is obtained by solving the following problem

$$TE_j = \underset{\theta_j^{CRS}, \lambda}{Min}\, \theta_j^{CRS} \tag{3.1}$$

subject to

$$Y_j \leq Y\lambda$$
$$\theta_j^{CRS} X_j \geq X\lambda$$
$$\lambda \geq 0$$

where X and Y are the input and output matrix of n farms, respectively; X_j and Y_j are the input and output vector of farm j, respectively; θ_j^{CRS} is technical efficiency of farm j under CRS and λ is an $n \times 1$ vector of weights, which will be solved by linear programming. In general, $0 \leq \theta_j^{CRS} \leq 1$, where $\theta_j^{CRS} = 1$ if the farm is producing on the production frontier and hence, technically efficient. When $\theta_j^{CRS} < 1$, the farm is technically inefficient.

In the case of variable returns to scale, one can find technical efficiency θ_j^{VRS} under variable return to scale (VRS) by adding the convexity constraint $\sum_{j=1}^{n} \lambda_j = 1$ to (1). Because the variable return to scale is more flexible so the convex hull envelops the data more tightly than under CRS, θ_j^{VRS} is always equal or greater than θ_j^{CRS} [11].

Scale efficiency (SE) is measured by dividing the two technical measures:

$$SE_j = \frac{\theta_j^{CRS}}{\theta_j^{VRS}} \tag{3.2}$$

In general, $0 \leq$ SE ≤ 1, with SE=1 representing efficient economy of scale. SE< 1 implies that the inputs are not scale efficient, which can be either increasing returns to scale (IRS) or decreasing returns to scale (DRS). Among farms with scale inefficiency,

[11] Some authors call θ_j^{VRS} "total" or "overall" technical efficiency and θ_j^{CRS} "pure" technical efficiency.

one can decide which farms with IRS or DRS by running a DEA problem with non-increasing returns to scale (NIRS) imposed. This can be done by adding the constraint $\sum \lambda_i \leq 1$ into equation (1). Let θ_j^{NIRS} be the obtained technical efficiency measures under NIRS. If $\theta_j^{NIRS} = \theta_j^{VRS}$ and $SE_j < 1$, the farm j is operating with decreasing return to scale. If $\theta_j^{NIRS} < \theta_j^{VRS}$ the farm j is under increasing return to scale.

Output-based Technical Efficiency

For the j^{th} farm out of n farms, output-based technical efficiency under constant return to scale (VRS) is obtained by solving the following problem

$$TE_j = \underset{\theta_j^{VRS}, \chi}{Min}\, \theta_j^{CRS} \tag{3.3}$$

subject to

$$\begin{aligned} & Y_j / \theta_j^{VRS} \leq Y\lambda \\ & X_j \geq X\lambda \\ & \lambda \geq 0 \\ & \sum_{j=1}^{n} \lambda_j = 1 \end{aligned}$$

Under CRS, the output-based and the input-based technical efficiency are the same.

3.3.2 Bootstrapping the DEA estimator

While DEA methods have been widely applied, most researchers have largely ignored the statistical properties in the estimators, so that any deviation from the frontier is attributed to inefficiency. Ignoring the noise in the estimation can lead to biased DEA estimates and misleading result. Recently, some attempts have been made to establish theoretically and empirically the statistical properties of DEA estimators. Banker (1993) and Korostelev et al. (1995) prove the consistency of DEA estimators. Kneip et al (1998) provides convergence results for the general multi-output, multi-input case. Simar and Wilson (1998, 2000) argue that bootstrap is currently the most feasible method to establish the statistical property for DEA estimators. While naïve bootstrapping has been used in several papers (Löthgren (1998), Löthgren and Tombour (1997), Ferrier and Hirshberg (1997)), it is criticized by Simar and Wilson (1999) as giving inconsistent results. To obtain consistent estimates, Simar and Wilson (1998, 2000) propose a smoothed bootstrapping method. This paper applies Simar and Wilson (1998, 2000) smoothed bootstrap procedure to correct the bias in DEA estimators and calculate their confidence interval.

Bootstrapping is based on the idea that, by re-sampling the data with replacement, one can mimic the underlying data-generating process (DGP) that actually produces true data. The smoothed bootstrap procedure of Simon and Wilson relies on the assumption that the distribution of efficient estimates is independently distributed. In this method, the efficiency estimates are estimated from the original data to form a pseudo dataset where the output vector is the same and the input vector is adjusted by the estimated efficiency scores. From the pseudo data, a new DEA efficiency score is calculated for each farm, taking the pseudo data as a reference. By replicating the re-sampling process B times, one can establish the empirical distribution of the efficiency measures from the B efficiency scores. The procedure is described in more detail in Appendix A1.

3.3.3. Stochastic Frontier Method

An alternative to the DEA approach is the stochastic frontier method, which is based on a well-specified production function. Under VRS, the production function is specified as (see Aigner et al. 1977, Battese and Coelli 1992):

$$\ln Y_i = f(X_i;\beta) + \varepsilon_i \tag{3.4}$$

where X_i is the input vector and Y_i the output vector for farm i; $f(X_i;\beta)$ is usually assumed to be either the Cobb-Douglass production technology or the translog technology. Both functional forms are used extensively in literature[12]. This chapter uses the Cobb-Douglass functional form for convenience, due to the relatively large number of inputs (10) in the production frontier function. Furthermore, the Cobb-Douglass functional form is also more convenient for testing returns to scale hypotheses. In addition, this chapter calculates technical efficiency using the translog functional form. Using a paired t-test, one cannot reject the hypothesis that the efficiency scores estimated from both specifications are equal at 1 percent level, although one can reject that hypothesis at 5 percent level.

The Cobb-Douglass production function under VRS is:

$$\ln Y_i = \beta_0 + \sum_{k=1}^{T} \beta_k \ln X_k + \varepsilon_i \tag{3.5}$$

The error term in equation (3) is taken to be composed of two components (Aigner et al 1977):

$$\varepsilon_i = v_i - u_i \tag{3.6}$$

[12] In Thiam et al (2001)'s meta-analysis, among 33 studies used stochastic frontier methods, 19 used the Cobb-Douglass functional form while 14 used a translog functional form.

where v_is are assumed to be independently and identically N(0, σ_v^2) representing the random errors. The term u_i represents the technical inefficiency of farm *i* but unlike v_i, it has a truncated distribution that contains only non-negative values. There is no consensus about the distribution of u_i with its distribution assumed half-normal, exponential and truncated normal-distribution and gamma distribution in previous studies. This chapter assumes that u_i has a half-normal distribution, which is considered by Greene (1997) as "the most useful formulation". In other words,

$$u_i = |U|, \text{ where } U \sim N(0, \sigma_u^2).$$

The technical efficiency of farm *i* is calculated as: $TE_i = \exp(-u_i | \varepsilon_i)$, which is greater than zero and less than one. The estimation of stochastic frontier model is done by the maximum likelihood method in STATA version 9.0 software (the *frontier* command).

3.3.4. Data

The data are taken from Vietnam Household Living Standard Survey 2003-2004 (VHLSS 2004). The survey is implemented every two years by the General Statistics Office of Vietnam with technical support from World Bank. In the VHLSS 2004 survey, there are 8813 households living in both rural and urban areas surveyed for detailed data, including about 4300 households producing rice. From the rice producing households, I chose a sub-sample of 600 households, using stratified sampling. After calculating the efficiency, I dropped 5 extreme observations, as it is known that DEA method is sensitive to outliers. The final sample includes 595 farms.[13] The sub-sample has values similar for most variables, to those in the larger sample.

The measure of output is the quantity of rice harvested during the previous 12 months. The inputs include ten inputs: fertilizers, pesticides, seed, family labor, hired labor, the value of owned fixed assets and equipment, rental of productive assets (including cattle hire), small tool and energy, other farming expenditure and rice land. Since household are also engaged in activities other than rice growing, family labor is measured by the total family hours allocated to farming, adjusted by the value of rice production over the value of total farm production. Thus, it is assumed that the marginal productivity of rice farming is equal that of other farming activities. Rice land is measured by the land area allocated for rice production. Other inputs are expenditures used for these inputs, measured in current money value. Because price information for most inputs is not available, the measure of technical efficiency in this study encompasses to some extend input-based allocative efficiency. In the sample, on average, rice accounts for 46 percent of agricultural household output value. This number is close to the value of rice production as a percentage of the value of total agricultural production value for all of Vietnam- 41.5% in 2001 (Vietnam Business Forum 2003). Summary statistics for these households are listed in Table 3.1.

Table 3.2 presents the composition of immediate input expenditures on various inputs for rice farming. Fertilizers and rental asset account for the highest share of input

[13] I chose a sample of 595 farms instead of 4300 farms to enable calculating the efficiencies by the DEA and bootstrap method. For example, to run a bootstrap of 2000 replications for a sample of 4300 farms will require simultaneously solving $4300\times(2\times 2000+1) \approx 17.2$ millions linear equations, an overburdened task for an average PC (see Simar and Wilson 2000 for the calculation of number of equations). In this analysis, the number of linear equations to be solved in the bootstrap step is $595\times(2\times 2000+1) \approx 2.4$ millions linear equations.

expenditures. Approximately 58 percent of immediate input expenditures are used for buying seeds (10.8 percent), fertilizers (36.1 percent) and pesticides (11.4 percent). About 29 percent are used for hiring outside labor (9.7 percent), hiring cattle, fixed asset and asset maintenance (19.5 percent). The rest, about 13 percent is used for buying or repairing small tools and buying energy (3.6 percent) and taxes, irrigation fee and other payments to the government (8.9 percent).

Table 3.1: Summary Statistics for Rice Farming Households, 2004

Variable	Mean	Std. Dev.	Min	Max
Input and output vectors				
Rice quantity (kgs)	7560	11125	100	100640
Rice value *	6562	8428	200	100048
Seed expenditures*	291	530	0	9900
Fertilizer expenditures*	976	1353	0	13800
Pesticide expenditures*	308	706	0	6540
Family hours for farming*	2184	1766	64	9432
Percent of rice (percent)	46	25	0.7	100
Estimated family hours for rice production (hours)	904	871	7.5	5333
Rice land area (square meters)	6991	8770	250	74000
Fixed asset and equipment value*	6414	12976	0	164500
Hired-in labor expenditure*	262	674	0	8750
Rental assets*	529	964	0	6540
Small tool and energy*	98	255	0	8750
Other farming expenditure*	242	419	0	8312
Household characteristics				
Total number of household members	4.71	1.79	1	13
Number of adults/ total household members	0.65	0.21	0.2	1
Age of household head	49	14	21	87
Years of schooling of household head	6.59	3.51	0	12
Production characteristics				
Total farm output*	17391	20784	350	212773
Capital/Labor ratio	5.21	18.35	0	250
Land/Labor ratio	4.21	5.54	0.22	81.6
Non-farm income/Total household income	0.32	0.26	0	0.96
Number of extension visits	1.70	3.11	0	27

* *in thousand VND.*

Table 3.2: Immediate Expenditure Share for Rice Farming

Cost	Percent
Seeds	10.8
Fertilizers	36.1
Pesticides	11.4
Hired-in labor	9.7
Rental assets	19.5
Small tool and energy	3.6
Other expenditure	8.9

3.4 Empirical results

3.4.1 Technical Efficiency

The estimated DEA and SFA efficiencies are in Table 3.3. The average technical efficiency estimated by the DEA method is higher than the average using the SFA method. Similar results have been found in Johansson (2005) for Swedish dairy farms, Kalaitzandonakes and Dunn (1995) for corn farms in Guatemala and Wadud and White (2000) for rice farmers in Bangladesh. Thiam et al (2001) reviews 27 stochastic frontier studies, six deterministic frontier studies and two DEA studies, and reports that the average technical efficiency of all studies is 0.68 while the average technical efficiency in two DEA studies are 0.95. On the other hand, in Sharma et al (1999) the average DEA estimate and SPF estimate are similar and in Paul et al (2004) and Brummer (2001), the average DEA estimates are smaller than the SFA estimates. The differences in empirical studies in comparing these two approaches could be due to differences in the data characteristics, in input and output variables, as well as in specification and estimation procedures.

The input-based estimates of TE are slightly higher than the output-based estimates. More specifically, the estimates indicate that with a given bundle of inputs, an average household can increase its output by 30.7% (=1/$TE_{VRS-OUT}$ -1). On the other hand, that household can reduce its inputs by 27.4% (=1/TE_{VRS-IN} -1) without changing the level of its output.

Table 3.3: DEA and SFA Estimates

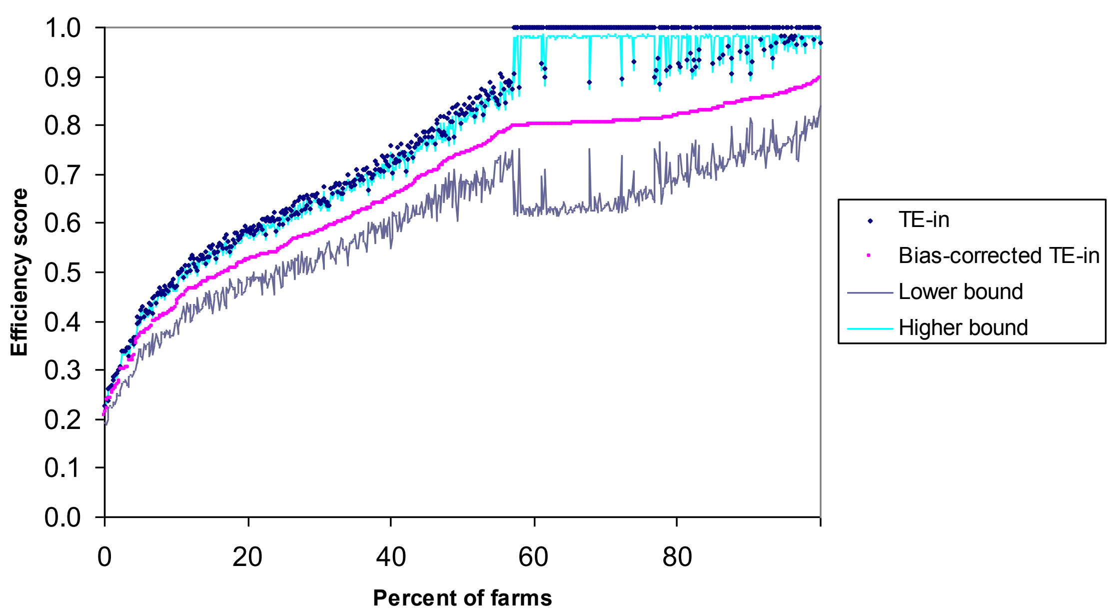
	DEA							Stochastic Frontier
	CRS	Output-based (VRS)	Input-based (VRS)					
	TE_{CRS}	$TE_{VRS-OUT}$	TE_{VRS-IN}	Bias-corrected TE	Lower bound	Higher bound	SE	TE by SFAA
Average	0.704	0.765	0.785	0.678	0.593	0.771	0.890	0.634
Median	0.711	0.816	0.824	0.741	0.627	0.811	0.958	0.674
Std. Dev.	0.244	0.238	0.212	0.167	0.137	0.208	0.160	0.193
Min	0.090	0.174	0.228	0.205	0.190	0.224	0.090	0.109
Max	1.000	1.000	1.000	0.896	0.844	0.986	1.000	0.952

Estimates from the input-based deterministic DEA model have downward biases in efficiency scores because in the model, the "true" production frontier is unknown, and the points on the observed production frontier may be inefficient in the presence of a "true" production frontier. Using the bootstrap method as in Simar and Wilson (2000), the bias-corrected TE is significantly lower than the initial DEA estimates and is closer to the stochastic frontier estimates.

Figure 3.2 shows the distribution of initial DEA estimates, bias-corrected DEA estimates and the 95-percent confidence interval for the input-based methods. The confidence interval is larger for the farms considered initially as technically efficient than for other farms. If we examine only the initial DEA estimates, it appears that, on average, rice farms in Vietnam can reduce their inputs by 27.4% and still can produce the same outputs. Yet, after correcting for the bias, they can reduce their inputs by 47.5% (1/ 0.678 -1) to produce the same level of outputs as before. An average rice farming household can reduce its inputs in the range from 29.7% to 68.6% with 95% confidence interval.

By the stochastic frontier method, the corresponding value is 57.8% (=1/0.634 - 1) for Cobb-Douglass specification. It is clear that the amount of input that could be saved is considerable.

Figure 3.2: Initial and Bias-Corrected Input-Based Technical Efficiency under VRS



To compare the estimates from the nonparametric and parametric approaches, one can use paired t-tests and the Spearman rank correlation. The results are shown in Table 3.4. Based on the paired t-test, on average, the estimated technical efficiencies based on the nonparametric method, both before and after correcting for bias, are higher than the estimates based on the parametric method, although the difference is smaller for bias-corrected estimates. The Spearman correlation coefficients between the efficiency rankings of the sample farms are positive and significant, implying that the efficiency scores calculated in both methods are not independent.

Table 3.4: Paired t- tests and Spearman Rank Correlation Tests

Efficiency	Sample Mean *DEA*	*SFA*	*t- ratio*	*Spearman rank correlation*
Initial TE	0.785	0.634	19.16*	0.5284*
Bias-corrected TE	0.678	0.634	6.50*	0.5526*

** significant at the 1% level*

Figure 3.3 shows the percentage cumulative frequency distribution of technical efficiency from both DEA and SFA methods. Again, the correlation between bias-corrected technical efficiency and stochastic technical efficiency estimates in Table 3.4 is also higher than between the uncorrected technical efficiency and stochastic technical efficiency estimates.

Figure 3.3: Percentage Cumulative Frequency Distribution of TE from SFA and DEA

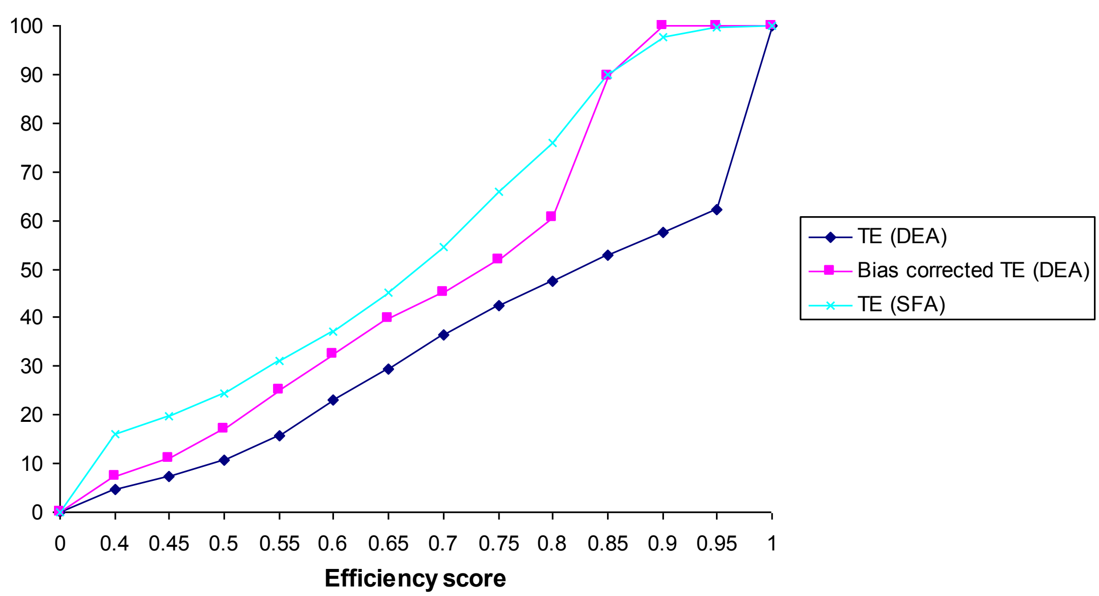


Table 3.5 shows the distribution of the technically efficiency of farms in the dataset according to the DEA method. Farms in the Southern Region- the main production region in Vietnam - are the most efficient. Farms in the Center Region are the least technically efficient[14]. In addition, average technical efficiency and the percentage of technically efficient farms are higher for large farms than for small farms and for diversified farms than for exclusive rice farms. Large farms are defined as farms with total farm output value higher than 15 million VND (about $1,000)[15]. Mainly rice farms are defined as farms for which the value of rice output is more than 70 percent of the total value of farm output. About 70 percent of farms in the sample are mainly rice farms and 37 percent of farms are large farms.

Table 3.5: Distribution of Average Technical Efficiency

Region	Average TE	Bias-corrected TE	Number of farms with TE=1	% of farms with TE=1
All farms	0.785	0.678	201	33.8
Red River Delta	0.801	0.698	49	28.3
North East	0.786	0.678	37	34.9
North West	0.806	0.688	23	42.6
North Central Coast	0.704	0.619	14	18.9
South Central Coast	0.715	0.622	15	27.8
Central Highlands	0.867	0.723	15	57.7
South East	0.785	0.652	14	53.8
Mekong River Delta	0.831	0.710	34	41.5
North	0.797	0.690	109	32.7
Center	0.709	0.621	29	22.7
South	0.829	0.701	63	47.0

[14] Thus, there are certain differences between the results in this chapter with those in Chapter 2, which is understandable because the two chapters use different dataset and time period. Moreover, chapter 2 studies the agricultural sector as a whole, while chapter 3 studies only rice farming.

[15] That number is chosen arbitrarily based on the distribution of farm output value.

Large farm	0.812	0.697	81	36.7
Small farm	0.770	0.667	120	32.1
Diversified farm	0.816	0.701	70	39.8
Mainly rice farm	0.772	0.668	131	32.0

3.4.2. Scale Efficiency

Table 3.6 summarizes the scale efficiency of rice farming households as estimated by DEA method. Similar to the distribution of technical efficiencies, farm households in the South are more scale efficient than farms in the North and the Center, and large farms are more scale efficient than small farms. However, mainly rice farms are more scale efficient than diversified farms. About 23.4% of total farms are working near their optimal scale of operation, and a majority of farms (59%) are operating in areas of increasing returns to scale. That suggests that, in general, a majority of rice farms can to gain scale efficiencies by increasing their operating scale.

For the stochastic frontier functional form, the sum of the coefficients from the Cobb-Douglass production frontier is 1.098, implying increasing returns to scale. The hypothesis of constant returns to scale (sum of coefficient equal to one) is rejected at one-percent level of significance.

Table 3.6: Distribution of Average Scale Efficiency

	SE	Number of farms with SE=1	DRS	IRS	% with SE=1	Total farm output (mil. VND)
All farms	0.890	139	104	352	23.4	17.4
Red River Delta	0.900	35	22	116	20.2	14.6
North East	0.893	26	15	65	24.5	13.4
North West	0.881	17	3	34	31.5	10.9
North Central Coast	0.881	3	14	57	4.1	11.4
South Central Coast	0.823	7	9	38	13.0	12.3
Central Highlands	0.879	14	3	9	53.8	34.7
South East	0.907	9	5	12	34.6	32.8
Mekong River Delta	0.923	28	33	21	34.1	31.1
North	0.895	78	40	215	23.4	13.6
Center	0.857	10	23	95	7.8	11.8
South	0.911	51	41	42	38.1	32.1
Large farm	0.924	62	68	91	28.1	33.1
Small farm	0.871	77	36	261	20.6	8.1
Diversified farm	0.831	37	14	125	21.0	26.1
Mainly rice farm	0.915	102	90	227	24.3	13.7

3.4.3. Factors Associated with Efficiency

A relevant question is: what factors influence the farm technical efficiency? The factors included for close examination in this study include household characteristics, production structure, land characteristics, and regional variables.

Household characteristics variables include household size, the ratio of adults over total household members, and the household head's age and schooling. The household head's schooling is categorized into four categories: no formal education, primary schooling (from 1 to 5 years), lower secondary schooling (from 6 to 9 years), and upper secondary schooling or higher (10 years and up). In the data, 32 percent of household heads have primary schooling, 45 percent have some secondary schooling, 14 percent have more than 9 years of schooling and only 7 percent have never gone to school. It is assumed that higher education makes farming more efficient. The effect of head's age is more ambiguous. On one hand, older farmers have more experience, and thus, are likely to be more efficient than younger farmers. On the other hand, younger farmers may be more willing to apply more efficient technology and more physically strong for farm work than older farmers.

Other variables include farm size (measured by the value of total farm output), the capital to labor ratio (million VND/hour), the land to labor ratio (square meter/hour), the non-farm income ratio, and the number of extension visits. Total farm output value includes both rice and other crop/livestock income. Capital is measured as the total value of fixed assets.

Binary variables include dummies for land characteristics (rented land, high quality land), education level (primary, lower secondary, upper secondary), whether the household get access to loans, to modern irrigation. Finally, there are regional binary variables which are categorized in two sets- one set includes dummies for the Center and the South region with the North being the reference region, and the other set includes dummies for the North East, the North West, the North Central Coast, the South Central Coast, the Central Highland, the South East and the Mekong River Delta regions, with the Red River Delta region being the reference region.

Four econometric models are used to determine the factors affecting technical efficiency. Model 1 is the standard Tobit model, in which the dependent variable is the original DEA estimate. This model is employed in most of papers using the DEA method to estimate the determinants of technical efficiency. However, this model has a disadvantage because it does not account for the bias and confidence interval in the DEA initial scores. Three models are developed with the information obtained from the bootstrap procedure. Model 2 is the weighted Tobit analysis. The dependent variable in Model 2 is the initial TEs calculated by DEA but with the weights equal to the reciprocals of the width between higher bounds and lower bounds. The idea is that, the higher the width is, the larger the measurement error can occur. Therefore, weighted Tobit analysis reduces the estimation errors by penalizing the observations with a larger width, or higher possibility of measurement error. Model 3 is a Tobit analysis similar to that of Model 1, but the dependent variable is the bias-corrected TE instead of initial TE. While this model is beneficial in correcting the bias from the deterministic model, it also has a disadvantage because the variances of bias-corrected TEs are often considerably higher than the variances of initial TEs (Simar and Wilson 2000). Finally, model 4 is maximum likelihood estimation for stochastic frontier TEs.

The results in table 3.7 show that farmer's age has a negative effect on TE although the effect is significant only for Model 1 and Model 2. This is consistent with the findings of Coelli and Battese (1996), Seyoum et al. (1998), Llewelyn and Williams (1996) and Dhungana et al (2004).

Primary education of the household heads is positively related to the farmer's technical efficiency in all models, but the impact is more statistically significant for the stochastic frontier estimates. The impacts of secondary and higher education on technical efficiency are more ambiguous. While secondary and higher education are associated with higher technical efficiency indices as calculated by the stochastic frontier method, they are insignificant for those calculated by non-parametric (Model 1) and semi-parametric methods (Model 2, 3). In particular, they are negative but insignificant for Model 1 and 2, and positive and significant for Model 4. This indicates that the role of primary education is stronger than the role of lower secondary or upper secondary education for improving farmers' efficiency.

Table 3.7: Factors Influencing Technical Efficiency (3 regions)

	Standard Tobit		Weighted Tobit		Bias-corrected		Stochastic frontier	
	Model 1		Model 2		Model 3		Model 4	
Dependent variable	TE by DEA		TE by DEA		Bias-corrected TE		TE by SPF	
Number of obs	595		595		595		595	
LR chi2(18) =	101.1		92.5		62.3		62.3	
Prob > chi2	0		0		0		0	
Log likelihood	-211		-204.2		251.9		251.9	
Adult ratio	0.11	(0.1)	-0.2	(0.3)	-0.24	(0.6)	0.2	(0.4)
Household size	-0.07	(0.9)	-0.08	(1.0)	-0.05	(1.3)	0.05	(1.1)
Capital/Labor	0.5	(0.1)	-1.49	(0.2)	0.62	(0.2)	-2.82	(0.7)
Land/Labor	0.21	(5.8)**	0.25	(5.7)**	0.05	(3.6)**	0.01	(0.4)
Head's age	-0.03	(2.8)**	-0.02	(1.8)*	-0.01	(1.3)	-0.01	(0.4)
Primary	0.79	(1.7)*	0.82	(1.7)*	0.53	(2.0)**	0.61	(2.1)**
Secondary	-0.31	(0.6)	-0.02	(0.1)	0.08	(0.3)	0.73	(2.5)**
High education	-0.38	(0.7)	-0.41	(0.7)	-0.02	(0.1)	0.6	(1.8)*
Farm output	21.3	(2.7)**	20.85	(2.1)**	8.14	(2.1)**	5.91	(1.4)
Land quality	0.13	(0.5)	0.37	(1.5)	0.27	(2.0)**	0.83	(5.5)**
Non-farm ratio	0.02	(0.0)	-0.09	(0.2)	0.12	(0.4)	-0.44	(1.5)
Irrigation	0.02	(0.1)	0.03	(0.1)	0.14	(0.9)	0.68	(3.8)**
Extension visit	0.01	(0.3)	0.04	(0.9)	0.01	(0.5)	0.01	(0.5)
Rented land ratio	-0.24	(0.3)	0.3	(0.3)	0.4	(0.8)	0.06	(0.1)
Borrow	-0.66	(2.7)**	-0.43	(1.7)*	-0.2	(1.5)	-0.13	(0.9)
Exclusive rice	-0.87	(3.0)**	-1.09	(3.6)**	-0.38	(2.5)**	0.53	(3.1)**
Center	-0.97	(3.2)**	-1.19	(4.2)**	-0.64	(3.8)**	-0.71	(3.8)**
South	-0.44	(1.2)	-0.85	(2.3)**	-0.26	(1.4)	-1.12	(5.4)**
Constant	10.2	(12)**	8.65	(9.3)**	7.33	(16)**	4.94	(9.4)**

*Note: absolute t-stat in parentheses; * and **, significant at 10% and 5%, respectively. The coefficients are scaled up by 10 for presentation purpose.*

One possibility for the small effect of higher education on efficiency is that farmers with higher education tend to shift to non-farm activities; therefore their education does not contribute for improving farm technical efficiency. In the data, the average non-farm ratio increases with the household head's education level. A simple regression also indicates that the non-farm ratio is positively associated (at 5% significant level) with the household head's year of schooling.

To test the hypothesis that household decisions are collective and influenced by the household member with highest education level rather than the household head's education, the maximal education level of the households was used as a regressor instead of head's education level. There was no significant relationship between the household's highest education level and its technical efficiency. This finding suggests that the head's education may be a more important factor in deciding the household technical efficiency.

The land over labor ratio has a significantly positive impact on technical efficiency for the nonparametric and semi-parametric models but not for the stochastic frontier model. This implies that increasing rice land per labor is generally associated with better technical efficiency. Given the shortage and fragmentation of land in a densely populated economy such as Vietnam, this finding is expected. Based on the World Rice Statistics of the International Rice Research Institute (IRRI 2005), it is estimated that nearly 90 percent of farms in Vietnam had farm areas of less than 1 hectare in 1994, while the corresponding ratios for the Philippines in 1991, Pakistan in 1990 and Thailand in 1988 were 37, 36 and 11 percent respectively. Studying the efficiency of Chinese agriculture, Nguyen et al. (1996) found that land fragmentation had a negative effect on farm efficiency in China. Thus, land consolidation in Vietnam may help to increase farm efficiency. On the other hand, the capital/labor ratio effect on technical efficiency is insignificant in all models.

Farm size has a significantly positive effect on technical efficiency in all models except Model 4, where the effect is positive but insignificant. This indicates that farm operations in Vietnam are in general not optimal in terms of technical efficiency. Agricultural concentration would help improve technical efficiency among Vietnamese farmers.

Among other factors, modern irrigation has positive effect but the effect is strongly significant only for the stochastic frontier model. Among the binary variables, the effect of land quality is positive in all models but significant only for Model 3 and Model 4. Farms with better land quality generally are in a better position to improve their technical efficiencies than those with poor land quality.

Farms with loans may have lower technical efficiencies than farms without loans although the effect is significant only for Models 1 and 2. The negative effect of debt on efficiency is possibly linked with the existence of agency costs. Farmers who are forced to borrow may have difficulty in their production and have more risks. At the same time, lenders may impose higher costs to these farmers, which, in turn, increases their costs and lower their technical efficiency. About 50% of the farms in our sample borrow money from various sources. The average loan value of the loans of these households is 8.4 million VND, of which about 3.5 million VND is reportedly used for agricultural production, while about 4 million VND is reportedly used for consumption and the rest (nearly 1 million VND) is said to be used for non-agricultural production purposes. In results not reported in Table 3.7, loans for agricultural production are found to be associated with lower technical efficiency, but there is no significant relationship between consumption loans and farm technical efficiency.

Regional dummies for both the Center and the South are negative, indicating that, other thing being equal, farms in the North are more technically efficient than those in the

South or in the Center. The negative impact of the Center dummy is strongly significant at 1% level in all models, while the South dummy is significant in Model 2 and 4, but insignificant in Model 1 and Model 3. The effect of the dummy variable for mainly rice farming is unclear: it is negative for the non-parametric and semi-parametric models (Model 1, 2, and 3) but positive for the parametric model (Model 4). Further investigation with separate subsets for exclusive rice farms and diversified farms may be necessary before reaching a definite conclusion about the differences in efficiency between these groups.

Other factors such as household size, household adult ratio, extension visits and rented land ratio are not significantly related to technical efficiency in all models. Use of extension in rural Vietnam is rather limited, with only 46% of households in the sample reporting at least one visit by an extension staff or to an extension service facility during the past year and only 6 percent having more than five visits. Farmers' rating of the quality of extension service is average. On a scale from 1 to 4 in which '1' is the best and '4' the worst, the average helpfulness score of the extension service is 1.9 for cropping decisions and 2.2 for livestock raising decisions..

Table 3.8 is similar to Table 3.7 except that now there are eight regions. Most rice production in Vietnam is in the Red River Delta and the Mekong River Delta. About 52% of Vietnam's rice is produced in the Mekong River Delta and 18% in the Red River Delta (IRRI 2006). Table 3.9 indicates that, on average, a farming household in the Mekong River Delta produces four times as much as farming household in the Red River Delta. Yet, it seems that, other factors being equal, rice growing in the Red River Delta is more efficient than Mekong River Delta. Rice farming households in the North Central

Coast and the South Central Coast are the least technically efficient among all the regions. Overall, the Red River Delta has the highest technical efficiency in rice farming. This result is consistent with the rice yield data. In 2002, the rice yield in the Mekong Delta was 4611 kg per hectare (300kg over the average in Vietnam), in the Red River Delta was 5641 kg/ha (1058kg over the average) (Vietnam Business Forum 2003).

Table 3.8: Factors Influencing Technical Efficiency (8 regions)

	Standard Tobit		Weighted Tobit		Bias-corrected		Stochastic frontier	
	Model 1		**Model 2**		**Model 3**		**Model 4**	
Dependent variable	TE by DEA		TE by DEA		Bias-corrected TE		TE by SPF	
Number of obs	595		595		595		595	
LR chi2(18) =	108.1 8		99.17		65.18		151.0 4	
Prob > chi2	0		0		0		0	
Log likelihood	-207		-201		253		211	
Adult ratio	0.33	(0.4)	0.1	(0.1)	-0.19	(0.5)	0.2	(0.5)
Household size	-0.07	(0.9)	-0.08	(1.0)	-0.05	(1.2)	0.08	(1.8)*
Capital/Labor	1.15	(0.8)	1.99	(1.1)	-0.12	(0.3)	-1.61	(3.3)**
Land/Labor	0.23	(6.1)**	0.25	(5.7)**	0.05	(3.7)**	0.02	(1.2)
Head's age	-0.03	(2.6)**	-0.02	(1.7)*	-0.01	(1.3)	-0.01	(1.3)
Primary	0.86	(1.8)*	0.94	(1.9)*	0.53	(2.0)**	0.37	(1.3)
Secondary	-0.24	(0.5)	0.06	(0.1)	0.07	(0.2)	0.29	(1.0)
High education	-0.29	(0.5)	-0.33	(0.6)	-0.03	(0.1)	0.15	(0.4)
Farm output	19.33	(2.2)	18.2	(1.8)*	8.53	(2.1)**	10.55	(2.4)**
Land quality	0.18	(0.7)	0.41	(1.6)	0.25	(1.7)*	0.62	(4.1) **
Non-farm ratio	-0.04	(0.1)	-0.03	(0.1)	0.15	(0.6)	-0.4	(1.4)
Irrigation	0.23	(0.7)	0.13	(0.4)	0.12	(0.7)	0.49	(2.7) **
Extension visit	0.01	(0.4)	0.04	(1.1)	0.01	(0.6)	0.02	(0.7)
Rented land ratio	-0.2	(0.2)	0.29	(0.3)	0.42	(0.9)	0	(0.0)
Borrow	-0.68	(2.8)**	-0.44	(1.8)*	-0.21	(1.6)	-0.19	(1.3)
Exclusive rice	-0.79	(2.7)**	-1.04	(3.4)**	-0.38	(2.4)**	0.53	(3.1) **
North East	0.19	(0.5)	0.01	(0.0)	-0.1	(0.5)	-0.41	(1.8)*
North West	0.43	(0.8)	0.39	(0.7)	-0.03	(0.1)	-1.52	(4.7)**
NCC	-0.88	(2.2)**	-0.8	(2.1)**	-0.67	(3.0)**	-0.99	(4.1)**
SCC	-0.76	(1.7)*	-1.56	(3.7)**	-0.68	(2.7)**	-1.13	(4.1)**
Central Highland	0.98	(1.4)	0.15	(0.2)	0.03	(0.1)	-0.86	(2.2)**
South East	-0.32	(0.5)	-0.75	(1.0)	-0.68	(1.9)*	-2.46	(6.4)**
Mekong Delta	-0.83	(1.8)*	-1.11	(2.3)**	-0.28	(1.2)	-1.45	(5.6)**
Constant	9.65	(9.9)**	8.13	(7.8)**	7.35	13.9**	5.92	(10.5)**

*Note: absolute t-stat in parentheses; * and **, significant at 10% and 5%, respectively. The coefficients are scaled up by 10 for presentation purpose. NCC and SCC stand for North Central Coast and South Central Coast respectively*

Table 3.9: Rice Value, Quantity and Percentage of an Average Farming Household, 2004

	Rice percentage	Rice Value (million VND)	Rice Quantity (tons)
Red River Delta	47.5	4.60	5.3
North East	35.8	4.29	4.4
North West	45.0	4.46	4.0
North Central Coast	44.5	4.98	5.5
South Central Coast	45.4	4.04	4.2
Central Highlands	27.8	4.55	4.3
South East	42.0	7.66	8.5
Mekong River Delta	63.7	18.41	23.6

3.5. How Robust are Production Efficiency Estimates? A Monte-Carlo Simulation

There have been many studies on efficiency using different techniques. Basically, most of the literature can be separated into two main streams. On one hand, econometric methods are used, and on the other hand the linear programming method known as Data Envelopment Analysis (DEA) is applied. The choice of the best method for empirical analysis is difficult because different methods are based on different assumptions and may lead to different results. Recently, there have been some studies aimed at comparing techniques based on simulated data. Banker et al (1993) compared the corrected OLS (COLS) method, also known as deterministic frontier approach (DFA), based on a Cobb-Douglass functional form and the DEA method. Banker et al. (1996) introduced correlation and model misspecification into the models in comparing DEA and COLS. Read and Thanassoulis (1996) also compared DEA and COLS, but under a Constant Elasticity of Substitution (CES) production. Gong and Sickles (1992) compared the performance of stochastic frontiers and DEA using simulated panel data, based on a complex technology (CRSH-Constant Ratio of Elasticity of Substitution, Homothetic) and allow different roles of the noise in confounding the robustness of efficiency estimates. Bojanic et al (1998) examine the behaviors of COLS, maximum likelihood and DEA estimators in the presence of heteroscedasticity. Several studies focus on the DEA estimator alone, including Pedraja-Chaparro et al (1999) on the robustness of DEA in terms of sample size, number of inputs and outputs, and correlation between inputs and outputs; and Resti (2000) on comparing different DEA models (CRS DEA, VRS DEA and Stochastic DEA) with simulated data based on the bank industry. There are also some studies confined to parametric frontier method. Ruggiero (1998) and Ondrich and Ruggiero (2001) examine both the stochastic frontier and the COLS models in the contamination of noise and misspecification.

The purpose of this section is, in a simulation study, to examine the properties of stochastic frontier approach (SFA), deterministic frontier approach (DFA) and data envelopment analysis (DEA) estimators in the frontier models in the presence of measurement errors, collinearity, omission of relevant variables, and inclusion of irrelevant variables. It also compares the impact of different functional forms and error distributions among parametric frontier models. This study aims to assess the robustness of the efficiency estimator based in different methods in both its relative ranking and absolute level.

This section contributes to the existing literature in certain terms. It is among the few (for example Bojanic et al 1998) that compare DEA, DFA and SFA models. Many researchers are unsure which of the three models to use in their work, which suggests a need for more studies that compare the advantages and disadvantages of different approaches. While most other previous studies are limited to evaluating the robustness of estimators to one or two problems, this study compares estimates of efficiency under several problems that can occur with empirical data in practice. It is also the first that considers the robustness of efficiency estimators to measurement errors in the input as a problem, as well as the first comparing DEA, COLS and stochastic frontier models in terms of correlation, omitted and irrelevant inputs.

In addition, unlike some studies (Bojanic et al 1998, Ruggiero 1998) which assume a Cobb-Douglass production technology, which invariably give advantages to certain models, this study assumes a more generalized functional form, the constant elasticity of substitution (CES), as the true underlying technology. Because the stochastic frontier approach studies often assume either Cobb-Douglass or translog form, the assumption of true underlying functional form being Cobb-Douglass form would favor stochastic frontier models over DEA model.

3.5.1. Experimental Design

The underlying function form is the general constant elasticity of substitution (CES) form, which has Cobb-Douglass as a special form[16]. The CES function is given by

$$y_i^{-\rho} = \gamma^{-\rho}(\sum_{k=1}^{n}\delta_k x(k)_i^{-\rho}) \tag{3.7}$$

in which $x(k)_i$ is the k^{th} input for farm i, $x(k)_i \geq 0$ and the output $y_i \geq 0$. In this function, there are n inputs. Assume that $\sum\delta_k = 1$, so that there is constant returns to scale. Assume

[16] One could assume that the production technology is the Cobb-Douglass form and test for the sensitivity to specification errors. However, the interest here is mainly on the merits and pitfalls of different functional forms in dealing with measurement errors and collinearity in "real life". The assumption of Cobb-Douglass functional form (or translog form) will allow SFA to perform much better compared with DEA, for example.

as well that $\rho \geq 0$, $\gamma > 0$ and $\delta_k > 0$ for all *k*'s. The function has a constant elasticity of substitution: $\sigma = 1/(1+\rho)$.

As in most previous studies, this study does not consider the multi-output, multi-input case. It assumes one output and three inputs. Setting the parameter values to be $\gamma = 1$, $\delta_1 = 0.6$, $\delta_2 = 0.2$, $\delta_3 = 0.2$, $\rho = 2.5$, the underlying technology is specified as:

$$y = (0.6x_1^{-2.5} + 0.2x_2^{-2.5} + 0.2x_3^{-2.5})^{-1/2.5} \tag{3.8}$$

The input levels x_1, x_2, x_3 are assumed to be normally distributed with means (20, 20, 15) and variance (2, 2, 2). In the baseline case, all the inputs are independent. Later, they will be allowed to be correlated in order to examine the impacts of multicollinearity among the explanatory variables. The input shares of x_1, x_2, x_3 are 60 percent, 20 percent and 20 percent, respectively.

The observed output values are generated by adding to (3.8) a random noise term and an efficiency term. In other words,

$$y_{oi} = y_i \times exp(v_i - u_i)$$

The inefficiency term u is characterized to be half-normal; the noise term v is assumed normally distributed. I assume that $\sigma_u = 0.3$, which will allow the mean technical efficiency levels to be 0.8. The noise term include v -the measurement errors of the dependent variables: the output in this case- and the random shocks (factors such as weather, illness, pests, etc in the case of agriculture) which can lead to output fluctuations.

Estimation of the inefficiency term proceeds by in the following steps. First, the sample size is varied to test whether it affects the results for the base model (explained below). Then, the sensitivity of stochastic and deterministic methods to various issues that might arise in data collection and model building is examined. The Monte Carlo simulation is conducted for 100 replications.

There are four estimation methods (models).

1. Model 1: Deterministic DEA model.

2. Model 2: Deterministic frontier analysis (DFA) model with a Cobb-Douglass functional form.

3. Model 3: A half-normal/normal stochastic frontier analysis (SFA^h) model with a Cobb-Douglass functional form.

4. Model 4: An exponential/normal stochastic frontier analysis (SFA^e) model with a Cobb-Douglass functional form.

Therefore, there are two deterministic models (Model 1 and 2) and 2 stochastic models (Model 3 and 4). Of the two deterministic models, one is nonparametric (DEA model) and the other is parametric. The two stochastic models are different in terms of the distribution of the inefficiency term. Model 3 assumes a half-normal distribution, which is the "correct" model in our setting while model 4 assumes an exponential distribution of the inefficiency term. Hence, the functional form of the technology is relevant in model 1 while all the other models assume incorrectly Cobb-Douglass functional form.

There following scenarios are used to generate data for the four models:

Scenario 1: Baseline case: there are no measurement errors in the independent variables, low noise term (σ_V= 0.05) and no correlation among inputs. The standard deviation of the noise term of 0.05 means that the random errors do not exceed 11% for 95% of our data.

Scenario 2: Measurement errors in independent variables and/or dependent variables ranging within bounds of 5%, 10% and 20% respectively.

Scenario 3: Higher noise terms with σ_v = 0.15 and σ_v = 0.3.

Scenario 4: Correlation ratios among inputs are set to be 0.5 and 0.8

Scenario 5: One relevant input is omitted in estimation.

Scenario 6: One irrelevant input x_4 is included in estimation.

Scenario 7: Instead of a Cobb-Douglass production function, one assumes translog functional form for the three models except the DEA model

The deterministic production frontier is similar to the stochastic production frontier, except that it does not allow for noise. For the Cobb-Douglass functional form, the deterministic production frontier model becomes:

$$\ln y_i = \beta_0 + \sum_k \beta_k \ln x_{ki} - u_i$$

The estimates of TE_i for each producer can be obtained by means of TE_i= exp (-u_i). The OLS method for the deterministic production frontier yields unbiased and consistent estimates of the slope and consistent but biased estimates of the intercept. Winsten (1957) suggested using the Corrected OLS (COLS) to deal with this problem. The method includes two steps. In the first step, OLS is used to obtain the parameters of the slope and the intercept. In the second step, the biased OLS intercept is shifted up so that the estimated frontier bounds up the data. The COLS intercept is adjusted by

$$\hat{\beta}_0^* = \hat{\beta}_0 + \max_i \{\hat{u}_i\}$$

where $\hat{u}_i$ are the OLS residuals. The OLS residuals are corrected by

$$-\hat{u}_i^* = \hat{u}_i - \max_i \{\hat{u}_i\} .$$

Finally, the technical efficiency estimates are found by

$$TE_i = \exp(-\hat{u}_i^* \} .$$

For each model, the mean values of selected criteria are derived. Five criteria are used to compare the performance of the simulated efficiency with the true efficiency. They are: (i) Spearman rank correlation between the true efficiency and the simulated efficiency by the model. The Spearman rank correlation gives us the information about the preciseness of efficiency ranking among units; (ii) the correlation between the true efficiency and the simulated efficiency; (iii) the mean absolute deviation between the true efficiency and the simulated efficiency; and (iv) the bias ratio between the true efficiency and the simulated efficiency, which is calculated by the rate between the mean absolute deviation and the true efficiency index.; and (v) the percentage of units in which the simulated efficiency scores are within 10 percent of the true efficiency. Mean values obtained from 100 replications are reported[17].

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[17] This means that for a sample size of 200, the results from each model are estimated from 20,000 simulated units. For the DEA model, this task involves solving 20,000 systems of linear equations for each case.

3.5.2. Monte-Carlo Simulation Results

Efficiency estimates and sample size

Based on Model 1, simulations with sample sizes of 25, 50, 100, and 200 observations were run. From Table 3.10, it is clear that both methods yield better results when the sample size increases. The DEA method performs best among all models for small samples (at n=25 and n=50). However, with sample size at 200, the SFA^h method is slightly better than DEA method. In terms of rank correlation, all models perform well when sample sizes are 100 or 200. But in terms of levels, i.e. which models yield the estimates closest to the true values, both DEA and SFA^h models perform better than the deterministic DFA or the stochastic frontier with the wrong inefficiency term distribution (SFA^e). However, the model SFA^e improves considerably when the sample size increases from 100 to 200. For the DEA model, there are little differences in estimated values when sample size is from 100 and up. It is curious that some performance ratios such as the mean absolute deviation and the percentage within 10% of true efficiency are better with a sample size of 100 rather than a sample size of 200.

When the sample size is increased further, there is little change in the Spearman rank correlation or in other criteria. Therefore, the sample size is kept at 200 in the other experiments.

Efficiency estimates and measurement errors in variables

Now consider measurement errors in the inputs and in the output (Model 2). Instead of observing the "true" quantity of the inputs and the output, the researcher only knows that their levels are uniformly distributed inside the bounds of "true" quantity by

5%, 10% and 20% respectively. In other words, $x_i = x_i^* \times \phi_x$ for inputs and $y = y^* \times \phi_y$ for output, and in which ϕ_x and ϕ_y are numbers randomly chosen in the interval (0.95, 1.05), (0.9, 1.1) and (0.8, 1.2) respectively.

As seen in Table 3.11, the DEA model is less robust to measurement errors than the SFA^h model, which is reasonable because as we know, DEA assumes no measurement errors and the measurement errors are considered as inefficiency. When the measurement errors are relatively small (within the bounds of 5 percent), DEA perform than SFA^e (the SFA model with incorrect assumption on the distribution of the inefficiency terms). However, with large measurement errors (within the bounds of 20 percent), SFA^e predicts the efficiency terms better than DEA does. Overall, although the Spearman rank correlation yielded by model DFA is quite robust to measurement errors, the model is the worst in reflecting the true level of efficiency with highest bias, mean absolute deviation and lowest percentage within the 10% of true efficiency. Measurement errors in output lead to more serious problems in estimating "true" efficiency than measurement errors in inputs.

Efficiency estimates and "noise" and correlation

"Noise" could reflect measurement errors in observed output level and/or random shocks. The latter includes weather, luck, illness, pests, etc. -factors that lead to unexpected output fluctuations in agriculture. The importance of noise in the "composite" error term is set at σ_v= 0.05 (low noise), σv= 0.15 (medium noise) and σ_v =0.3 (high noise). The results are presented in Table 3.12.

All models are sensitive to noise. The degree of rank correlation reduces significantly at similar degree for both methods. However, in predicting the absolute level of efficiency, the SFA method generally performs much better than DEA, as reflected by lower bias, lower mean absolute deviation, as well as the percentage of units within 10% of true efficiency. The prediction of absolute technical efficiency by DEA is seriously impaired by the presence of noise. The DFA model performs the worst in terms of efficiency level.

The influences of multicollinearity are presented in Table 3.13. All models are robust to multicollinearity among inputs in term of relative ranking. There are almost no differences in different criteria, even when there is a very high correlation among inputs with the correlation ratio of 0.8. In terms of absolute levels, the model SFA^h is the best, followed by DEA, SFA^e and finally DFA.

Efficiency estimates and omitted relevant variables/included irrelevant variables

I test three cases of omitting one relevant variable by omitting x_1, x_2, and x_3 in turn (but keeping the other two variables) and one case of including an irrelevant variable x_4. The irrelevant variable x_4 is drawn from normal distribution with mean= 15 and variance= 2. Input x_4 is irrelevant because it plays no role in contributing to the output in equation (2).

Table 3.14 indicates that the SFA^h and DEA models are robust to the omission of one relevant variable. The DEA model, however, is more sensitive to the omission than the SFA^h in terms of absolute efficiency levels. For example when variable x_1 is omitted, only 61.9% of units reporting efficiency scores within a 10% bound from DEA method (compared with 86.7% for the case of no omission), while the corresponding number from SFA method is 89.4% (compared with 93.5% for the case of no omission). Among three inputs, omitting x_1 leads to more significant dampening of results than the other two variables. This is reasonable because as reflected by the coefficients in equation (2), x_1 is the most important input in producing output. Both models are very robust to the inclusion of one irrelevant variable too. The SFA^e model is similarly more robust than the DEA model, while the DFA model performs worst in terms of absolute level of efficiency prediction.

Efficiency estimates and functional form in the parametric method

In addition to the Cobb-Douglass functional form, the trans-log functional form is now used. The performances of these two forms are compared under the assumption of both stochastic and deterministic process. Therefore, there are four models: Cobb-Douglass stochastic frontier, Translog stochastic frontier, Cobb-Douglass deterministic frontier and Translog deterministic frontier.

Table 3.15 shows that the Cobb-Douglass form is slightly better than the more flexible translog form in both stochastic and deterministic models. While the stochastic frontier approach is only slightly preferable to the deterministic approach in terms of rank correlation, it is much better in terms of absolute value for technical efficiency terms. It also has tighter confidence intervals for simulated efficiency, as reflected by the percentage of units within 10% of true efficiency.

In addition, one may want to check the robustness of the results to the presumed true underlying functional form. For this purpose, the factor ρ in (3.8) is changed to -5 and -10 instead of the original number at -2.5. As it is well-known, when ρ goes to zero, the model becomes Cobb-Douglass model. Thus, it is predicted that the stochastic frontier and the deterministic frontier models should predict worse when we increase the absolute value of ρ. However, Table 3.16 shows that there are almost no changes in the results when we change factor ρ. This indicates the stability of the results.

Table 3.10: Sample Size and Efficiency

		Spearman rank correlation	Simple correlation	Bias	Mean absolute deviation	Percentage within 10% of true efficiency
25 observations	DEA	0.914	0.938	0.055	0.043	84.5
	DFA	0.844	0.877	0.073	0.059	73.0
	SFA^h	0.839	0.881	0.109	0.079	64.5
	SFA^e	0.839	0.849	0.125	0.09	57.2
50 observations	DEA	0.926	0.946	0.049	0.038	88.9
	DFA	0.907	0.925	0.066	0.053	77.8
	SFA^h	0.905	0.929	0.062	0.047	82.0
	SFA^e	0.912	0.914	0.093	0.068	66.0
100 observations	DEA	0.932	0.946	0.048	0.038	90.5
	DFA	0.926	0.939	0.078	0.062	68.3
	SFA^h	0.93	0.948	0.047	0.037	90.7
	SFA^e	0.932	0.935	0.073	0.055	73.5
200 observations	DEA	0.936	0.947	0.054	0.043	86.7
	DFA	0.939	0.948	0.084	0.067	63.5
	SFA^h	0.941	0.955	0.042	0.033	93.5
	SFA^e	0.942	0.945	0.067	0.05	75.8

Table 3.11: Measurement Error and Efficiency

Measurement error

In inputs	5%				10%				20%			
	DEA	DFA	SFA^h	SFA^e	DEA	DFA	SFA^h	SFA^e	DEA	DFA	SFA^h	SFA^e
Spearman rank correlation	0.928	0.932	0.936	0.937	0.908	0.923	0.928	0.924	0.842	0.911	0.914	0.915
Simple correlation	0.94	0.942	0.952	0.937	0.923	0.933	0.945	0.929	0.862	0.92	0.934	0.917
Bias	0.057	0.09	0.043	0.076	0.066	0.098	0.046	0.078	0.093	0.111	0.05	0.085
Mean absolute deviation	0.046	0.073	0.034	0.056	0.053	0.079	0.036	0.057	0.074	0.089	0.039	0.062
Percentage within 10% of true efficiency	84.3	58.5	92.6	70.7	77.1	52.5	90.8	69.7	59.3	44.7	88.2	66.3

In output	5%				10%				20%			
	DEA	DFA	SFA^h	SFA^e	DEA	DFA	SFA^h	SFA^e	DEA	DFA	SFA^h	SFA^e
Spearman rank correlation	0.922	0.922	0.926	0.927	0.883	0.884	0.891	0.886	0.766	0.771	0.775	0.768
Simple correlation	0.933	0.933	0.944	0.931	0.897	0.897	0.916	0.895	0.786	0.789	0.813	0.801
Bias	0.064	0.098	0.047	0.077	0.088	0.126	0.058	0.092	0.146	0.182	0.089	0.118
Mean absolute deviation	0.051	0.078	0.037	0.057	0.071	0.101	0.045	0.067	0.117	0.145	0.067	0.083
Percentage within 10% of true efficiency	78.07	53.62	90.62	70.12	60.24	38.25	82.82	63.06	38.23	25.54	64.15	58.20

In both inputs and outputs	5%				10%				20%			
	DEA	DFA	SFA^h	SFA^e	DEA	DFA	SFA^h	SFA^e	DEA	DFA	SFA^h	SFA^e
Spearman rank correlation	0.915	0.919	0.925	0.923	0.862	0.874	0.877	0.879	0.719	0.752	0.753	0.750
Simple correlation	0.928	0.930	0.942	0.931	0.877	0.885	0.904	0.889	0.737	0.771	0.799	0.781
Bias	0.067	0.099	0.048	0.074	0.096	0.132	0.062	0.094	0.166	0.197	0.090	0.125
Mean absolute deviation	0.053	0.079	0.037	0.055	0.076	0.105	0.048	0.068	0.132	0.158	0.069	0.088
Percentage within 10% of true efficiency	76.3	52.3	90.0	71.6	56.5	35.6	80.2	63.2	32.6	21.5	64.0	55.8

Table 3.12: Noise and Efficiency

		Spearman rank correlation	Simple correlation	Bias	Mean absolute deviation	Percentage within 10% of true efficiency
σ_V= 0.15	DEA	0.710	0.722	0.212	0.170	18.8
	DFA	0.716	0.725	0.254	0.204	11.5
	SFA^h	0.728	0.774	0.097	0.073	62.8
	SFA^e	0.728	0.756	0.131	0.092	54.7
σ_V= 0.15	DEA	0.463	0.460	0.428	0.343	5.0
	DFA	0.478	0.470	0.465	0.372	3.1
	SFA^h	0.475	0.513	0.18	0.129	41.1
	SFA^e	0.476	0.516	0.169	0.116	48.4

Table 3.13: Correlation and Efficiency

		Spearman rank correlation	Simple correlation	Bias	Mean absolute deviation	Percentage within 10% of true efficiency
Corr=0.5	DEA	0.938	0.949	0.056	0.045	85.1
	DFA	0.94	0.949	0.0848	0.0681	63.3
	SFA^h	0.941	0.956	0.042	0.033	93.7
	SFA^e	0.942	0.944	0.072	0.053	72.4
Corr=0.8	DEA	0.942	0.952	0.06	0.048	82.5
	DFA	0.94	0.949	0.083	0.066	64.2
	SFA^h	0.945	0.958	0.04	0.031	94.7
	SFA^e	0.942	0.943	0.071	0.053	73.5

Table 3.14: Omitted Relevant Variables, Included Irrelevant Variables and Efficiency

		Spearman rank correlation	Simple correlation	Bias	Mean absolute deviation	Within 10% of true efficiency
Omit x_1	DEA	0.902	0.915	0.086	0.069	61.8
	DFA	0.918	0.929	0.099	0.079	52.5
	SFA^h	0.921	0.940	0.048	0.038	89.4
	SFA^e	0.922	0.928	0.075	0.055	70.9
Omit x_2	DEA	0.933	0.944	0.065	0.052	78.1
	DFA	0.938	0.947	0.084	0.067	63.5
	SFA^h	0.941	0.955	0.042	0.033	93.6
	SFA^e	0.940	0.942	0.07	0.052	73.6
Omit x3	DEA	0.914	0.927	0.081	0.065	65.7
	DFA	0.924	0.935	0.096	0.077	54.3
	SFA^h	0.926	0.944	0.047	0.036	90.5
	SFA^e	0.926	0.927	0.079	0.058	68.7
Include x4	DEA	0.930	0.943	0.052	0.041	88.1
	DFA	0.939	0.948	0.083	0.067	64.5
	SFA^h	0.939	0.953	0.042	0.033	93.6
	SFA^e	0.940	0.943	0.069	0.051	75.1

Table 3.15: Functional Form and Efficiency

	Spearman rank correlation	Simple correlation	Bias	Mean absolute deviation	Percentage within 10% of true efficiency
DFA (C- D)	0.939	0.948	0.084	0.067	63.5
DFA (Translog)	0.928	0.938	0.089	0.072	59.4
SFA^h (C- D)	0.941	0.955	0.042	0.033	93.5
SFA^h (Translog)	0.935	0.951	0.043	0.034	92.7
SFA^e (C- D)	0.942	0.945	0.067	0.05	75.8
SFA^e (Translog)	0.934	0.938	0.072	0.053	72.7

Table 3.16: Different ρ and Efficiency

		Spearman rank correlation	Simple correlation	Bias	Mean absolute deviation	Percentage within 10% of true efficiency
ρ = -2.5	DEA	0.936	0.947	0.054	0.043	86.7
	DFA	0.939	0.948	0.084	0.067	63.5
	SFA^h	0.941	0.955	0.042	0.033	93.5
	SFA^e	0.942	0.945	0.067	0.050	75.8
ρ = -5	DEA	0.938	0.950	0.052	0.041	87.8
	DFA	0.934	0.945	0.087	0.070	61.5
	SFA^h	0.940	0.954	0.042	0.033	93.8
	SFA^e	0.941	0.943	0.069	0.051	74.8
ρ = -10	DEA	0.937	0.948	0.055	0.044	85.6
	DFA	0.935	0.944	0.087	0.069	61.4
	SFA^h	0.939	0.953	0.042	0.033	93.7
	SFA^e	0.938	0.943	0.068	0.051	74.7

3.6. Summary and Conclusion

This chapter has analyzed technical efficiency for a sample of rice producers in Vietnam using the parametric, semi-parametric and non-parametric frontier approaches. It compares the efficiency estimates obtained from these approaches and discusses the possible reasons for the differences in the technical efficiency estimates.

The mean technical efficiency is 0.704 under CRS, 0.765 under VRS for output-oriented DEA, and 0.785 under VRS for input-oriented DEA. When a bootstrap procedure is used to correct for bias, it yields a mean estimate of 0.678 for input-oriented DEA. Confidence intervals are also computed for the bias-corrected estimates. Stochastic frontier estimation yields a mean estimate of 0.634. The variance of estimates from the DEA and SFA methods are similar. But the variances of bias-corrected technical efficiency estimates after bootstrapping are significantly lower than the values under the parametric approach. The Spearman correlation test confirms that the efficiency scores calculated from different approaches are positively and significantly correlated.

The results reveal substantial production inefficiency for a sample of rice farmers in Vietnam and hence significant potential for farmers to reduce their costs by increasing efficiency. The estimates suggest that a typical farm can reduce its cost by 30-69% depending upon the method employed. A further 12 percent cost reduction can be obtained by operating at the optimal scale. A majority of farms, particularly in the Center region, are operating with increasing returns to scale. Given the importance of rice production for income, food security, employment, and exports in Vietnam, the benefits from increasing farm efficiency are very substantial.

Results from stochastic, non-parametric as well as new semi-parametric approaches suggest that efficiency in production is increased by education, especially primary education. The impacts of secondary and higher education are less robust to model specification. Secondary schooling is highly positive for the stochastic model but not for the other models. The analysis also indicates that increasing land holdings and farm size has substantial benefits for efficiency improvement. Technical efficiency varies widely across regions. The Red River Delta, which is very densely populated and has very small landholdings, has a system of irrigation and highly labor intensive rice cultivation methods, and is the most technically efficient. The Mekong River Delta, which produces more than a half of Vietnam's rice, has more potential for improving technical efficiency. Although most arable land is under intensive cultivation in the North, only 67 percent of arable land is under cultivation in the Mekong River Delta (UNEP 1998). On the other hand, factors such as the non-farm income ratio (non-farm income as a percentage of total household income) or extension support do not significantly affect farm technical efficiency. For extension support, the reason may be due to limited exposure of farmers to extension personnel. Policies to improve farmer's education, land quality and consolidate landholdings are likely to increase farmers' technical efficiency. In addition, the distribution of technical efficiency and scale efficiency across regions also provides useful information to policy makers for raising efficiency for each region.

This chapter also compared the robustness of three different methods used for calculating/estimating efficiency from frontier models, DEA, DFA and SFA, using a Monte-Carlo simulation. The DEA method is better than the SFA method for small samples. Except for noise, both methods are quite robust in terms of relative efficiency ranking. The SFA^h model, which is the model with correct inefficiency term distribution, is the most robust model in large samples. Except for the sensitivity to noise, the DEA model should be the second choice, followed by the SFA^e (the SFA model with incorrect inefficiency term distribution). The DFA model is the least robust in predicting correct efficiency levels. Therefore, except in the case when the ranking, rather than the efficiency levels, is the study aim, researchers should not use the DFA model. Multicollinearity and correlation among inputs do not appear to be serious problems for either the DEA or the SFA methods. Both methods are also little affected by adding one irrelevant variable and, to a lesser degree, omitting one relevant variable. However, both methods are rather sensitive to measurement errors in explanatory variables and noises. Compared together, the SFA method is more robust than the DEA method with respect to measurement error and noises.

The general advice is that, for small samples, one should consider DEA. In larger samples, if one is pretty sure about the distribution of the error term (which is doubtful) and more worried about measurement errors and/or has reasons for paying more attention to the levels of efficiency rather than the efficiency ranking, then the SFA method is a more appropriate choice. On the other hand, if what one really cares is the ranking of efficiency among units then all the models considered in this study are quite robust, although the SFA method is the method that is most robust to large measurement errors.

CHAPTER 4: ESTIMATION OF FOOD DEMAND FROM HOUSEHOLD SURVEY DATA IN VIETNAM

This chapter analyzes the food consumption patterns of Vietnamese households, estimating a complete demand system that includes socio-demographic information. Demand elasticities are estimated using the AIDS model and the latest Vietnamese household survey data that were collected in 2006. The results indicate that food consumption patterns in Vietnam are affected by income, prices, as well as socio-economic and geographic factors. All food categories have positive expenditure elasticities and negative own-price elasticities. In particular, rice has mean expenditure elasticity of 0.36 and mean own-price elasticity of -0.80. Thus, a one percent increase in the price in rice will reduce rice consumption by 0.8 percent, on average. On the other hand, a one percent increase in the income leads to an increase in rice demand of 0.36 percent. This chapter indicates that food consumption patterns vary across urban and rural areas, and across regions and income groups. It also recommends that targeted food policies that are based on specific food demand patterns in the groups.

Keywords: Vietnam, food consumption, food demand, AIDS, elasticity.

4.1. Introduction

Household food consumption behavior has long been an important area of research for economists. Studies on food consumption help to provide a better understanding of how the demand for food responds to changes in food prices and changes in household income. This information is essential for evaluating the welfare effects of many types of economic shocks as well as the welfare impacts of trade liberalization and policy intervention. Demand analysis can be based on either aggregated time-series data or household surveys. Unfortunately, in many developing countries the availability of reliable time-series data on aggregate demand, prices and income is limited. In addition, the use of aggregate data implicitly assumes that national averages of demand behave similarly as an individual consumer's demand. In contrast, many household surveys have been implemented in these countries, which provide comparatively rich and fairly accurate micro data on household consumption patterns. Food demand analysis based on household surveys has been increasingly used in recent years. In developing countries, where large percentages of household expenditures are allocated to food, consumer expenditure surveys are particularly useful because they can provide information on specific subpopulations of households that are more likely to be affected by changes in commodity prices or household incomes.

Several papers have been written on household food demand in Vietnam, particularly rice demand, most of which are unpublished. Haughton et al (2004) used data from the 1998 Vietnam Living Standard Survey (VLSS) to estimate the price and expenditure elasticities of rice, using a double-log specification. The mean own-price elasticity of rice was estimated to be -0.42, while the mean expenditure elasticity of rice is 0.09. Benjamin and Brandt (2004) used panel data from the 1993 and 1998 Vietnam Living Standard Surveys to estimate Engel curves for Vietnam. The expenditure elasticity of rice was estimated to be 0.49 and 0.41 for the urban north and the urban south, respectively, and 0.64 and 0.63 for the rural north and rural south. As part of a comprehensive study on rice market liberalization in Vietnam, Minot and Goletti (2000) used the Almost Ideal Demand System (AIDS) functional form to estimate household food demand in Vietnam in 1998. Their expenditure elasticities of rice were 0.48 for the North and 0.11 for the South, while the estimated own-price elasticities were -0.2 in the North and -0.38 in the South. Finally, Niimi (2005) examined the robustness of Deaton's method to correct the bias from using unit values (defined as expenditure divided by purchased quantity) as proxies for missing market prices (Deaton 1990), using the 1993 and 1998 VLSS data. The author used three models with unit values: household specific unit values, communal mean unit values and corrected household-specific unit values using Deaton's method, to compare with estimates based on communal market price data. The results showed that Deaton's method generated markedly different price elasticities compared with those estimated using market prices. On the other hand, using communal mean unit values yields elasticity estimates closest to the ones estimated using market price data. These results suggest that using a simple model with communal unit values as proxies for price, may be more preferable to using the complicated model proposed by Deaton (1990) to estimate elasticities in the absence of market price data.

This chapter contributes to the analysis of food demand by applying a method based on Cox and Wohlgenant (1986) to correct for the bias from using unit values as proxies for prices. Using household expenditure data and a linear approximation of the Almost Ideal Demand System (AIDS) developed by Deaton and Muellbauer (1980), this chapter estimates food demand parameters for Vietnam. The AIDS model is the most popular method in demand analysis, which allows for comparisons with other studies. Buse (1994) stated that the AIDS model also have a number of advantages, in particular: it is built on a well-structured analytical framework; it is relatively easy to estimate in its linear form; it is straightforward to be applied to aggregate data; it permits testing the restrictions of demand theory (adding-up, homogeneity and symmetry).

The structure of the rest of this chapter is organized as follows. Section 4.2 presents the model and the estimation methods. Section 4.3 describes the data and summarizes food consumption patterns in Vietnam. Section 4.4 presents the estimation results. The last section provides concluding remarks.

4.2. Model and Estimation

The Almost Ideal Demand System (AIDS) is the most common functional form used to estimate systems of demand. This chapter assumes weak seperability of demand, thus ignoring non-food commodities in the estimation. The model takes the following form:

$$w_i = \alpha_i + \beta_i \ln\left(\frac{\mathrm{x}}{\mathrm{P_c}}\right) + \sum_{j=1} \theta_{ij} \ln(p_j) + \sum_{m=1} \gamma_{im} Z_{im} + u_i \qquad (4.1)$$

where w_i is the budget share of food item i, p_j is the j^{th} food item, Z_{im} is a set of household characteristics, x is the value of food consumption expenditure per person, and P_c is a price index defined by

$$ln\ P_c = \delta_0 + \sum_j \delta_j \ln p_j + \frac{1}{2}\sum_j \sum_k \theta_{jk} \ln p_j \ ln\ p_k \qquad (4.2)$$

The presence of the Z vector in equation (4.2) implies that the differences in tastes for foods are mainly determined by those household characteristics.

In practice, a linear approximation of the Almost Ideal Demand System (LA/AIDS) is often employed. In the LA/AIDS model, to avoid nonlinearity, $ln\ P_c$ can be approximated by the logarithm of Stone's price index.

$$ln\ P_c = \sum_j \overline{w}_j \ln p_j \qquad (4.3)$$

In this equation, $\overline{w}_j$ represents the mean budget share of food item j.

The following set of restrictions are derived from economic theory and imposed upon the parameters in the LA/AIDS model to make the model consistent with the theory of demand.

Adding-up restrictions:

$$\sum_i \alpha_i = 1;\ \sum_i \beta_i = 0;\ \sum_i \theta_{ij} = 0;\ \sum_i \gamma_{im} = 0; \qquad (4.4)$$

Homogeneity restriction:

$$\sum_j \theta_{ij} = 0 \qquad (4.5)$$

Symmetry restriction:

$$\theta_{ij} = \theta_{ji} \qquad (4.6)$$

By differentiating equations (4.1) and (4.2) with respect to prices and expenditure, one obtains the following elasticity measures:

Marshallian owned-price elasticity of food item *i*:

$$\epsilon_{ii} = (\theta_{ii} - \beta_i w_i)/w_i - 1 \tag{4.7}$$

Marshallian cross-price elasticity of food item *i* with respect to the price of food item *j*:

$$\epsilon_{ij} = (\theta_{ij} - \beta_i w_j)/w_i \quad \forall\, i \neq j \tag{4.8}$$

Expenditure elasticity of food item *i*:

$$\eta_i = \beta_i/w_i + 1 \tag{4.9}$$

The Hicksian price elasticity is estimated from the Slutsky equation:

$$\epsilon_{ij}^h = \epsilon_{ij} + \eta_i w_j \ \forall\, i, j \tag{4.10}$$

One problem with using household expenditure surveys for estimating household demand is that many household surveys do not collect price data. A common practice has been to calculate unit values by dividing expenditures by corresponding quantities and use them as a direct substitute for market prices (Deaton 1988). However, it has been argued (Deaton 1990, Cox and Wohlgenant 1986, Huang and Lin 2000) that there are some problems with treating unit values as market prices. First, such a calculated unit value may reflect not only differences in prices, but also differences in the qualities of the goods that households purchase. The quality effects implicit in unit values may be influenced by prices and income as consumers respond to changes in price and income by altering both the quantity and the quality of the goods they purchase. Prais and Houthakker (1955) define the "quality elasticity" as the positive relationship between unit values and household income. Second, because unit values are calculated by dividing expenditures by quantities, the approach suffers from common measurement errors in both the quantity and the expenditure data.

Several methods have been proposed to overcome the quality and measurement errors problems. Deaton (1990) developed a procedure to correct the price elasticities. He assumed that households within the same geographical cluster face the same market prices, thus, within-cluster variation in unit values and expenditures is used to estimate the effects of household income and characteristics on quantities and qualities of purchased goods, as well as to separate measurement errors from price data. Based on corrected quantities and unit values, it is then possible to estimate the "corrected" demand system, removing the impacts of both quality effects and measurement errors. The method is widely applied in literature, for example in Nicita (2004), Niimi (2005), and Friedman and Levinsohn (2002). The disadvantage of Deaton's method is that the covariance of residuals, which is used to estimate corrected price elasticities, can be influenced by many unexplained factors, not just price variation. Deaton's approach is also hard to implement, using complicated matrix multiplication.

The Deaton's method has also been criticized for its empirical values. Niimi (2005), Gibson and Rozelle (2002), and Brubakk (1997) have empirically examined the robustness of Deaton's method. They show that Deaton's method generates price elasticities that are vary markedly from those estimated with market prices.

Cox and Wohlgenant (1986) proposed another approach. They assumed that the deviations of unit values from regional or seasonal means reflect quality effects. They regressed the mean-deviated unit values on household characteristics to exclude the quality effects from unit values and obtain quality-adjusted prices. These quality-adjusted prices are then used in their household demand system estimation. Cox and Wohlgenant's approach is used in several papers, such as Park et al. (1996), Gao et al. (1994), Lazaridis (2003). An important advantage of Cox and Wohlgenant's approach is its ease of use. A major disadvantage is that the adjusted price would vary from household to household, in contrast with the theory that the households in the same market face similar market prices at a given time. Moreover, Cox and Wohlgenant's approach does not deal with measurement error problems. This paper applies a modified version of the Cox and Wohlgenant's approach that is more suited to the assumption of common market prices faced by consumers in the same geographical unit. In addition, the Deaton's approach is also calculated for comparison. The Deaton's approach is described in detail in Appendix A3. The modified Cox and Wohlgenant approach is described in detail as follows.

The Cox and Wohlgenant approach (CW) assumes that prices are functions of food item characteristics. The quality effects can be identified as the difference between the unit value paid by the household and the communal average unit value, and therefore can be attributed to household characteristics. In this chapter, the price/quality function is characterized by the following equation:

$$v_i = \bar{v}_i + \varphi_i x + \omega_i f_i + \textstyle\sum_m b_i Z_{im} + e_i \qquad (4.11)$$

Here, v_i is the unit value paid by the household for good i, $\bar{v}_i$ is the communal mean unit value, f_i is the share of food budget spent on food away from home, x is the household food expenditure per capita, e_i is the residual, and Z_{im} are the household characteristics in equation (4.1). This model assumes that quality is influenced by taste and convenience, and taste and convenience is influenced by the share of food away from home in the food budget (Huang and Lin 2000), and household expenditure per-capita, in addition to various household demographic characteristics.

The quality-adjusted prices for each good, denoted by p_i is generated by adding the communal mean unit value to the residual derived from (4.11).

$$p_i = \bar{v}_i + \hat{e}_i \tag{4.12}$$

These quality- adjusted prices proposed by Cox and Wohlgenant are inconsistent with the hypothesis that households in the same market face the same prices. Since $\hat{e}_i$ is random, p_i would vary among households in the same market. Moreover, empirical work by Niimi (2005) using a household survey for Vietnam indicates that the communal unit values are better proxies for market prices than household specific values because the former help mitigate measurement errors. Therefore, this study uses the communal mean quality-adjusted prices, $\bar{p}_{i,}$ as the corrected prices in the LA/AIDS model, which are defined as follows:

$$\bar{p}_i = \overline{\bar{v}_i + \hat{e}_i} \tag{4.13}$$

Thus, each household in the commune is assumed to face the same market price, represented by $\bar{p}_i$, for the "standard" good, i.e. without quality effects. By substituting $\bar{p}_i$ from (4.13) into equations (4.1) and (4.2) with the imposed restrictions of (4.4), (4.5), and (4.6), one can estimate the demand system and then use the results to construct the price and expenditure elasticities of food demand as given in equations (4.7), (4.8) and (4.9).

It is common in household surveys for some households to report no expenditure on particular food items during the survey period. The presence of zero consumption poses problems for econometric estimation of food demands. Most studies included zero observation in parameter estimation, without accounting for the fact that the sample is censored. The resulting estimated parameters are therefore biased. Several econometric techniques have been developed to deal with this situation. Heien and Wessells (1990) apply a two-step Heckman procedure to correct for the bias. Another approach is Shonkwiler and Yen (1999)'s approach. Shonkwiler and Yen (1999) use a two-step procedure to overcome the zero consumption problems. Using Monte Carlo simulation, Shonkwiler and Yen (1999) showed that their method yields consistent estimators than the method proposed by Heien and Wessells (1990).

4.3. Data and Food Consumption in Vietnam

The data analyzed in this chapter are from the 2006 Vietnam Household Living Standards Survey (VHLSS), a nationwide survey conducted in 2006. The 2006 VHLSS was conducted by Vietnam's General Statistics Office. The main objective of the survey is to collect data on household living standards, as measured by households' income and expenditure, as well as household members' occupation, health and education status. The survey was conducted in all of Vietnam's 64 provinces, and expenditure data were collected from 9,189 households. Food consumption expenditure was obtained for both regular and holiday expenditures. The data were collected for both purchased foods and self-supplied foods (home production). The 9,189 households were sampled from 3060 communes in Vietnam.

Data on food expenditures were collected for 56 food items. The analysis of this chapter aggregates these food items into 10 food groups for food eaten at home, plus food away from home (FAFH). Expenditure shares are calculated as a fraction of total food consumption, including both purchased food and consumption of food produced at home. Table 4.1 presents the percentage shares of total food consumption for each of the 11 food groups: Rice (26 percent[18]), other staple foods (3 percent), pork (13 percent), poultry (6 percent), other meats[19] (3 percent), fish and seafood (10 percent), vegetables (7 percent), fruit (3 percent), drinks (5 percent), other foods (15 percent), and food consumed away from home (FAFH, 10 percent). Appendix A2 shows how each of the 56 food item is allocated to these food categories. The analysis assumes that food consumption is weakly separable from the demand of non-food goods and services in order to estimate the demand for food categories separately from the demand for non-food commodities.

For Vietnam as a whole, 53 percent of household expenditure is devoted to food, 55 percent in rural areas and 48 percent in urban areas. Rice is the most important single food. On average, expenditure on rice per month is about 50 thousand VND per capita in rural areas and 44 thousand VND per capita in urban areas. Rice accounts for nearly 30 percent of food expenditure in rural areas and 17 percent in urban areas. The "other foods" category is the second most important food group in terms of expenditure, accounting for nearly 15 percent of total food expenditure. This category is comprised of diverse foods such as fat and oil, cakes, fish sauce, spice, sugar, salt, condensed milk, and ice cream. Pork is the most important meat, amounting to 13 percent of food

[18] The percentages in parentheses represent average percentages of all households.
[19] This category includes beef, buffalo meat, other meat, and processed meat, in which beef and buffalo meat constitute about 63 percent in terms of value.

expenditure in both rural and urban areas. Food away from home (FAFH) makes up nearly 10 percent of food expenditure, yet its share is much larger in urban areas than in rural areas. In urban areas, over 16 percent of food expenditure is allocated to FAFH; while in rural areas, the corresponding figure is 7 percent. Thus, while FAFH is the second most important food group in urban areas (after rice), it only ranks fifth among eleven food categories in rural areas.

The differences in food consumption patterns across different regions are substantial. In the regions where a large percentage of the population lives in urban areas, such as the South East and the South Central Coast, rice expenditure percentages are lower, and FAFH percentages are higher, than the other regions. The largest discrepancy is observed when comparing the most urban region- the South East- with the least urban region- the North West. In the North West, rice consumption is 38 percent of food expenditure while FAFH is less than 3 percent. In the South East, rice is just 18 percent and FAFH is 15 percent of food expenditure.

Differences in consumption patterns are also observed across different income groups. The population can be divided into five quintiles, based on the real household expenditure per capita. Among the poorest quintile, rice accounts for 41 percent, meat and fish 26 percent, and FAFH 3 percent, of food expenditure. In contrast, among the richest quintile, rice consumption is 14 percent, meat and fish 34 percent, and FAFH 18 percent, of food expenditure. It is clear that higher income households spend more on meat, fish and FAFH and spend less on rice than the poorer households. There are also differences in food consumption patterns between ethnic minorities and the ethnic majority. As a group, ethnic minorities consume less meat, fish and FAFH, and more rice, than the ethnic majority group. Regarding occupation, farmers eat more rice, and less meat, fish and FAFH, than non-farmers.

Unit values are calculated for each category by dividing purchased food value by purchased food quantity. To construct aggregate unit values for food groups, unit values for individual food items are calculated by dividing expenditure by quantity for each individual food item. For some foods, such as other meat and other seafood, data were collected on values but not on quantities. These items were dropped from estimating the unit value of the food group to which these food items belong. Food group unit values are calculated as weighted averages of the individual unit values, with the weights being the (household- level) expenditure shares of the individual goods within the food group. For households that reported zero consumption, the unit values were assumed to be the same as the average unit values of the other households in the same geographical groups, in this case the communes.

Following Cox and Wohlgenant (1986) and Niimi (2005), I drop as outliers all unit values that are more than five standard deviations from their means, and replaced those unit values with the mean of the unit values of households in the communes. From the individual unit values, one can calculate the communal unit values as the mean[20] of individual unit values of the households in the commune. Since no quantity for food away from home (FAFH) is reported, provincial price deflators are used as a proxy for the price of FAFH. The unit value data are summarized in Table 4.2.

Table 4.2 also indicates the degree of non-consumption in the data. It shows that most of the food groups are consumed by nearly all households. Rice, other food, pork,

[20] The median would be an alternative to the mean

vegetables, fish and fruits are all consumed by more than 98 percent of the sample. The two least consumed groups are other meats and FAFH, which are still consumed by nearly 80 percent of the households in the sample. Overall, the data show that zero consumption is not a serious problem. Therefore, this chapter will not use the method suggested by Shonkwiler and Yen (1999) to deal with the issue of zero-consumption[21].

Table 4.3 summarizes the variables used in the analysis in this chapter. The regressors include the prices (as proxied by individual unit values, communal unit values or quality-corrected unit values) of 11 food categories, log of food expenditure per capita, household demographic variables and variables that control for community, geographic and seasonal differences. The demographic variables include household head's age, household size, household head's years of schooling, the proportion of infants (<3 years), children (3-15 years) and elderly household members (>59 years), and dummy variables indicating whether the household head is an ethnic minority or whether the head is female. The average household has 4.3 members. The average head's age is 49 years old and the average head's schooling is 7 years. The proportions of infants, children and elderly are 0.04, 0.20 and 0.13, respectively. About 25 percent of households' heads are female heads and 15 percent are ethnic minorities.

The community variables include binary variables for mountainous and seaside communes. The geographical variables consist of dummy variables for urban areas, and Vietnam's seven regions (with the Red River Delta being the default region). The seasonality variables are dummy variables for different quarters during the year.

[21] In fact, application of Shonkwiler and Yen's method yields results that are similar to the estimates that did not make use of that method in this study.

Table 4.1: Shares of Food Expenditures (%)

	Rice	Other Staples	Pork	Other meats	Poultry	Fish	Vegetables	Fruits	Other foods	Drink	FAFH	Food share
All	26.4	2.9	13.1	5.6	2.9	9.9	6.7	3.4	14.5	4.9	9.6	53.3
Rural	29.6	3.0	13.1	6.0	2.4	9.6	6.8	3.2	14.4	4.6	7.3	55.0
Urban	16.9	2.6	13.1	4.5	4.5	10.8	6.4	4.1	15.0	5.7	16.4	48.2
Red River Delta	26.6	2.8	15.4	6.3	3.7	6.3	7.0	3.5	13.0	4.9	10.3	49.1
North East	30.8	3.0	15.4	8.9	2.5	5.5	7.7	3.2	12.3	4.4	6.4	57.2
North West	38.4	2.9	12.9	8.8	3.4	5.9	7.5	2.8	10.0	4.6	2.7	67.6
North Central Coast	31.6	3.3	12.4	5.2	2.9	10.2	6.0	2.8	13.9	4.6	7.0	51.1
South Central Coast	22.3	2.9	10.2	3.4	3.8	12.3	5.9	3.5	16.5	5.0	14.2	51.4
Central Highlands	30.2	3.4	11.4	5.2	3.7	9.4	6.8	3.1	14.8	5.8	6.1	53.2
South East	18.3	3.0	12.1	3.8	3.3	11.8	6.9	4.0	16.7	5.5	14.5	52.9
Mekong River Delta	23.4	2.5	11.8	4.2	1.5	15.4	6.1	3.6	16.7	4.6	10.0	53.9
Quintile 1	41.4	3.3	10.5	5.7	1.5	8.4	7.3	2.5	13.3	3.5	2.7	67.6
Quintile 2	31.6	2.8	12.9	5.9	2.0	10.3	7.2	3.0	14.7	4.0	5.4	58.0
Quintile 3	25.7	2.9	14.2	5.8	2.6	10.4	6.8	3.4	14.8	4.8	8.7	53.1
Quintile 4	20.2	2.9	14.1	5.4	3.4	10.6	6.5	3.6	15.0	5.4	12.9	47.5
Quintile 5	13.7	2.7	13.6	5.1	5.1	9.8	5.9	4.6	14.9	6.8	18.0	40.8
Ethnic majority	24.5	2.8	13.2	5.2	3.1	10.4	6.6	3.6	15.0	5.0	10.7	51.0
Ethnic minorities	37.5	3.6	12.1	7.8	2.2	7.1	7.3	2.6	12.0	4.4	3.4	66.3
Non-farmer	17.6	2.7	13.0	4.1	4.2	11.4	6.2	3.9	15.6	5.6	15.7	49.7
Farmer	29.8	3.0	13.1	6.2	2.5	9.3	6.9	3.2	14.1	4.6	7.2	54.7

Table 4.2: Unit Values of Food Categories and Percentage of Consuming Households

	Individual unit vales		Communal mean unit values		Percentage of consuming households
	Mean	S.D.	Mean	S.D.	
Rice	5.18	1.37	5.23	1.17	99.9
Other staples	8.30	4.67	8.33	3.64	94.3
Pork	28.81	7.28	28.84	5.81	99.6
Poultry	31.05	11.74	30.87	10.37	93.3
Other meats	42.31	19.66	41.58	16.63	79.2
Fish	18.41	11.50	18.43	9.84	98.5
Vegetables	4.74	2.44	4.75	1.86	99.7
Fruits	3.36	2.63	3.26	2.17	98.5
Other foods	9.82	15.89	9.82	10.36	100.0
Drinks	19.38	24.03	19.36	14.90	98.5
FAFH	0.98	0.10	0.98	0.10	78.3

* The unit values are in thousand VND per kg, except per liter for drink and except FAFH in which provincial deflators are used.

Table 4.3: Definition and Description of Variables

	Mean	S.D.		Mean	S.D.
Log of prices of					
Rice	1.63	0.21	Proportion of infants	0.04	0.09
Staple	2.03	0.43	Proportion of children	0.20	0.20
Pork	3.34	0.20	Proportion of elderly	0.13	0.26
Poultry	3.37	0.35	***Community variables***		
Other meat	3.63	0.48	Near sea	0.05	0.23
Fish	2.80	0.46	Mountainous	0.30	0.46
Vegetables	1.47	0.44	***Geographical variables***		
Fruits	0.97	0.70	Urban	0.25	0.43
Other foods	1.95	0.83	North East	0.14	0.35
Drink	2.74	0.78	North West	0.05	0.21
FAFH	-0.02	0.1	North Central Coast	0.11	0.31
Log of food expenditure	7.79	0.5	South Central Coast	0.09	0.29
Demographic Characteristics			Central Highlands	0.06	0.24
Head's age	49.4	13.6	South East	0.13	0.34
Household size	4.25	1.69	Mekong River Delta	0.20	0.40
Female-headed	0.25	0.43	*Seasonality*		
Head's schooling	6.97	3.70	Quarter 2	0.45	0.5
Ethnic minority	0.15	0.36	Quarter 3	0.35	0.5
			Quarter 4	0.51	0.48

4.4. Empirical Results

The system of demand equations is estimated using Seemingly Unrelated Regressions (SUR) with homogeneity and symmetry restrictions imposed. One equation (the FAFH equation) is omitted to satisfies the adding-up restriction. The coefficients of this equation are obtained by imposing the adding-up restriction in (4.4). The elasticities are all evaluated at mean values. Table 4.4 reports the SUR estimation with quality-corrected unit values used as the prices. Most of the coefficients are significant at the 5% significant level, including the demographic and geographic variables. The implication is that differences in geographic location, ethnicity, household size and composition, and education lead to differences in consumer behavior. The R-squared values range from 0.04 (staples) to 0.64 (rice). For a model expressed in budget shares using cross-section data, these low R-squared values are quite common[22].

Based on the SUR results, urban households tend to spend a smaller share of their food budgets on rice, pork, poultry, and other food and more on beef (other meats), fruit, other foods, and FAFH. Thus urban households tend to have more dietary diversity and consume less traditional meals, which are composed mostly by cereals and pork, than rural households. Households in coastal areas consume higher shares of fish and drink, but smaller shares of other staples, poultry, other meat, fruit and vegetables, relative to households in non-coastal plain areas. In contrast, households living in mountainous and hilly areas consume smaller shares of fish and other foods, but higher shares for rice and poultry than those in plain areas.

Household size negatively affects the consumption shares of such traditional foods as rice, pork, poultry, vegetables, fruit, and other food but affects positively the consumption shares of other meats, drinks and FAFH. Households with a higher proportion of elderly members consume higher shares of other staples, pork, other meats, fruits and other foods but lower shares of rice, and FAFH. Households with more infants consume lower shares of rice and FAFH, and higher shares of pork, other meats, fruits, other foods (including milk) and drinks. Households with more children spend higher proportions on various at-home foods such as rice, other staples, pork, other meats, fish, and other foods, but lower proportions on FAFH. Thus, it appears that a higher

[22] For example the ranges are 0.08-0.3 in Albay, Boz and Chern (2007), 0.06-0.15 in Huang and Lin (2000), and 0.13-0.39 in Abdulai and Aubert (2004).

percentage of household dependents lowers the share of FAFH and increases the consumption of traditional at-home foods such as rice and pork.

The age of the household head negatively affects FAFH share and positively influences the shares of rice and poultry. Thus, households with older heads tend to consume traditional diet based on rice, while households with younger heads are more likely to consume meals away from home. Regarding the role of the head of household's level of education, there is a clear and positive impact on the consumption of pork, poultry, other meats, fruit, and drink, and a negative impact on the consumption of rice, fish, and vegetables. This means that households with better educated household heads tend to consume more protein-rich foods than households with less educated heads. Female-headed households consume lower shares of rice and drinks but higher shares of fruit and FAFH. Perhaps women in female-headed households are more likely to work outside the home and at longer hours than those in male-headed households, thus these households rely more on FAFH, and less on at-home foods than the male-headed households. Households whose heads belong to the ethnic minority groups tend to consume relatively more rice, other staples and poultry, but less pork, fish, fruit, and other foods.

Table 4.4: Results From the SUR Equations

	Rice		Staples		Pork		Poultry		Other meats	
Log of price of										
Rice	0.44	(1.0)	-0.42	(3.2)	-0.64	(2.0)	-0.83	(4.5)	-0.02	(0.2)
Staples	-0.42	(3.2)	0.73	(9.4)	-0.40	(3.0)	-0.10	(1.2)	-0.17	(3.1)
Pork	-0.64	(2.0)	-0.40	(3.0)	2.46	(5.4)	-0.45	(2.3)	0.02	(0.2)
Poultry	-0.83	(4.5)	-0.10	(1.2)	-0.45	(2.3)	-0.37	(2.3)	0.35	(4.4)
Other meats	-0.02	(0.2)	-0.17	(3.1)	0.02	(0.2)	0.35	(4.4)	0.21	(2.8)
Fish	-1.20	(6.2)	-0.31	(4.1)	0.58	(3.1)	-0.14	(1.2)	0.52	(6.8)
Vegetables	0.19	(1.3)	0.18	(3.1)	-1.29	(8.9)	0.49	(5.7)	0.25	(4.2)
Fruit	-0.42	(4.5)	0.03	(0.9)	-0.27	(2.9)	0.02	(0.4)	0.19	(5.1)
Other foods	-2.28	(21.7)	-0.10	(2.6)	0.60	(6.3)	0.17	(2.9)	0.32	(8.1)
Drink	-0.82	(8.1)	-0.11	(2.8)	0.12	(1.2)	0.01	(0.1)	0.14	(3.5)
FAFH	6.00	(11.6)	0.66	(3.3)	-0.73	(1.4)	0.86	(2.9)	-1.81	(9.2)
x/P*	-18.3	(75.4)	-0.03	(0.4)	1.74	(8.2)	0.56	(4.3)	2.21	(24.5)
Urban	-3.08	(11.3)	-0.05	(0.5)	-0.91	(3.8)	-1.02	(7.0)	0.95	(9.4)
Log(head age)	1.50	(3.1)	-0.28	(1.6)	0.22	(0.5)	0.72	(2.7)	0.35	(1.9)
Household size	-0.20	(3.0)	-0.02	(0.7)	-0.20	(3.4)	-0.16	(4.5)	0.10	(4.2)
Female head	-0.78	(3.4)	0.10	(1.2)	0.36	(1.8)	-0.23	(1.9)	-0.02	(0.2)
Log (school)	-0.81	(4.2)	-0.09	(1.3)	0.86	(5.2)	0.39	(3.8)	0.47	(6.7)
N. East	0.24	(0.7)	-0.28	(2.1)	1.10	(3.4)	1.80	(9.2)	-1.05	(7.7)
N. West	1.82	(3.2)	-0.61	(3.0)	-0.34	(0.7)	1.80	(6.0)	0.61	(2.9)
N. C. Coast	-0.18	(0.5)	0.36	(2.9)	-2.54	(8.4)	-1.19	(6.5)	-0.32	(2.5)
S. C. Coast	-4.97	(13.5)	0.17	(1.3)	-5.07	(15.7)	-2.66	(13.5)	0.06	(0.5)
C. Highland	-0.08	(0.2)	0.33	(2.0)	-3.29	(8.2)	-1.21	(4.9)	0.00	(0.0)
S. East	-3.60	(9.7)	0.26	(2.0)	-3.81	(11.9)	-2.36	(12.0)	-1.22	(9.0)
M.R.Delta	-1.86	(5.7)	-0.29	(2.5)	-3.84	(13.4)	-1.94	(11.0)	-1.94	(15.9)
Ethnic	3.14	(9.1)	0.53	(4.2)	-1.26	(4.2)	0.63	(3.4)	-0.25	(1.9)
Infant	-9.62	(8.6)	0.73	(1.8)	2.44	(2.5)	0.47	(0.8)	1.71	(4.1)
Children	1.31	(2.3)	0.47	(2.3)	1.65	(3.4)	0.04	(0.1)	0.82	(3.9)
Old	-1.99	(4.3)	0.37	(2.2)	1.80	(4.4)	0.05	(0.2)	0.39	(2.3)
Quarter 2	0.86	(1.6)	0.07	(0.4)	-0.82	(1.7)	-0.12	(0.4)	-0.47	(2.3)
Quarter 3	-0.16	(0.6)	0.05	(0.5)	-0.51	(2.2)	-0.34	(2.4)	0.03	(0.3)
Quarter 4	1.44	(3.0)	-0.17	(1.0)	-0.72	(1.7)	0.53	(2.0)	-0.48	(2.7)
Coastal	-0.15	(0.4)	-0.31	(2.0)	-0.72	(1.9)	-0.66	(2.9)	-0.32	(2.0)
Mountainous	1.25	(4.2)	0.16	(1.5)	0.20	(0.8)	0.91	(5.8)	0.10	(0.9)
Constant	150.6	(52.2)	6.72	(6.3)	-2.26	(0.8)	2.49	(1.6)	-17.2	(15.6)
R-squared	0.62		0.04		0.10		0.18		0.23	

Fish		Vegetables		Fruit		Other foods		Drink		FAFH	
-1.20	(6.2)	0.19	(1.3)	-0.42	(4.5)	-2.28	(21.7)	-0.82	(8.1)	6.00	(9.1)
-0.31	(4.1)	0.18	(3.1)	0.03	(0.9)	-0.10	(2.6)	-0.11	(2.8)	0.66	(2.6)
0.58	(3.1)	-1.29	(8.9)	-0.27	(2.9)	0.60	(6.3)	0.12	(1.2)	-0.73	(1.1)
-0.14	(1.2)	0.49	(5.7)	0.02	(0.4)	0.17	(2.9)	0.01	(0.1)	0.86	(2.3)
0.52	(6.8)	0.25	(4.2)	0.19	(5.1)	0.32	(8.1)	0.14	(3.5)	-1.81	(7.3)
0.19	(1.0)	-0.53	(6.0)	0.05	(0.9)	-0.24	(3.1)	-0.08	(1.2)	1.15	(3.0)
-0.53	(6.0)	-0.04	(0.5)	-0.04	(1.0)	-0.18	(3.8)	0.05	(1.2)	0.91	(3.3)
0.05	(0.9)	-0.04	(1.0)	0.23	(5.8)	0.17	(5.5)	0.10	(3.5)	-0.07	(0.4)
-0.24	(3.1)	-0.18	(3.8)	0.17	(5.5)	-0.25	(3.2)	0.27	(6.2)	1.52	(7.2)
-0.08	(1.2)	0.05	(1.2)	0.10	(3.5)	0.27	(6.2)	0.08	(1.6)	0.24	(1.2)
1.15	(3.9)	0.91	(4.1)	-0.07	(0.5)	1.52	(9.7)	0.24	(1.6)	-8.71	(9.1)
0.66	(3.5)	-1.11	(10.4)	0.78	(11.0)	-0.68	(4.0)	2.24	(20.6)	11.9	(24.9)
0.37	(1.8)	0.06	(0.5)	0.29	(3.6)	-0.64	(3.4)	0.15	(1.3)	3.87	(7.2)
0.16	(0.4)	0.03	(0.2)	0.15	(1.0)	-0.06	(0.2)	0.25	(1.1)	-3.03	(3.1)
-0.01	(0.3)	-0.28	(9.6)	-0.11	(5.5)	-0.61	(12.6)	0.09	(2.9)	1.41	(10.5)
0.04	(0.3)	0.16	(1.6)	0.23	(3.4)	-0.23	(1.4)	-1.06	(10.1)	1.42	(3.1)
-0.68	(4.7)	-0.39	(4.6)	0.23	(4.1)	-0.14	(1.0)	0.46	(5.4)	-0.31	(0.8)
-0.01	(0.0)	0.68	(4.3)	-0.05	(0.5)	0.85	(3.3)	-0.41	(2.5)	-2.88	(4.0)
0.78	(1.8)	0.23	(0.9)	0.05	(0.3)	-1.01	(2.5)	0.01	(0.0)	-3.34	(3.0)
3.48	(13.2)	-0.99	(6.6)	-0.42	(4.2)	1.09	(4.5)	-0.03	(0.2)	0.74	(1.1)
4.76	(17.0)	-0.96	(6.0)	0.05	(0.5)	3.53	(13.9)	0.09	(0.6)	5.00	(6.9)
3.00	(8.5)	0.09	(0.4)	-0.19	(1.4)	2.71	(8.5)	0.89	(4.3)	-2.24	(2.5)
4.55	(16.4)	0.35	(2.2)	0.26	(2.4)	3.72	(15.0)	0.08	(0.5)	1.76	(2.5)
7.36	(30.5)	-0.70	(4.9)	0.33	(3.5)	3.51	(16.4)	-0.56	(4.0)	-0.07	(0.1)
-0.70	(2.6)	0.02	(0.1)	-0.30	(2.9)	-1.47	(6.1)	0.21	(1.4)	-0.56	(0.8)
-0.62	(0.7)	-0.75	(1.5)	1.37	(4.2)	9.08	(11.4)	2.11	(4.1)	-6.92	(3.1)
1.77	(4.1)	0.22	(0.9)	0.30	(1.8)	1.56	(3.9)	0.03	(0.1)	-8.16	(7.4)
0.22	(0.6)	0.20	(1.0)	0.90	(6.6)	1.06	(3.2)	0.28	(1.3)	-3.28	(3.6)
1.89	(4.5)	-0.07	(0.3)	-0.26	(1.6)	0.14	(0.4)	0.00	(0.0)	-1.23	(1.1)
0.74	(3.6)	0.13	(1.1)	-0.03	(0.3)	-0.48	(2.6)	-0.21	(1.8)	0.78	(1.5)
1.26	(3.4)	-0.04	(0.2)	-0.25	(1.7)	0.14	(0.4)	-0.10	(0.5)	-1.61	(1.7)
3.35	(10.2)	-0.69	(3.7)	-0.44	(3.5)	-0.75	(2.5)	0.74	(3.8)	-0.06	(0.1)
-0.99	(4.3)	-0.01	(0.1)	0.16	(1.9)	-0.65	(3.1)	-0.03	(0.2)	-1.11	(1.9)
1.53	(0.7)	18.3	(14.5)	-2.17	(2.6)	20.4	(11.2)	-10.8	(8.9)	-67.6	(11.9)
0.27		0.07		0.09		0.13		0.10			

Note: z-statistics in parentheses. The shaded areas are for estimates significant at 95% level of confidence. The coefficients are scaled up by 100 for easy presentation.

Table 4.5 shows expenditure elasticities and the Marshallian (uncompensated) and own-price elasticities, obtained by four methods: SUR with individual unit values, SUR with communal unit values, modified Cox and Wohlgenant (CW)'s quality-adjusted approach, and Deaton's approach to correct unit value bias. Expenditure elasticities are all positive, implying all eleven food categories are normal goods. Results from the model with individual unit values are very different with the three other models, which suggest that using individual unit values as prices can lead to substantially different results compared to using some kinds of correction models.

The CW quality-adjusted model yields slightly different estimates from the model with communal unit values and with the Deaton's model. This chapter will use the results from the CW quality-adjusted model as the basis for the analysis. Very few studies have been conducted to compare these correction methods, so it would be presumptuous to draw any conclusion about which method performs best. Yet, Deaton's approach has been criticized by some authors such as Huang and Lin (2000), Niimi (2002), and Gibson and Rozelle (2002) for being biased estimates of prices, which is why the modified CW approach, with communal quality-corrected unit values proxying prices, will be the main model for analysis.

For most of the food groups, the unadjusted communal value method and the CW-adjusted elasticities are similar. The food groups for which there are important differences between the two models are rice, other meat and FAFH. Therefore, a simple model that ignores the differences in quality may lead to significant bias in the estimates of the elasticities of rice, other meat and FAFH.

Table 4.5: Expenditure and Own-Price Elasticities

Expenditure elasticities	Individual	Communal	C& W	Deaton
Rice	0.96	0.37	0.31	0.53
Staples	1.00	0.96	0.99	0.99
Pork	1.01	1.13	1.13	1.12
Poultry	1.01	1.10	1.10	1.20
Other meats	1.02	1.63	1.75	1.73
Fish	1.03	1.05	1.07	0.99
Vegetables	0.99	0.85	0.84	0.69
Fruit	1.00	1.20	1.23	1.13
Other foods	0.98	0.98	0.95	0.98
Drink	1.02	1.44	1.46	1.52
FAFH	1.07	2.10	2.24	2.08
Marshallian own-price elasticities				
	Individual	Communal	C& W	Deaton
Rice	-0.89	-0.73	-0.80	-0.69
Staples	-0.75	-0.74	-0.75	-0.73
Pork	-0.79	-0.79	-0.83	-0.55
Poultry	-1.09	-1.08	-1.07	-0.90
Other meats	-0.94	-0.83	-0.95	-1.04
Fish	-0.94	-0.99	-0.99	-1.24
Vegetables	-0.97	-0.99	-1.00	-0.88
Fruit	-0.93	-0.93	-0.94	-0.88
Other foods	-1.07	-1.01	-1.01	-0.89
Drink	-1.01	-1.03	-1.00	-1.01
FAFH	-1.11	-2.65	-2.03	N/A*[23]

FAFH and other meat (mostly beef) are the two most expenditure-elastic food groups. In contrast, rice is the least expenditure-elastic good. Rice, other staples, vegetables, and other foods are necessities (i.e. they have expenditure elasticities less than 1), while pork, poultry, beef, fish, fruit, drinks and FAFH are luxury goods (expenditure elasticities greater than 1). Thus when household income increases, the

[23] As the price index of FAFH is assumed to be the same for every household in the commune, there is no variation of unit values within a commune. Thus, the Deaton's approach cannot be used to estimate the price elasticity of FAFH.

expenditure shares of meats, fish, fruit, drinks and FAFH will increase while the shares of rice, other staples, vegetables and other foods decrease.

The estimated expenditure elasticity for rice is 0.31 after quality adjustment using the CW method. Estimates from past studies vary widely, from 0.09 to 0.83 (Haughton et al 2004, Benjamin and Brandt 2004, Canh 2008, Niimi 2005, Minot and Goletti 2000). These estimates may differ for several reasons. First, they use different specifications (double-log model, Engel curve estimation or AIDS model). Second, some studies estimate only the demand for rice (Haughton et al 2004), while others include both food and non-food items (Canh 2008). Third, except for Canh (2008), all previous studies examine food demand in Vietnam in 1990s, while the estimates presented here are based on 2006 data. Food demand patterns may change considerably as income and nutritional status improve.

Because the expenditure elasticity of rice is lower than the elasticities for all other food groups, the importance of rice in the Vietnamese diet will decrease as economic growth continues. This trend has been observed in recent years. In 1993, rice expenditure was 30 percent of total consumption expenditures and contributed 75 percent of calorie intake (Minot and Goletti 2000). In 2006, rice accounts for only 14 percent of total consumption expenditure, 26 percent of food expenditure, and 59 percent of calorie intake. However, rice will certainly remain the most important single food item in the Vietnamese diet for many years to come.

Future expenditures on meat, fish and fruit will increase significantly because their expenditure elasticities are larger than one. Particularly, the role of beef (in the ‘other meat’ category) and fruit will rapidly increase if Vietnam maintains its rapid economic growth.

The expenditure elasticity of FAFH is comparatively high, at 2.2. Therefore, income growth will lead to a significant increase in FAFH share among Vietnam’s food consumption, shifting away from eating at-home to outside meals. In 1993, FAFH accounted for 1 percent and 2 percent of food expenditure in the rural North and the rural South, and 6 percent and 10 percent of food expenditure in the urban North and the urban South (Benjamin and Brandt 2004). In 2006, FAFH represents 7 percent and 16 percent of food expenditure in rural and urban areas, respectively. This growing trend of FAFH share will continue in the future as Vietnam’s economy develops and its population becomes more urbanized.

Table 4.5 also shows estimates of own-price elasticities in Vietnam. It reports both Marshallian (uncompensated) and Hicksian (compensated) price elasticities. As expected, all the own-price elasticities are negative. Based on the quality-adjusted Marshallian price elasticities, FAFH, poultry and other foods are relatively price elastic foods, with Marshallian price elasticities above unity. Meanwhile, rice, other staples, pork, other meats, fish, and fruit have Marshallian price elasticities of less than unity.

The most price-elastic food is FAFH (-2.0); an increase in its price will reduce its consumption substantially. Poultry also has rather large own-price elasticity (-1.07). Thus, a uniform increase in the price of all foods will make households cut their consumption of FAFH and poultry considerably, while they are more reluctant to reduce their consumption of rice, staples and pork. Yet, the own-price elasticities of all foods are rather large, with their absolute values greater than 0.7, implying that household food consumption is sensitive to food price changes.

Tables 4.6 and 4.7 provide detailed information on the own-price and cross-price elasticities of food demands. Most of the Marshallian cross-price elasticities are very small, at less than 0.1. Some cross-price effects are important for rice and FAFH. As rice is the most important food, the consumption of all other food groups is significantly affected by the price of rice. Except for vegetables and FAFH, all other foods are complements to rice because their cross-price elasticities with respect to the price of rice are negative. The cross-price elasticities between rice and other food groups are the highest in terms of absolute values for FAFH (+0.30), drink (-0.29), other meats (-0.20), poultry (-0.18) and fruit (-0.18). Many food consumption items are also sensitive to the price of FAFH (represented by the general province-level price). Households tend to toward more traditional diets, based on rice and other staples, as FAFH price increases. Among the other food groups besides rice and FAFH, only the price of pork has important impacts on other food consumption. An increase in the price of pork leads to a reduction in the other meat products (poultry and other meats), and a cut in the expenditure on staples other than rice, vegetables, fruits, and FAFH, but leads to an increase in the consumption of rice, fish and other foods. Therefore, these estimates indicate that rice, fish and other foods are substitutes for pork, while all the other food groups are complements.

The Hicksian cross-price elasticities are larger than the Marshallian cross-price elasticities, implying that after incorporating income effects, the cross-price effects are more important. For example, when the price of rice increases, the uncompensated demands of pork, poultry and fish decrease, reflecting that these foods are complements to rice. Yet, to “compensate” for the utility loss due to an increase in the price of rice, the demand for other food groups, including pork, poultry and fish, must rise.

Table 4.6: Marshallian Owned- Price and Cross-Price Elasticities of Food Demand

	With respect to the price of										
	Rice	Staples	Pork	Poultry	Other meats	Fish	Vegetables	Fruit	Other foods	Drink	FAFH
Rice	-0.80	0.00	0.07	0.01	0.02	0.02	0.05	0.01	0.01	0.00	0.29
	(0.02)	(0.00)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.07)
Staples	-0.14	-0.75	-0.14	-0.03	-0.06	-0.11	0.06	0.01	-0.03	-0.04	0.23
	(0.04)	(0.03)	(0.05)	(0.03)	(0.02)	(0.03)	(0.02)	(0.01)	(0.01)	(0.01)	(0.09)
Pork	-0.08	-0.03	-0.83	-0.04	0.00	0.03	-0.11	-0.03	0.03	0.00	-0.07
	(0.02)	(0.01)	(0.04)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.05)
Poultry	-0.18	-0.02	-0.09	-1.07	0.06	-0.03	0.08	0.00	0.02	0.00	0.14
	(0.03)	(0.01)	(0.03)	(0.03)	(0.01)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.07)
Other meats	-0.20	-0.08	-0.09	0.08	-0.95	0.10	0.03	0.04	0.00	0.01	-0.69
	(0.04)	(0.02)	(0.04)	(0.03)	(0.03)	(0.03)	(0.02)	(0.01)	(0.01)	(0.01)	(0.08)
Fish	-0.14	-0.03	0.05	-0.02	0.05	-0.99	-0.06	0.00	-0.03	-0.01	0.11
	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.04)
Vegetables	0.07	0.03	-0.17	0.08	0.04	-0.06	-1.00	0.00	0.00	0.02	0.15
	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.04)
Fruits	-0.18	0.00	-0.11	-0.01	0.05	-0.01	-0.03	-0.94	0.02	0.02	-0.04
	(0.03)	(0.01)	(0.03)	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.05)
Other foods	-0.14	-0.01	0.05	0.01	0.02	-0.01	-0.01	0.01	-1.01	0.02	0.11
	(0.01)	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)
Drink	-0.29	-0.04	-0.04	-0.02	0.01	-0.06	-0.02	0.01	-0.01	-1.01	0.00
	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.04)
FAFH	0.30	0.03	-0.24	0.02	-0.23	0.00	0.01	-0.05	-0.02	-0.04	-2.03
	(0.07)	(0.03)	(0.07)	(0.04)	(0.03)	(0.04)	(0.03)	(0.02)	(0.02)	(0.02)	(0.13)

Shading areas: significant at 5%

Table 4.7: Hicksian Owned- Price and Cross-Price Elasticities of Food Demand

	With respect to the price of										
	Rice	Staples	Pork	Poultry	Other meats	Fish	Vegetables	Fruits	Other foods	Drink	FAFH
Rice	-0.72	0.01	0.11	0.02	0.03	0.05	0.07	0.02	0.06	0.02	0.32
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.07)
Staples	0.12	-0.72	-0.01	0.02	-0.03	-0.01	0.13	0.05	0.11	0.01	0.32
	(0.04)	(0.03)	(0.05)	(0.03)	(0.02)	(0.03)	(0.02)	(0.01)	(0.01)	(0.01)	(0.09)
Pork	0.22	0.00	-0.68	0.02	0.03	0.14	-0.03	0.01	0.19	0.06	0.04
	(0.02)	(0.01)	(0.04)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.05)
Poultry	0.11	0.01	0.05	-1.01	0.09	0.07	0.16	0.04	0.18	0.05	0.25
	(0.03)	(0.01)	(0.03)	(0.03)	(0.01)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.07)
Other meats	0.26	-0.03	0.14	0.17	-0.90	0.28	0.15	0.10	0.26	0.10	-0.52
	(0.04)	(0.02)	(0.04)	(0.03)	(0.03)	(0.03)	(0.02)	(0.01)	(0.01)	(0.01)	(0.08)
Fish	0.14	0.00	0.19	0.04	0.08	-0.88	0.01	0.04	0.12	0.04	0.21
	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.04)
Vegetables	0.29	0.06	-0.06	0.13	0.07	0.02	-0.94	0.03	0.12	0.06	0.23
	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.04)
Fruits	0.14	0.04	0.05	0.06	0.09	0.11	0.05	-0.90	0.20	0.08	0.08
	(0.03)	(0.01)	(0.03)	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.05)
Other foods	0.11	0.02	0.17	0.07	0.05	0.08	0.06	0.05	-0.87	0.07	0.20
	(0.01)	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)
Drink	0.10	0.01	0.15	0.06	0.06	0.08	0.08	0.06	0.20	-0.93	0.14
	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.04)
FAFH	0.89	0.10	0.05	0.15	-0.16	0.22	0.16	0.03	0.30	0.07	-1.81
	(0.07)	(0.03)	(0.07)	(0.04)	(0.03)	(0.04)	(0.03)	(0.02)	(0.02)	(0.02)	(0.13)

Shading areas: significant at 5%

Disaggregated elasticities

In order to gain a better understanding of food demand in Vietnam, this subsection examines the expenditure and price elasticities for different household groups by running separate regressions for these groups. This information is important for policymakers in formulating, and in evaluating, the possible effects of food policies and programs on different groups. Table 4.8 summarizes expenditure elasticities for different household groups.

Households in urban areas have higher food expenditure elasticities than those in rural areas for rice, FAFH, drinks and other meats, but lower elasticities for other food groups. Thus, as the expenditure allocated for food rises, urban households are more likely to spend on rice, other meats, drinks and FAFH and less likely to spend on other foodstuffs than their rural counterparts.

The food patterns are also somewhat different across regions. The income elasticity of rice is lowest in the North and highest in the South. In contrast, the income elasticity of FAFH is higher in the Center and the North than in the South. Nevertheless, the general pattern is similar for all three regions. Some exceptions concern fish and other staples. Fish demands are relatively income elastic in the North and in the Center but income inelastic in the South. In contrast, the demand for other staples is inelastic in the Center and elastic in the South. Thus, households in the Center tend to prefer to buy more fish and rather than other staples as their incomes rise, whereas Southern households are more likely to spend more on other staples and less on fish as their income rises.

Regarding the expenditure groups, the poorest 20 percent of households have relatively high expenditure elasticities for poultry, fish, vegetables and fruit than other groups. Interestingly, the mean expenditure elasticity for rice of the poorest group is lower than that of the richest group, although it is higher than the other quintiles. The relatively high expenditure elasticity for rice (0.46) in this group implies that these households in the poorest group may be constrained in their access to food, as they increase significantly the consumption of rice, the most basic component in the Vietnamese diet, as their income rises. Poorer households tend to increase their food consumption more than rich households do when their food expenditure rises. In fact, except for rice and staples, the expenditure elasticities of the poorest 20 percent of Vietnamese households for all the other nine food groups are equal or greater than one. Meanwhile, for the richest 20 percent, only five among 11 food groups have expenditure elasticities that are greater than unity.

Turning to the Marshallian own-price elasticities, rural demand is more price elastic for rice, poultry, other meats, vegetables and fruit but less price elastic for the other food. Geographically, Vietnam has three regions: the North (including North East, North West, and Red River Delta), the Center (including North Central Coast and South Central Coast) and the South (including Central Highland, Mekong River Delta and South East). Households in the Center have the highest price elasticity for rice but the lowest price elasticity for FAFH. In general, households in the South are more price elastic than those in the North and the Center.

When the prices of rice, other staples and pork increase, the poorest quintile is most likely to cut their corresponding food consumption since their demand for such foods is more price elastic than the demands of other groups. Because rice, other staples and pork supply the basic diet for most Vietnamese, poor households' food security and nutrition are vulnerable to food price increases. On the other hand, the richest households tend to reduce their share of FAFH and drink more than the poor do when the prices of these food groups increase.

Table 4.8: Disaggregated Expenditure and Marshallian Price Elasticity

	Rice	Staples	Pork	Poultry	Other meats	Fish	Vegetables	Fruits	Other foods	Drinks	FAFH
Expenditure elasticity											
Rural	0.25	1.00	1.27	1.15	1.68	1.09	0.88	1.23	0.97	1.45	2.12
Urban	0.46	0.96	0.88	0.99	1.75	0.97	0.75	1.14	0.91	1.46	2.49
North	0.22	1.00	1.07	1.17	1.89	1.18	0.78	1.31	0.99	1.35	2.37
Center	0.31	0.91	1.13	1.02	1.79	1.03	0.85	1.16	0.92	1.50	2.39
South	0.39	1.02	1.20	1.05	1.56	0.97	0.87	1.15	0.92	1.52	2.11
Quintile 1	0.46	0.67	1.15	1.29	1.35	1.39	1.16	1.14	1.02	1.06	1.48
Quintile 2	0.41	0.98	1.18	1.08	1.16	1.30	1.11	1.00	0.99	1.13	1.87
Quintile 3	0.37	1.08	1.23	1.00	1.22	1.34	0.87	0.81	0.91	0.96	2.29
Quintile 4	0.42	0.89	1.14	0.89	1.23	1.12	0.93	0.96	0.86	1.25	2.44
Quintile 5	0.55	0.91	0.84	1.01	1.53	0.93	0.74	1.11	0.91	1.39	2.46
Marshallian own-price elasticity											
Rural	-0.82	-0.74	-0.81	-1.07	-1.07	-0.99	-1.02	-0.97	-1.00	-1.00	-1.80
Urban	-0.72	-0.76	-0.94	-1.05	-0.46	-0.99	-0.91	-0.81	-1.03	-1.02	-2.24
North	-0.80	-0.85	-0.60	-1.01	-0.98	-0.89	-0.96	-0.92	-0.99	-0.97	-1.97
Center	-0.90	-0.69	-0.80	-1.12	-0.66	-0.96	-0.97	-0.89	-1.04	-1.07	-1.23
South	-0.81	-0.70	-1.04	-1.12	-1.01	-1.11	-1.02	-0.98	-1.02	-0.99	-2.66
Quintile 1	-0.89	-0.91	-0.98	-1.01	-1.09	-1.05	-1.03	-0.97	-0.99	-0.99	-1.26
Quintile 2	-0.87	-0.64	-0.89	-1.02	-1.14	-0.99	-1.04	-0.99	-1.02	-1.01	-1.51
Quintile 3	-0.84	-0.77	-0.76	-1.08	-1.07	-1.01	-0.97	-0.97	-1.02	-0.98	-1.79
Quintile 4	-0.83	-0.66	-0.73	-1.11	-0.93	-0.96	-1.00	-0.92	-1.02	-1.04	-1.96
Quintile 5	-0.82	-0.70	-0.84	-1.04	-0.54	-0.95	-0.94	-0.88	-0.99	-1.05	-2.29

4.5. Summary and Conclusion

This chapter has analyzed the food consumption patterns of Vietnamese households, by estimating a complete demand system. Demand elasticities were estimated using the AIDS model and the latest Vietnamese household survey data. The results indicate that food consumption in Vietnam is affected by income and prices, as expected, and also that the structure of food consumption varies in response to socio-economic and geographic factors.

All food items have positive expenditure elasticities and negative own-price elasticities. In particular, rice has mean expenditure elasticity of 0.36 and mean own-price elasticity of -0.80. Thus, one percent increase in the price of rice will reduce rice consumption by 0.8 percent, on average. On the other hand, one percent increase in the food expenditure would lead to an increase in rice demand by 0.36 percent. Thus, in order to increase food consumption and nutrition status in Vietnam, policies that aim at increasing household income (income policies) may be ineffective compared with policies that affect prices (price policies) in the case of rice. In contrast, income policies may be more effective in enhancing meat and fish consumption than price policies, as the expenditure elasticities of these foods are higher than their own-price elasticities. However, both price and income policies are important, as the expenditure and price elasticities are highly statistically significant.

This study indicates that demand functions in urban and rural areas, and across regions and income groups are different. It points out that targeted food policies should be formulated based on the specific food demand patterns of each group. Socio-economic factors such as household size and composition, as well as the age and education status of the heads of households, significantly affects food consumption in most cases.

Recently, a worldwide food price crisis has occurred in many developing countries, including Vietnam. During the first nine months in 2008, food prices increased by more than 30 percent and rice prices by nearly 60 percent in Vietnam. Because own-price elasticities are high for most food groups, such a price hike may have a severe impact on food consumption and endanger the food security and nutritional status of Vietnam's population.

Vietnamese food consumption patterns have been changing over the past 15 years. In particular, the role of rice has diminished while the consumption shares of meat, fish, fruit and food eaten away from home have all increased considerably. Future studies based on a panel and time series data could shed some light on those changing food consumption patterns.

CHAPTER 5: ANALYSIS OF CALORIE AND MICRONUTRIENT CONSUMPTION IN VIETNAM

Abstract

This chapter analyzes calorie and micronutrient consumption in Vietnam using the recent household survey data collected in 2006. The data suggest that food insecurity is still a major problem in Vietnam, with nearly 40 percent of the population being unable to meet their calorie requirement. Employing nonparametric and parametric estimation techniques, the chapter examines the relationship between household calorie consumption and per capita household expenditure in Vietnam. The analysis indicates a positive and significant relationship between per capita expenditure and per capita calorie consumption. The mean calorie elasticity is estimated to be between 0.21 and 0.31 by the parametric method and 0.20 by non-parametric method. In addition, simulated income and food price changes indicate that undernutrition is very responsive to changes in income and food prices. This chapter also estimates protein and micronutrient elasticities, an area often overlooked in empirical studies. Estimates of expenditure elasticities of micronutrients are high, ranging from 0.3 for iron and calcium, to nearly 0.7 for vitamin C and 0.8 for vitamin A. This implies that income growth leads to large increase in household micronutrient intakes, particularly for vitamin intakes.

Keywords: Vietnam, food, calorie, micronutrient, elasticity.

5.1. Introduction

Meeting food security is critical to successfully achieving the Millennium Development Goals. Many authors have addressed poverty reduction concerns in Vietnam, for example Minot and Baulch (2005) and Baulch and Masset (2003), but few studies have specifically addressed food security and nutrition aspects in this country. The exceptions are Molini (2007), Mishra and Ray (2006) and Ray (2007). Molini (2006) describes the changes in food consumption patterns in Vietnam over time and finds evidence of substitution of low micronutrient food items, such as rice and cereals, and in favor of high micronutrient items, such as fruit, vegetables, fish and meat, during the 1990s. He also estimated the elasticity of calories with respect to expenditure for the years 1993 and 1998 and found a significant reduction in the calorie income elasticity over time, reflecting a general improvement in food security. Mishra and Ray (2006) examine changes in the prevalence of undernourishment (POU), as measured by the percentage of Vietnamese households unable to meet their daily minimum calorie requirements, from 1993 to 1998. They show that the prevalence of undernourishment in Vietnam was severe, with over 80 percent of Vietnam households undernourished in both years, as measured by calorie requirement standards established by the WHO.

There have been two major strands of research on the relationship between nutritional status and economic status in developing countries. The first focuses on efficiency wages, initiated by Leibenstein (1957), and later expanded by Mirrlees (1975) and Stiglitz (1976). This literature argues that productivity, and thus wages, depends on nutritional status. According to this line of thought, wages cannot fall below beyond a certain point because workers need enough nutrition and food consumption to enable them to work effectively. This literature is primarily concerned with explaining unemployment in low-income countries.

A second strand of research postulates that nutrition, as measured by calorie consumption, is conditioned by income and by the demand for food. The demand for calories will rise with income; therefore, economic growth will help eliminate malnutrition. There have been many studies on the income elasticity (or expenditure elasticity) of calorie demand, but the empirical evidence is unclear. Subramanian and Deaton (1996), and Dawson and Tiffin (1998) estimated that the calorie-income elasticity for India was in 0.3 to 0.5 range. Sahn (1988) found income elasticities of calories ranging from 0.28 for low-income groups to 0.76 for high-income groups in Sri Lanka. Pitt (1983) estimated a calorie-income elasticity for Bangladesh of around 0.8. In contrast, Behrman and Deolalikar (1987) for India, Bouis and Haddad (1992) for the Philippines, and Ravallion (1990a) for Indonesia have estimated calorie-income elasticities that are close to zero. If the calorie-income elasticities are insignificant or close to zero, economic growth may not be accompanied by an improvement in nutritional intakes.

This chapter adds to this body of evidence by examining food security and nutrition in Vietnam. Using the 2006 Vietnam Household Living Standard Survey (VHLSS) data, it estimates the expenditure elasticity of calorie demand, using both parametric and non-parametric approaches. It also analyzes the response of calorie intakes to simulated income and food price changes. In addition to the calorie-expenditure elasticity, expenditure and food price elasticities for micronutrients are also estimated.

The remainder of the chapter is structured as follows. Section 5.2 discusses calorie consumption, calorie prices and dietary diversity in Vietnam. Section 5.3 provides parametric and nonparametric estimates of calorie elasticities and calorie price elasticities. Section 5.4 discusses the impacts of income and food prices on calorie consumption. Section 5.5 provides expenditure elasticities estimates of micronutrients such as iron, calcium and vitamins. Finally, Section 5.6 provides the conclusion.

5.2. Calorie Consumption, Calorie Price and Dietary Composition

The 2006 VHLSS was conducted by Vietnam's General Statistics Office to collect data on household living standards, including data on household expenditure, income, and information on household members' occupations, health and education status. The survey was conducted nationwide. Expenditure and food consumption data were collected from 9,189 households in the 2006 survey. Information on food consumption expenditures were obtained for both regular and holiday expenses. The data were collected for both purchased goods and self-supplied food (home production). Data on food expenditures were collected for 56 food items.

For this study, the data on food consumption are aggregated into ten at-home food groups, and a food away from home group (FAFH). All food consumption is transformed into calories based on the calorie conversion table used by General Statistics Office of Vietnam to calculate the food poverty line (see appendix A2). This conversion table was constructed by Vietnam's National Institute of Nutrition. The Vietnamese food composition table in this study differs from that used in Molini (2006) and Mishra and Ray (2006), who use the FAO's food composition table for international use (which was first published in 1949) to obtain calorie consumption. The calorie conversion table used in this study should reflect better calorie consumption in Vietnam because it was based on Vietnamese diets while the FAO table was constructed based on the most common food items consumed around the world. Thus, the FAO table may not reflect actual food consumption in a particular country.

For certain food items, VHLSS data were collected on value only, not on quantity. For these items, the average price of calories was calculated for the food items having quantity information. This price is then used to derive the equivalent calorie consumption from the food items without quantity data in the same food group, based on the value data. For example, the "other vegetables" have no quantity information. I calculated the average calorie price for "vegetables", based on those items in "vegetables" group having quantity data, such as beans, peas, and morning glory. Then, the approximated calories from "other vegetables" item was derived, using the expenditure for "other vegetables" item and the average price of "vegetables" group. For FAFH, I use the average price of calories for each household from all ten food categories consumed at home. Thus, it is assumed that consumers pay the same price for one calorie consumed at home and away from home.[24]

Table 5.1 presents the mean prices of purchasing 1000 calories for each food category. As expected, rice provides calories at the lowest cost, followed by other staples. On the other hand, poultry and other meats (mainly beef) are the most expensive in terms of calorie content. On average, a household in the richest quintile pays almost triple the amount paid by a household in the poorest quintile for a given

[24] For robustness checking, an alternative assumption was used that the calorie price for FAFH is 1.5 the average calorie price. The results are similar.

amount of calorie consumption. This reflects the fact that poorer households consume higher shares of foods that provide calories at a low cost, such as rice and other food staples, than do richer households. In addition, as seen in Table 5.1, poorer households also consume lower-quality items within all food categories. Therefore, the calorie prices paid by poorer households are lower than those paid by richer households. The gaps between calorie prices paid by poorer and richer households are most notable for those food items that richer households consume more frequently, such as FAFH, fruits, other foods and fish. This implies that, for these food items, richer households pay more for food attributes other than calorie content, such as quality, taste, and vitamins. It is calculated that, on average, a household in the top income quintile pays almost 5,800 VND for 1,000 calories while a household in the bottom quintile pays just 2,000 VND for the same amount of calories. In a similar manner, on average, an urban household pays 5,160 VND per 1,000 calories while a rural household only pays 2,880 VND.

Table 5.2 presents total per capita calorie consumption and the percentage of calorie consumption from different food sources in Vietnam in 2006. To save space, only information for the poorest and the riches quintiles are reported in Table 5.2. Rice is the main calorie source for most households, providing 59 percent of total calorie consumption, and accounting for 26 percent of food expenditure. It is the primary food in the diets of all Vietnamese, regardless of sector, income or region. The importance of rice and staple foods declines as household incomes increase. In the top income quintile, rice and staples provide 59 percent of calorie consumption. Rice and other staple foods provide 77 percent of calorie consumption for the households in the lowest expenditure quintile. Other commodity groups have smaller shares of total household calorie consumption. The category 'Other foods' includes items such as fats and oils, eggs, milk (except fresh milk), which contributes nearly 10 percent of calorie consumption. Food away from home (FAFH) comprises nearly 8 percent of calorie consumption.

Table 5.1: Average Price of 1000 Calories, by Type of Food (thousands VND), 2006.

	Mean	Bottom 20%	Top 20%	Rural	Urban
Rice	0.35	0.28	0.46	0.33	0.41
Other staples	0.66	0.49	0.84	0.63	0.74
Pork	2.32	1.79	2.95	2.22	2.64
Other meats	13.99	8.90	17.55	12.85	16.22
Poultry	11.85	9.68	14.85	11.27	13.65
Fish	7.28	4.85	11.59	6.27	10.27
Vegetables	2.12	1.59	2.89	1.92	2.70
Fruits	3.35	1.93	5.33	2.85	4.70
Other foods	3.64	1.99	6.38	3.06	5.38
Drink	0.96	0.75	1.44	0.86	1.24
FAFH	1.07	0.49	2.14	0.83	1.76

The budget shares of high quality protein-rich foods (meats, milk, eggs, oil, fish etc.) and time-saving, convenience foods (FAFH) increase as income increases. For example, the budget share of meat and fish of households in the highest expenditure quintile is more than twice the corresponding figures in the poorest quintile. In terms of quantity, the quantity of meat and fish consumed among the highest expenditure quintile is 51 kg per capita per year, while that among the lowest expenditure quintile is 19 kg per capita per year. Similarly, the budget share of FAFH in the top-income quintile is more than five times that of the poorest quintile. In addition, protein-rich and time-saving foods have higher expenditure shares in urban areas than in rural areas. Meat and fish contribute 8 percent of calorie consumption in rural areas but 11 percent in urban areas. The FAFH share of calorie consumption is only 6 percent in rural areas but 13 percent in urban areas.

Except for rice and staples, all foods are consumed in larger quantities by households in the higher expenditure groups. For rice, the lowest-expenditure group consumes less than the lower-middle expenditure (quintile 2) and the middle-expenditure (quintile 3) groups but higher than the upper-middle (quintile 4) and the highest expenditure (quintile 5) groups. This indicates that when their incomes increase, households increase their rice consumption. However, when their income reaches a certain level, households substitute rice with other foods, resulting in a reduction in the consumption of rice. In contrast, the consumption of other staples at first reduces from quintile 1 to quintile 2 but then increases as income increases. It is possible that households in the lowest-expenditure group consume large amount of low cost staple foods such as corn/maize, cassava, and sweet potatoes, which are less expensive in terms of price per calorie than rice. When their income increases, they substitute such staple foods with rice. However, as their income continues to rise, they might increase their consumption of staples such as wheat, noodles, rice noodles, and wheat, which are more expensive than rice.

Table 5.2: Shares of Calorie Availability, Dietary Diversity, and Quantity Consumed.

	Rice	Staples	Pork	Other meats	Poultry	Fish	Vega-tables	Fruits	Drink	Other foods	FAFH	Simpson Index	Total Calories
Shares of calories (%)													
All	59.0	5.0	5.4	0.3	0.9	2.1	4.4	3.3	1.7	9.9	7.8	0.58	2348
Rural	62.5	4.8	4.9	0.3	0.9	2.0	4.4	3.3	1.6	9.2	6.1	0.55	2376
Urban	48.5	5.6	7.0	0.6	1.0	2.4	4.5	3.3	2.0	12.0	12.9	0.68	2265
Lowest 20%	71.3	5.5	3.1	0.1	0.6	1.5	4.7	2.5	1.2	6.7	2.5	0.44	2030
Highest 20%	44.1	6.0	7.8	0.8	1.3	2.4	4.7	3.9	2.4	12.7	13.8	0.71	2559
Shares of food expenditures (%)													
All	26.4	2.9	13.1	5.6	2.9	9.9	6.7	3.4	4.9	14.5	9.6		
Rural	29.6	3.0	13.1	6.0	2.4	9.6	6.8	3.2	4.6	14.4	7.3		
Urban	16.9	2.6	13.1	4.5	4.5	10.8	6.4	4.1	5.7	15.0	16.4		
Lowest 20%	41.4	3.3	10.5	5.7	1.5	8.4	7.3	2.5	3.5	13.3	2.7		
Highest 20%	13.7	2.7	13.6	5.1	5.1	9.8	5.9	4.6	6.8	14.9	18.0		
Quantities consumed (per capita/year, in kg except in liter for drink)													
All	140.2	17.1	12.9	1.0	4.9	16.7	38.2	11.3	15.6	49.0	n/a		
Rural	150.0	17.1	11.9	0.6	4.8	16.0	36.3	10.2	13.2	45.8	n/a		
Urban	110.7	16.9	15.9	2.1	5.0	18.8	44.0	14.5	22.5	58.6	n/a		
Lowest 20%	145.3	18.5	6.2	0.2	2.7	9.5	23.5	6.0	6.9	28.0	n/a		
Highest 20%	117.5	20.5	20.3	2.7	7.0	20.5	51.4	19.2	31.5	70.8	n/a		

Table 5.3: Previous Estimates of Calorie Consumption in Vietnam

	1992-93			1997-98			2004		2006		
	All	Rural	Urban	All	Rural	Urban	Rural	Urban	All	Rural	Urban
Total per capita calories (calories/day*)											
Thang and Popkin 2004	2129	2173	1893	2111	2158	1783					
Dien et al. 2004				2055	2145	1812					
Molini 2006	2053	2060	2021	2267	2281	2218					
Ray 2007		2571	2165		2553	2039	3206	2824			
This study									2348	2376	2265
Percentage of calories from cereal											
Thang and Popkin 2004	85.9			80.3							
Dien et al. 2004				79.3	81.9	71.2					
Molini 2006	78			74							
Ray 2007		86.9	83		85.7	79.2	70.6	61.1			
This study									64.0	67.3	54.1

* Estimates of Dien et al. 2004 and Thang and Popkin 2004 are based on adult equivalence scale. The rest is based on per capita. The results of Mishra and Ray (2006) are similar to Ray (2007) for 1997-98.

Dietary diversity is often considered an important measure of household food security. A study by Hoddinott and Yohannes (2002) of 10 developing countries showed a strong positive association between household-level dietary diversity and food energy availability. The authors suggested that dietary diversity could be a useful measure for food security, especially if obtaining detailed data on food security status is time consuming and expensive. Arimond and Ruel (2004) examined data from 11 demographic and health surveys and found that dietary diversity is positively associated with child nutritional status, in particular with children's height-for-age Z-scores. Table 5.2 demonstrates that richer households consume more diversified diets than poorer households, including much higher shares of such foods as meat, fish, fruits, all of which are important sources of protein, vitamins, calcium, iron and other micronutrients. Specifically, household dietary diversity can be measured by the Simpson index, which is also included in Table 5.2. This index of food diversification can be written as: I =1-$\sum w_{i,}^{2}$ in which w_i is the calorie share of food *i.* A high Simpson index, which in the range 0 to 1, reflects a more diversified diet. Table 5.2 indicates that the Simpson index of richer households is much higher than it is for poorer households. The Simpson index of the households in the bottom quintile is 0.44, while that of those in the top quintile is 0.71. As expected, urban households consume more diversified diets than rural households. The Simpson index of urban households is 0.68, compared with 0.55 of rural households.

The total per capita calorie availability among Vietnamese households is estimated to be 2348 calories/per day. Rural households have higher calorie intakes than urban households, as found by previous studies of Vietnam and other developing countries (for example Molini 2006 for Vietnam, Ray 2007 for Vietnam and India, and Sahn 1988 for Sri Lanka).

Table 5.3 compares results from the 2006 VHLSS with previous estimates of calorie consumption in Vietnam. The estimates of calorie intakes among Vietnamese households in 2006 are higher than the estimates of Molini (2006), Thang and Popkin (2004), Dien et al (2004) for 1997-98 data but less than the estimates of Ray (2007) for 2004 data. There are several possible reasons for these differences. First, the calorie conversions used here are based on a Vietnamese calorie conversion table while Ray (2007) and Molini (2006) used an international calorie conversion table. Second, the quantities of calories in this study for the food items reported without quantity information (other than FAFH) are adjusted, based on the average prices of calories of the food groups into which the items are categorized, while the correction methods for these food items are not explained in any of the above-mentioned previous studies. Third, the method used here to calculate calorie consumption due to FAFH is different from that of Molini (2006). Molini (2006) used a 'median 1,000 calories price' as the 'price' for FAFH while this study uses the average calorie price for all other food with quantity information as the 'price' for FAFH. The other studies did not explain how they estimated calorie consumption for FAFH. Finally, the estimates given in this chapter pertain to 2006, while most of other studies report estimates for the 1990s. The exception is Ray (2007) who estimated calorie consumption, using both 1997-98 and 2004 data. However, the results in Ray (2007) appears too high, both with respect to previous studies on Vietnam and other studies pertaining to other developing countries.

Several previous studies have pointed out the divergence between Vietnam's record on poverty reduction and its record on malnutrition. Baulch and Masset (2003) argued that monetary poverty, i.e. poverty measured in terms of money values, is less persistent than either malnutrition among adults (measured by Body Mass Index) or stunting among children in Vietnam in the 1990s. They claimed that defining chronic poverty based on either monetary poverty or on malnutrition can lead to significantly different results. Chronic poverty is much more severe when measured by malnutrition than when measured by monetary poverty. Mishra and Ray (2006) pointed out that malnourishment was very prevalent in Vietnam throughout the 1990s, and there was no progress in reducing malnutrition in the 1990s regardless of achievements in reducing monetary poverty. Based on the WHO criteria of minimum calorie requirements, they estimated that 82 percent and 86 percent of Vietnamese households were undernourished in 1992/93 and 1997/98, respectively.

Based on the estimates of calorie consumption presented above, this study calculates the incidence of undernutrition, using the nutrition threshold of 2100 calories/day. Households are defined as undernourished if their per capita calorie availability is less than 2,100 calories/day in 2006[25]. Table 5.4 presents the undernutrition and poverty situation in Vietnam. The poverty line used is the national poverty line, set by General Statistics Office of Vietnam of 2,559.85 thousand VND per year or around 213 thousand VND per month (equivalent to $13/month at the nominal exchange rate in 2006). The poverty (undernutrition) headcount is simply the percentage of households living under the poverty (undernutrition) line. The poverty (undernutrition) gap is the

[25] In contrast, Mishra and Ray (2006) used the WHO's minimum calorie requirements to calculate undernutrition prevalence. They did not describe specifically what that calorie requirements are.

normalized shortfall of households with real per capita expenditure (calorie intake) below the poverty (undernutrition) line, expressed in proportion to the poverty (undernutrition) line.

Mathematically, these indices are calculated as (Foster, Greer and Thorbecke 1984):

$$P(\alpha)= \sum p(k_i, z)= (1- k_i / z)^{\alpha} (\alpha \geq 0) \text{ for } k_i <z \quad (5.1)$$

$$= 0 \text{ otherwise,}$$

where k_i is the real per capita expenditure (or calorie intake) of household *i* and z is the poverty line (or undernutrition line). When α =0, one has the poverty (or undernutrition) headcount index P(1); when α =1, one obtains the poverty (or undernutrition) gap P(2).

Table 5.4 indicates that undernutrition is prevalent among Vietnamese households, even though less than 16 percent of Vietnamese households are classified poor in monetary terms. Almost 38 percent of households in Vietnam, 36 percent in rural areas and 45 percent in urban areas are undernourished. On average, rural households have higher (monetary) poverty rates and lower income but have lower undernourishment rates and higher calorie consumption than urban households. Even among the richest quintile, 29 percent of the households have lower calorie consumption than the minimum requirements.

Table 5.4 shows that undernutrition is less severe in rural areas than in urban areas, even though the average rural household typically has a lower income than the average urban household. Perhaps working in rural areas, which often involves manual farm work, requires more energy and thus more calories than in urban areas. Studies of Vietnam by Mishra and Ray (2006) and Mollini (2007) found that the average calorie consumption of the urban population is significantly lower than that of rural population. Studies of other countries, such as Skoufias (2003) for Indonesia, Ray (2007) for India, and Sahn (1988) for Sri Lanka, also found that the rural populations consumed more calories per capita than urban populations.

Table 5.4: Undernutrition and Poverty Indices

	Undernutrition headcount	Undernutrition gap	Poverty headcount	Poverty gap
All	38.1	6.2	15.5	3.7
Rural	36.0	5.7	19.5	4.7
Urban	44.6	7.9	3.4	0.6
Red River Delta	36.2	5.4	8.8	1.5
North East	28.9	4.2	23.2	5.2
North West	43.3	6.3	50.4	16.6
North Central Coast	46.5	7.6	24.2	5.9
South Central Coast	46.7	7.7	10.7	2.2
Central Highlands	42.0	7.6	24.6	6.7
South East	44.1	8.4	6.4	1.7
Mekong River Delta	32.0	5.4	9.4	1.7
Quintile 1	60.6	11.0	79.1	18.8
Quintile 2	40.3	6.0	0.0	0.0
Quintile 3	31.8	4.8	0.0	0.0
Quintile 4	30.1	4.7	0.0	0.0
Quintile 5	28.6	4.9	0.0	0.0
Non-poor	33.4	5.2	0.0	0.0
Poor	63.9	12.1	100	23.7
Ethnic majority	38.4	6.3	9.5	1.8
Ethnic minorities	36.9	5.9	49.2	14.1
Non-farmer	47.0	8.8	5.3	1.1
Farmer	34.7	5.3	19.5	4.7

5.3. Estimating Calorie-Expenditure Elasticities

This section presents estimates of the calorie-expenditure elasticity using both parametric and non-parametric methods.

5.3.1. Parametric Estimation

The impact of income (or expenditure) on calorie consumption is estimated using an econometric model of consumer demand. Calorie consumption is typically modeled as a function of several variables. First, household per capita expenditure is expected to have a positive impact on per capita calorie consumption because as income increases, households normally spend more on food. Second, the prices of food categories affect calorie consumption by both income effects (reducing real income as price increases) and substitution effects (substitute one food item for another as food prices change). In Vietnam, as in many other developing countries, food prices are typically higher in urban areas than in rural areas, which may affect calorie consumption. Third, certain household characteristics can affect calorie consumption. Household composition affects food choices, and therefore, calorie consumption. For instance, adults tend to consume more calories than children and males more than females. Household size also influences calorie consumption. Economies of scale in food buying, storing, and preparing within the household will permit more consumption of food per household member and therefore more calorie consumption per capita in larger households. On the other hand, in larger households, children are a larger share of household members, and children eat less than adults, so food expenditure per capita may decrease as household size increases, resulting in a possible negative relationship between calorie consumption per capita and household size. Another important determinant of household per capita calorie consumption is education. The impact of education on calorie consumption is not always clear. Better-educated adults are more aware of nutrition demand, thus may want to adjust their calorie consumption to meet the recommended calorie intakes. In developing countries where a large percentage of the population is undernourished, this often means an increase in calorie intakes. But better-educated adults may need less energy than less-educated adults because they are less likely to engage in manual work. Better-educated households might also put more "weight" on food quality, convenience and taste than do less-educated households. Thus, better education might enable households to substitute foods rich in calories with foods with higher quality or better taste. I use two measures of education: head's schooling years and the average years of schooling from adult women in the family. While household heads are important as the likely decision-maker in the family, it is often the women who prepare meals for the family. Therefore, women's schooling may play an important factor in determining food consumption, and thus the calorie consumption per capita, of household members. Other relevant household characteristics include the number of household members working in agriculture, and the dummy variables that indicate whether the household lives in an urban area, or belongs to an ethnic minority.[26] Farming often requires more calorie consumption than non-farm work. Food availability and eating habits may differ between the urban and the rural areas and between the ethnic majority and the ethnic minorities. Finally, some dummy variables such as geographical regions and seasonality are included to capture unobserved geographic and seasonal differences.

[26] The Chinese, who are economically well-off and live mainly in urban areas, are considered part of the ethnic majority together with the Kinh (or Viet) people.

The following functional form is employed to estimate the expenditure elasticity of calorie:

$$lnC_i = \beta_{1i} lnX_i + \beta_{2i}(lnX)^2 + \Sigma_j\, \theta_{ij}\, ln\, p_{ij} + \Sigma_k \gamma_{ik} Z_{ik} + \alpha_i + \epsilon_i \quad (5.2)$$

and the expenditure elasticity of food consumption:[27]

$$lnF_i = \beta_{1i} lnX_i + \beta_{2i}(lnX)^2 + \Sigma_j\, \theta_{ij}\, ln\, p_{ij} + \Sigma_k \gamma_{ik} Z_{ik} + \alpha_i + \epsilon_i \quad (5.3)$$

where $\underline{C_i}$ is per capita calorie consumption of household i; F_i is per capita food consumption; X_i is per capita expenditure (PCE)[28]; p_i is a vector of prices of food groups; Z_i is a vector of household characteristics; and ϵ_i is the error terms. Both lnX and $(lnX)^2$ are used to a capture possible non-linear relationship between expenditure and calorie consumption. Similar to Ravallion (1990a), average unit values of food groups within each of the cluster (commune in this paper) are used for the prices in p_i.

The vector Z_i includes household head's age, years of schooling of the household head; average years of schooling of adult women (> 15 years); household size; the proportions of household members who are infants (<3 years), children (3-15 years) and adults (>59 years); number of household members engaged in agriculture; and dummy variables for urban households, ethnic minorities, regions, and seasonality.

Two models are estimated. The first (OLS1) excludes commune fixed effects, while the second includes commune fixed effects to control for possible unobserved community influences on eating patterns. In the latter (OLS2), the price variables,

[27] Chapter 4 presented estimates of expenditure and price elasticities for different types of food. In contrast, equation (5.3) is used to estimate the expenditure elasticity of all food. More complicated methods than the double-log specification, such as AIDS or QUAIDS, could also be used to estimate the food expenditure elasticity, but they are not included in this chapter because it requires information on prices of non-food items that are either unavailable or unreliable. Moreover, the calorie-expenditure elasticity, not food expenditure elasticity, is the focus of this chapter.

[28] PCE includes the imputed rental value of housing and the use value of durable goods.

geographic variables and urban variable are omitted because these variables do not vary within communes. The regression results are presented in Table 5.5, with the coefficients of regions and seasonality omitted. The White Correction for robust standard errors is used to correct for heteroskedasiticity.

In both models, the log of PCE variable has a positive and significant effect on calorie consumption while the log of PCE squared variable has a negative and significant effect. The mean expenditure elasticity of calorie intake is estimated to be 0.25 in the model without communed fixed effects and 0.22 in the model with commune fixed effects. To my knowledge, only one previous study (Molini 2007) has estimated calorie elasticities for Vietnam. The income elasticities of calories are estimated by Mollini (2007) to be 0.36 in 1993 and 0.25 in 1998, the latter of which is similar to these estimates for 2006.

In the model without community fixed effects, the prices of other staples, pork, other meats, poultry, other foods and drink have negative and significant effects on calorie intake. The price of pork has the largest negative impacts on calorie demand, followed by the price of staples. On the other hand, the price of vegetables has a positive effect on calorie intake, possibly because households shift to more calorie-rich foods such as rice and other staples when the price of vegetables increases. The impact of rice prices on calorie intakes is positive. At first glance, this result seems puzzling because rice is the largest component of the diet for most Vietnamese households, providing about 60 percent of calories, and one might expect that an increase in the price of rice would lead to a decrease in total calorie intake. However, over 50 percent of the households in the 2006 VHLSS sample grew rice, and most of these farmers were net rice sellers. Thus, rice prices increases may have a positive “income-effect” among rural households, such that they increase their overall calorie consumption. This income effect may compensate the negative effect of the price of rice on calorie intake.

When separate regressions are estimated for urban and rural households, the impact of rice prices on the calorie intakes is positive and significant among rural households and negative and insignificant among urban households. To further investigate this aspect, I estimate separate regressions with dependent variables being logarithms of calories from 11 food categories. In rural areas, increases in the prices of rice lead to higher calorie consumption from pork, vegetables, and “other foods”, and have no significant impact on calorie consumption from all other food categories. In urban areas, increases in the prices of rice lead to lower calorie consumption from rice, higher calorie consumption from vegetables, other meats, and drinks and have no significant impacts on calorie consumption from other food categories.

In short, it appears that rice price increases lead to increases in the calorie consumption of rural households, while they have a negative but insignificant impact on calorie consumption of urban households. Since about 75 percent of households in our sample are from rural areas, the overall impact of an increase in the price of rice on household energy availability is positive.

Table 5.5: Regressions of Calorie Per Capita and Food Consumption Per Capita

	Calorie equation				Food expenditure equation			
	OLS1a		OLS2a		OLS1b		OLS2b	
	Coeff	t-stat	Coeff	t-stat	Coeff	t-stat	Coeff	t-stat
Log of PCE	0.91	10.08	1.02	8.56	1.54	14.75	1.72	14.27
Log of PCE squared	-0.04	-7.39	-0.05	-6.76	-0.05	-8.54	-0.07	-9.47
Prices of								
Rice (log)	0.03	2.41			0.07	5.89		
Staples (log)	-0.04	-6.81			0.00	0.75		
Pork (log)	-0.13	-7.77			0.10	5.76		
Other meats (log)	-0.03	-3.64			0.00	0.19		
Poultry (log)	-0.02	-3.6			-0.02	-2.76		
Fish (log)	-0.03	-3.94			0.04	5.31		
Vegetables (log)	0.00	0.65			-0.01	-1.12		
Fruit (log)	-0.02	-5.81			0.02	4.18		
Other foods (log)	-0.01	-2.65			0.01	2.80		
Drink (log)	-0.04	-7.05			-0.01	-2.55		
FAFH (log)	0.03	0.72			0.36	7.92		
Head's age (log)	0.02	1.31	0.04	2.5	-0.03	-2.00	-0.02	-1.33
Household size (log)	-0.10	-12.1	-0.11	-12.6	-0.11	-13.3	-0.14	-14.5
Head's schooling (log)	-0.01	-1.88	-0.01	-1.86	0.01	1.07	0.01	1.01
Women's schooling (log)	-0.04	-6.97	-0.01	-2.24	-0.03	-6.93	-0.01	-1.67
Female head	-0.03	-4.61	-0.02	-2.93	-0.02	-3.27	-0.02	-2.58
Urban	-0.04	-4.67			0.05	5.83		
Minority	0.09	9.45	0.06	3.05	0.06	6.38	0.00	0.27
Infant proportion	-0.34	-11.5	-0.38	-11.7	0.03	1.09	-0.02	-0.67
Children proportion	-0.05	-3.18	-0.07	-4.05	0.00	0.25	-0.01	-0.79
Elderly proportion	-0.10	-7.38	-0.13	-8.26	-0.02	-1.50	-0.04	-2.56
Female proportion	-0.03	-2.15	-0.05	-3.23	-0.06	-4.24	-0.08	-4.85
Farming members	0.10	13.16	0.08	7.36	0.01	4.77	0.01	4.68
Constant	3.84	9.76	2.54	4.96	-1.92	-4.33	-1.56	-3.06
R-square	0.30		0.65		0.77		0.89	

Note: Shading areas implies significant at 5 percent.

Household size has a significant negative effect on calorie intake per capita, indicating that larger households tend to consume lower calorie intake per capita than smaller households. This is observed in most calorie elasticity studies, such as in Mollini (2007) for Vietnam, Gibson and Rozelle (2002) for Papua New Guinea, and Abdulai and Aubert (2004a) for Tanzania. It is linked with the Deaton and Paxson's (1998) paradox that, in most countries, the per capita demand for food decreases with household size. Deaton and Paxson (1998) argued that since larger households enjoy shared household public goods, they should have higher per capita consumption of private goods such as food, provided that they do not substitute too much toward the cheaper public goods. Yet, most studies show that both food demand and calorie consumption per capita decline with household size. Deaton and Paxson (1998) offered several possible explanations including that larger household have more economies of scale in food preparation, are better at eliminating wastage, and have higher food price elasticity. However, they state that among these explanations, "none holds out the promise of resolving the puzzle." A thorough investigation of why household calorie per capita decreases with household size is beyond the scope of this chapter.

The female proportion, infant proportion and elderly proportion variables are significant and negative, indicating that households with higher percentages of females, infants and elderly people tend to consume lower calories per capita. This seems reasonable since holding all else constant, women typically require less energy than men, and children and elderly people need fewer calories than working-age adults.

Average women's schooling reduces calorie consumption. While the household head's schooling has a negative impact on calorie intake, the effect is insignificant, revealing that women's schooling may be more important than the head's schooling in making household nutrition decisions.[29] It is possible that better-educated households tend to substitute away from basic calorie-rich foods (such as rice and other staples) to other characteristics such as quality and taste. Another reason could be that better-educated households are less likely to work in physically demanding manual jobs, and therefore their energy requirements for everyday work are lower than those of less-educated households.

The coefficient on the urban variable is negative and significant, implying that households in rural areas consume more calories than those in the urban areas. There are at least three reasons for this. First, households in rural areas tend to consume a higher percentage of rice and other staple foods, which are rich in calories. In contrast, households in urban areas usually consume more diversified diets, with higher percentages of fruits, meats, fish and drink. Second, although household incomes in urban areas are higher than in rural areas, the prices of food, and thus the prices of calories, in rural areas are much lower than in urban areas. The average per capita expenditure of households in urban areas is about 1.8 times that of households in rural areas but the price of calories in urban areas is about double the price in rural areas. Lower prices per calorie in rural areas appear to have a positive effect on calorie consumption in those areas. Third, the urban population is less likely to work in physically demanding jobs than the rural population. The coefficient of farming variable is significant and positive, implying farming households tend to have higher calorie consumption than comparable non-farm households. One possible reason is that farming activities often require more calories

[29] About 25 percent of households have women as household heads.

than non-farm activities. Ethnic minority households tend to have higher calorie consumption than ethnic majority households. Perhaps it is because ethnic minority households tend to rely more on the traditional diets, which have a higher percentages of calorie-efficient foods such as rice and other staple foods.

Comparing the model with and without commune fixed effects; the addition of those commune fixed effects increases the R-square significantly, from 0.31 to 0.65. However, the calorie elasticities in both models are very similar, implying the results are robust to unobservable community variables.

Turning to the food expenditure regressions, several remarks are in order. First, the impacts of factors such as household size, women's schooling, female head, ethnic minority, female proportion and farming have the same signs as in the calorie equation. Larger households, more educated women, households with a higher proportion of females, female-headed households, and ethnic majority households have lower food expenditure per capita than otherwise comparable households. On the other hand, farming households have higher food expenditure per capita than non-farming households.

Second, higher prices for pork, fish, fruit, other foods and FAFH lead to an increase in total food expenditure per capita. On the other hand, increases in the prices of poultry and drink lead to a decrease in total food expenditure per capita. This suggests that household food consumption patterns vary by different food categories. For most foods, the reduction in quantity does not compensate for the rise in prices, resulting in an increase in food expenditure per capita. For poultry and drink, however, households decrease their consumed quantity substantially, therefore their food expenditures per capita decline.

Third, some other significant factors should be noted. Other things equal, urban households have higher food expenditure than rural households but lower calorie consumption. This is as expected since food prices are much higher but energy requirements are generally lower in urban areas than in rural areas. While the household head's age has a positive impact on calorie consumption, it has a negative impact on food expenditure. Accordingly, households with younger household heads tend to spend more on food but consume fewer calories than household with older heads. It is possible because young people appreciate food characteristics other than calorie content, such as taste, quality, and vitamin etc., more than older individuals.

The OLS results for calorie consumption assume zero correlation between per capita expenditure and the error terms. But this assumption may not hold, for several reasons. First, household income and therefore, expenditure could be constrained by nutrition, as efficiency wage theories suggest, resulting in a biased estimate of per capita expenditure in OLS due to endogeneity. Second, the OLS regressions may suffer from measurement error bias. Calorie consumption is calculated from household food consumption; therefore any measurement error in household food consumption is transmitted into both calorie consumption and household expenditure data, leading to correlated measurement errors. Bouis and Haddard (1992) examined the issue and argued that the upward bias from correlated errors will generally outweigh the downward attenuation bias from the measurement error in expenditure data, resulting in a net upward bias. Subramanian and Deaton (1996) used non-food expenditure as an instrument and argued that the estimates from instrumental variable (IV) and OLS provide the lower bounds and the upper bounds of the true estimates.

In this study, three sets of instruments for PCE are used to overcome the possible problem of endogeneity and correlated measurement errors. The first specification (IV1) uses the logarithm of per capita non-food expenditure and its square. Non-food expenditure is a valid instrument if the measurement errors of non-food expenditure are assumed to be uncorrelated with measurement errors in food expenditure. It has been used by Subramanian and Deaton (1996), and by Gibson and Rozelle (2002), among others. The second set of instruments (IV2) is the logarithm of household per capita income and its square. Income is a valid instrument if calorie consumption does not affect household income. The data indicate that income should not, in general, be a constraint of calorie intake. It takes only 3 percent of household per capita income per day to buy 2,000 calories from rice per day for an average household. Even for an average household among the lowest-expenditure quintiles, it only takes about 6 percent of the household's per capita income per day to buy 2,000 calories from rice. Therefore, per capita income could be a valid instrument. The third set (IV3) includes the logarithm of wealth (estimated as the total value of fixed assets and durable goods) and its square. Measurement errors in non-food expense, income and wealth should be uncorrelated with measurement errors in food expenditure because these types of data were collected in different parts of the questionnaire.

Table 5.6: IV Regressions of Calorie Consumption Per Capita

	IV1		IV2		IV3	
	Coef.	**z**	**Coef.**	**z**	**Coef.**	**z**
Log of PCE	0.97	8.41	1.22	8.39	1.90	5.12
Log of PCE squared	-0.04	-6.45	-0.06	-6.62	-0.10	-4.59
Price of						
Rice (log)	0.03	2.21	0.02	1.92	0.03	2.56
Staples (log)	-0.04	-7.50	-0.05	-7.58	-0.04	-7.14
Pork (log)	-0.13	-7.65	-0.14	-8.21	-0.12	-6.68
Other meats (log)	-0.03	-3.28	-0.03	-3.32	-0.02	-2.55
Poultry (log)	-0.02	-3.69	-0.02	-3.48	-0.02	-3.68
Fish (log)	-0.03	-4.17	-0.03	-4.58	-0.02	-2.67
Vegetables (log)	0.01	0.85	0.01	0.88	0.00	0.6
Fruit (log)	-0.02	-5.40	-0.02	-5.48	-0.02	-4.12
Other foods (log)	-0.01	-2.91	-0.02	-3.31	-0.01	-1.85
Drink (log)	-0.04	-6.84	-0.04	-7.23	-0.03	-6.29
FAFH (log)	0.04	0.88	0.02	0.44	0.11	2.22
Head's age (log)	0.01	0.39	0.00	0.14	0.01	0.58
Household size (log)	-0.14	-16.99	-0.13	-16.38	-0.14	-17.2
Head's schooling (log)	-0.03	-4.08	-0.03	-4.03	-0.03	-4.38
Women's schooling (log)	-0.01	-1.33	-0.01	-2.15	0.00	-0.68
Female head	-0.03	-6.06	-0.04	-7.05	-0.03	-5.12
Urban	-0.03	-4.41	-0.04	-4.56	-0.02	-2.92
Minority	0.07	7.39	0.08	8.24	0.08	6.98
Infant proportion	-0.30	-9.95	-0.27	-8.81	-0.32	-9.75
Children proportion	-0.01	-0.69	0.01	0.40	-0.03	-1.5
Elderly proportion	-0.10	-6.98	-0.09	-6.55	-0.10	-7.03
Female proportion	-0.04	-2.75	-0.03	-2.49	-0.04	-2.78
Farming members	0.04	17.50	0.04	18.12	0.04	16.4
Constant	3.67	7.28	2.58	4.07	-0.28	-0.18
R-square	0.31		0.31		0.29	
Durbin-Wu-Hausman test	7.44		9.37		31.90	

The results from using IV regressions are presented in Table 5.6. The Durbin-Wu-Hausman test statistics imply that the OLS estimates may suffer from endogeneity bias. The signs and statistical significance of most variables are similar to the OLS estimates, except that children proportion variable has no impact on calorie consumption in the IV regressions.

Table 5.7 reports the expenditure elasticity of calories based on the OLS and IV results. The mean expenditure elasticity of calories is smaller for urban households and higher-income households than rural and lower-income households. The results from the model with commune fixed effects are slightly smaller than the model without these effects. The mean elasticity of calories is quite high for households in the bottom-income quintile, indicating that raising incomes of the poor may significantly reduce their nutritional deprivation.

Table 5.7 also shows that the mean expenditure elasticity of calories is much smaller than the mean expenditure elasticity of food (0.63 for OLS1 and 0.58 for OLS2). The difference reflects the shift from calorie-inexpensive foods such as rice and other cereals to more calorie-expensive foods. Thus, when income increases, households both increase calorie consumption and switch to higher quality, more calorie-expensive foods.

Table 5.7: Expenditure Elasticities of Calorie and Food Demand

	Calorie elasticity					Food expenditure elasticity	
	OLS 1	OLS 2	IV1	IV2	IV3	OLS 1	OLS 2
All	0.24	0.22	0.24	0.27	0.23	0.63	0.58
Rural	0.25	0.24	0.25	0.28	0.26	0.65	0.60
Urban	0.20	0.17	0.19	0.21	0.14	0.58	0.51
Red River Delta	0.23	0.21	0.23	0.26	0.21	0.62	0.56
North East	0.25	0.23	0.25	0.28	0.26	0.65	0.60
North West	0.28	0.27	0.28	0.33	0.33	0.69	0.65
North Central Coast	0.26	0.24	0.25	0.29	0.27	0.65	0.60
South Central Coast	0.24	0.22	0.23	0.26	0.22	0.63	0.57
Central Highlands	0.25	0.23	0.25	0.28	0.25	0.64	0.59
South East	0.22	0.19	0.21	0.23	0.16	0.59	0.53
Mekong River Delta	0.24	0.21	0.23	0.26	0.22	0.62	0.57
Quintile 1	0.31	0.30	0.31	0.36	0.39	0.72	0.69
Quintile 2	0.27	0.25	0.27	0.31	0.30	0.67	0.62
Quintile 3	0.24	0.22	0.24	0.27	0.24	0.63	0.58
Quintile 4	0.22	0.19	0.21	0.23	0.17	0.6	0.53
Quintile 5	0.17	0.13	0.16	0.16	0.05	0.53	0.45
Non-poor	0.23	0.20	0.23	0.25	0.21	0.61	0.55
Poor	0.31	0.31	0.29	0.33	0.34	0.73	0.70
Ethnic majority	0.23	0.21	0.21	0.29	0.21	0.62	0.56
Ethnic minorities	0.29	0.27	0.24	0.43	0.34	0.69	0.65
Non-farmer	0.21	0.18	0.20	0.22	0.15	0.59	0.52
Farmer	0.25	0.23	0.25	0.28	0.26	0.65	0.60
Male-headed	0.25	0.22	0.24	0.27	0.24	0.63	0.58
Women-headed	0.23	0.21	0.22	0.25	0.20	0.62	0.56

Table 5.8: Regressions of Calorie Price

	Without fixed effect		With fixed effect	
	Coef.	t	Coef.	t
Log of PCE	0.61	5.36	0.68	4.61
Log of PCE squared	-0.01	-1.99	-0.02	-2.21
Price of				
Rice (log)	0.05	4.02		
Staples (log)	0.05	7.97		
Pork (log)	0.23	13.21		
Other meats (log)	0.03	3.56		
Poultry (log)	0.00	0.8		
Fish (log)	0.07	8.85		
Vegetables (log)	-0.01	-1.63		
Fruit (log)	0.04	9.17		
Other foods (log)	0.03	5.47		
Drink (log)	0.02	4.34		
FAFH (log)	0.31	7.35		
Head's age (log)	-0.04	-3.12	-0.05	-3.51
Household size (log)	-0.01	-0.79	-0.01	-1.59
Head's schooling (log)	0.00	0.65	0.00	0.07
Women's schooling (log)	0.01	2.92	0.02	3.01
Female head	0.00	0.46	0.00	0.71
Urban	0.07	9.13		
Minority	-0.02	-2.60	-0.05	-3.20
Infant proportion	0.36	12.36	0.34	10.83
Children proportion	0.04	2.49	0.04	2.40
Elderly proportion	0.07	5.28	0.08	5.48
Female proportion	-0.03	-2.17	-0.03	-1.75
Farming members	-0.11	-14.44	-0.05	-5.23
Constant	-4.65	-9.40	-3.04	-4.88
R-square	0.73		0.86	
Calorie price elasticity	0.40			0.35

Table 5.8 presents the results from calorie price regressions. The set of explanatory variables are the same as in Tables 5.5 and 5.6. In this instance, the dependent variable is the logarithm of the price of calories, which is calculated by dividing total food expenditure by total calorie consumption. Table 5.8 shows that the mean calorie price elasticity is 0.40 in OLS1 and 0.35 in OLS2. Thus, richer households both have higher per capita calorie consumption and pay more for a given amount of calories than poorer households. A 10 percent increase in expenditure leads to an approximately a 6 percent increase in food expenditure, 2.0-2.5 percent increase in calorie consumption and 3.5-4.0 percent increase in price per calorie.

The positive elasticity of the price of calorie implies that households switch to more calorie-expensive foods as their expenditure increases. There are two possible kinds of substitution. First, there is between-group substitution, as households shift from such calorie-inexpensive food groups such as rice and other staples to calorie-expensive food groups such as pork and fish. Second, within-group substitution reflects the shift among food items within a food group. For example, as household expenditure increases, a household may buy less ordinary rice and more glutinous rice (which is more calorie-expensive).

Estimating separately with the calorie prices of the food groups (not reported here), the calorie price elasticities are found to be high for such calorie-expensive foods as fish (0.17), fruits (0.28), other foods (0.29), and drink (0.13). In contrast, they are low among the lower-cost sources of calories: rice (0.07), other staples (0.07), pork (0.04), other meat (0.06), poultry (0.02), and vegetables (0.01)[30]. It means that as expenditure

[30] Recall that the calorie price of FAFH is assumed to be the average calorie price of all other foods.

increases, households are likely to pay more per calorie from less commonly consumed foods such as fruits, fish and drink than from rice, other staples, or pork.

5.3.2. Nonparametric Estimation

The relationship between calories and income may be characterized by non-linear because, as incomes increase, severe undernourished individuals may respond more strongly than those who are better-nourished. To allow for that possibility, this subsection uses nonparametric procedures to estimate the calorie-income relationship.

Figure 5.1 presents an unconditional kernel (non-parametric) regression of the logarithm of per capita calories on the logarithm of per capita expenditure. The figure shows increasing per capita calorie consumption with household per capita expenditure. The curve for rural households is higher than the curve for urban households, reflecting higher calorie consumption for rural households at similar levels of expenditure. This is not surprising because work in rural areas, particularly farm work, generally requires more energy than work in urban areas. The slopes of the curves indicate the expenditure elasticities of calorie consumption. The figure shows that calorie consumption rises steeply as expenditure increases at low level of expenditure and then flattens at higher expenditure levels. This implies a higher expenditure elasticity of calorie consumption for poorer households. The differences in slope are sharper in rural areas than in urban areas.

This non-parametric function is an estimate of the following equation:

$$y_i \quad = q(X_i) + \varepsilon_i \text{ with } E(\varepsilon_i | X_i) = 0 \qquad (5.4)$$

in which x_i, y_i are the per capita expenditure and the per capita calorie consumption, respectively, of household *i.* The functional form $q(x_i)$ is unknown and is estimated by kernel regression.

Figure 5.1: Kernel Regression of Calories on Expenditure (Bandwidth= 0.4)

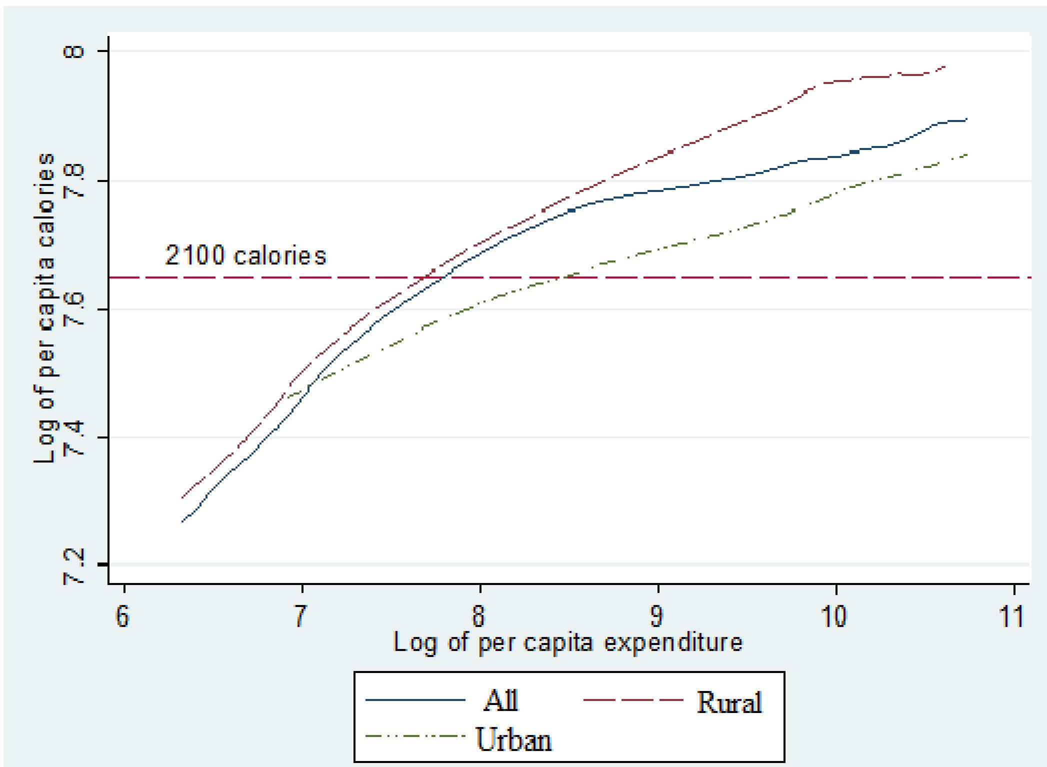


Figure 5.2 presents the non-parametric estimation of calorie elasticity, derived from the estimation in (5.4). Figure 5.2 indicates that for non-parametric procedure, the expenditure elasticity of calorie is lower as expenditure increases. The mean calorie elasticity is estimated at 0.20. For the poorest quintile households, the calorie elasticities are in the range 0.15-0.3. The calorie elasticities fall rapidly across expenditure levels. For the richest quintile, the calorie elasticities are estimated to be in the range of 0 to 0.05 for both non-parametric. Compared with the parametric estimates of calorie elasticities in Table 5.7, the non-parametric estimates are lower than the parametric estimates.

Figure 5.3 presents a nonparametric estimate of average calorie prices as a function of ln(PCE). It indicates that the prices of calories increase as expenditure increases in both rural and urban areas. The figure implies that as their incomes increases, households shift to foods that are relatively expensive sources of calories; pay more for other characterisitics of foods, such as taste, quality, micronutrient, and convenience. The calorie prices are higher in urban areas than in rural areas at similar level of expenditure, which are clearly reasonable since food prices, and thus calorie prices, are higher in urban areas.

Figure 5.2: Nonparametric Estimates of Calorie Elasticity (bandwidth= 0.2)

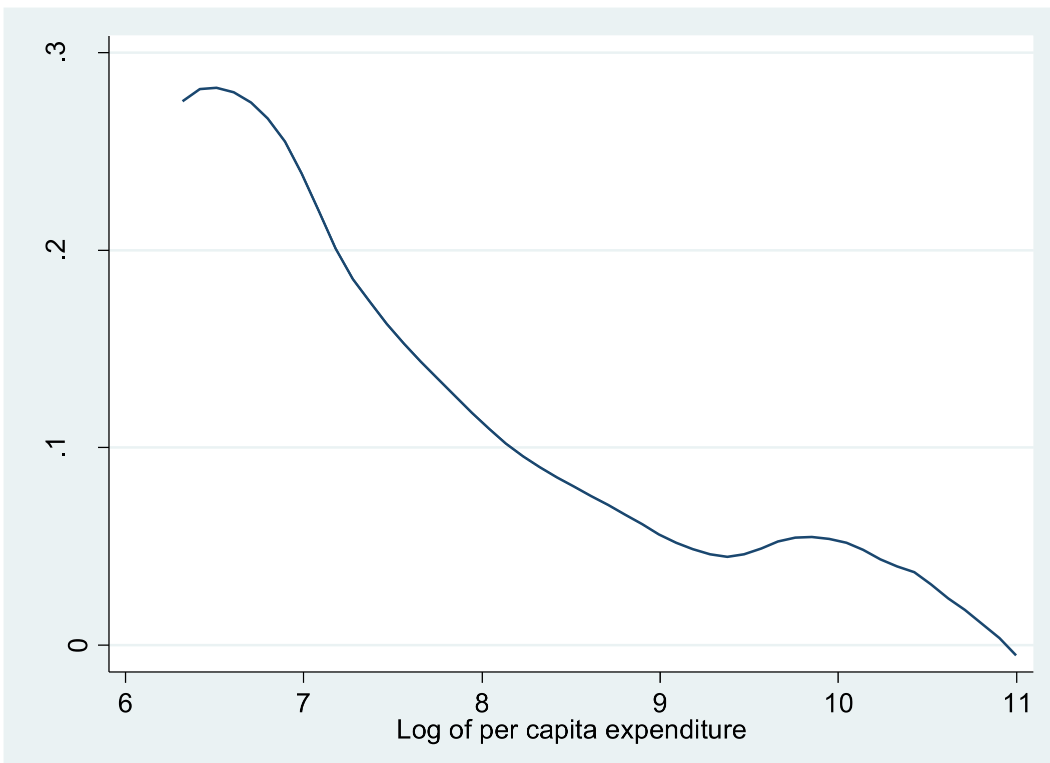
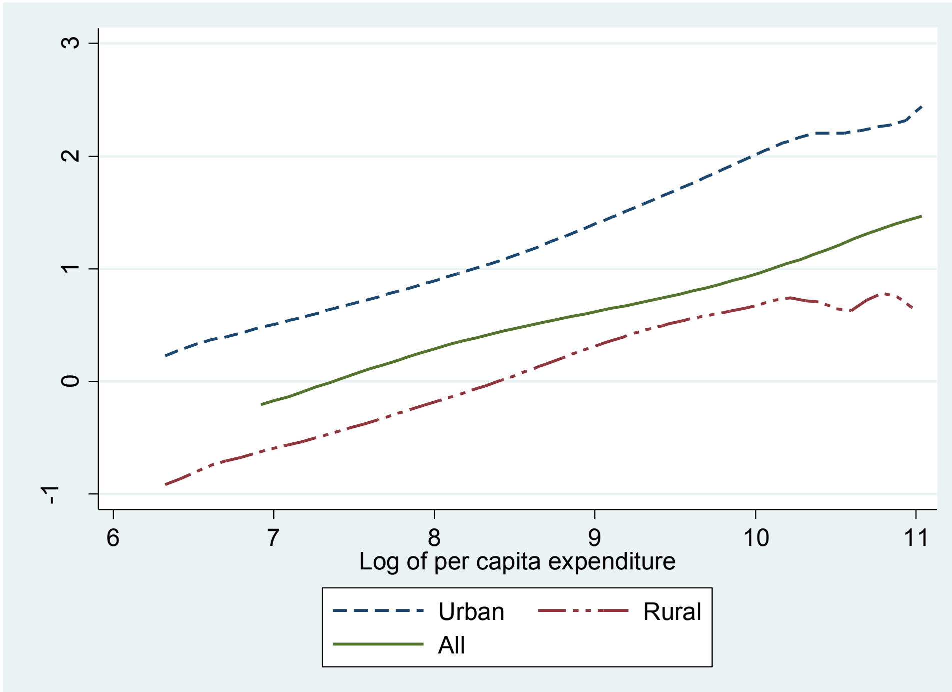


Figure 5.3: Nonparametric Estimate of Average Calorie Price (bandwidth= 0.4)



5.4. Simulating the Effects of Income and Price Changes

From the definitions of elasticity, one has the following equations

$$\Delta C^{y} = C^{0}\frac{\varepsilon_{I}\Delta Y}{Y^{0}} \tag{5.7}$$

$$\Delta C^{p} = C^{0}\frac{\varepsilon_{pi}\Delta P_{i}}{P_{i}^{0}} \tag{5.8}$$

where ΔC^{y} is the change in calorie consumption due to real income (expenditure) change; ΔC^{p} is the change in calorie consumption due to food price change.

From (5.7) and (5.8), one obtains the following equation, which is used to estimate the expected changes of calorie consumption from changes in both real incomes and commodity prices.

$$\Delta C = C^{1} - C^{0} = C^{0}\frac{\varepsilon_{I}\Delta Y}{Y^{0}} + C^{0}\frac{\varepsilon_{pi}\Delta P_{i}}{P_{i}^{0}} \tag{5.9}$$

where

$C^0,\ C^1$: Calorie consumption at time 0 and at time 1, respectively.

ΔY: Change in per capita expenditure from time 0 to time 1.

ΔP_i: change in price of commodity i from time 0 to time 1.

Y^0, P_i^0: level of per capita expenditure and price of commodity i at time 0, respectively.

ε_I: Income elasticity of calorie consumption

ε_{pi}: Price elasticity of calorie consumption with respects to commodity i.

Table 5.9 presents the results from six scenarios, using the results from the normal OLS (without commune fixed effects) regressions, run separately for urban and rural areas[31]. The 2100 calories/day criterion is used as the calorie norm for determining undernutrition. The six scenarios are (1) income increases by 10 percent; (2) income increases by 50 percent; (3) prices of all food commodities increase by 10 percent; (4) prices of all food commodities increase by 50 percent; (5) price of rice increases by 10 percent and (6) price of rice increases by 50 percent. The assumption of a 50 percent increase in expenditure and food prices is fairly realistic. From 2003 to 2007, overall food prices and staple food (mostly rice) prices increased at the average rate of 10.9 percent and 11.5 percent annually, respectively. In 2008, there was a surge in the prices of food, in particular the price of rice. From January to September, 2008, food price in Vietnam increased by 33 percent and food staples prices by 54 percent. With regards to income,

[31] Since there is few differences between the OLS and the IV estimates, I chose to use the OLS estimates in this subsection.

GDP per capita in Vietnam increased by 64 percent during the period from 2002 to 2006 according to the World Bank's World Development Indicators.

A number of points are worth considering when examining Table 5.9. First, a 10 percent increase in real expenditure will reduce the headcount undernutrition index by about 3.3 percentage points (a 9 percent reduction), while a 50 percent increase will reduce the headcount undernutrition index by nearly 17 percentage points, from 38 percent to 21 percent (a 44 percent reduction). Expenditure increases lead to more pronounced undernutrition in rural areas than in urban areas, and in the poorest quintile compared with the richest quintile. For example, a 50 percent increase in expenditure leads to a 48 percent reduction in headcount undernutrition in rural areas, and a 34 percent reduction in urban areas; a 47 percent reduction among the poorest quintile, but only a 30 percent reduction among the richest quintile.

Second, when holding expenditure constant, food price increases lead to substantially higher levels of undernutrition. For example, a 10 percent increase in all food prices results in an 11 percent increase in the undernutrition headcount index (from 38 percent 42 percent); while a 50 percent price increase raises the undernutrition headcount index by 56 percent (from 38 percent to 60 percent). Urban households and better-off households are more sensitive to increases in food prices. A 50 percent food price increase could raise the undernutrition index by 44 percent in rural areas, and by 87 percent in urban areas, by 28 percent among the poorest quintile, and by 100 percent among the richest quintile.

Table 5.9: Impacts of Changes in Income and Prices on Undernutrition

	Headcount index	Nutrition gap		Headcount index	Nutrition gap
Original					
All	38.1	6.2			
Rural	36.0	5.7			
Urban	44.6	8.0			
Lowest quintile	60.6	11.0			
Highest quintile	28.6	4.9			
Income increase by 10%			***Income increase by 50%***		
All	34.8	5.4	All	21.4	3.0
Rural	32.4	4.8	Rural	18.7	2.5
Urban	41.9	7.1	Urban	29.5	4.6
Lowest quintile	55.6	9.4	Lowest quintile	32.0	4.7
Highest quintile	27.2	4.4	Highest quintile	19.9	3.0
Food price increase by 10%			***Food price increase by 50%***		
All	42.3	7.2	All	59.6	12.7
Rural	38.8	6.3	Rural	51.7	9.2
Urban	53.0	10.0	Urban	83.4	22.9
Lowest quintile	63.7	12.1	Lowest quintile	77.3	17.3
Highest quintile	33.1	6.0	Highest quintile	57.4	13.5
Rice price increase by 10%			***Rice price increase by 50%***		
All	37.9	6.2	All	37.5	6.1
Rural	35.5	5.6	Rural	33.6	5.2
Urban	45.2	8.2	Urban	48.9	9.0
Lowest quintile	60.1	10.9	Lowest quintile	58.0	10.4
Highest quintile	29.0	4.9	Highest quintile	30.3	5.3
Pork price increase by 10%			***Pork price increase by 50%***		
All	40.0	6.7	All	48.4	8.5
Rural	38.0	6.1	Rural	46.6	8.0
Urban	46.2	8.4	Urban	53.6	10.2
Lowest quintile	62.6	11.7	Lowest quintile	72.2	14.6
Highest quintile	29.7	5.1	Highest quintile	35.4	6.4

Third, the impact of rice prices is more ambiguous than the impact of overall food prices. While an increase in all food prices harms both rural and urban areas, an increase in rice prices improves nutrition in rural areas while reducing nutrition in urban areas. A 10 percent rice price increase has almost no effect on the undernutrition index. Even a 50 percent rice price hike brings about a change of less than 2 percent of undernutrition index. However, the impact differs between urban and rural areas. A 50 percent rice price surge causes a reduction of undernutrition in rural areas by 7 percent, while raising it in urban areas by 10 percent. The impact of a 50 percent rice price increase is slightly beneficial to the lowest expenditure quintile (a reduction of 4 percent in undernutrition for a 50 percent price surge). Yet, even the richest quintile suffers an increase in its undernutrition rate of only 6 percent when the price of rice increases by 50 percent.

The reason for this minor impact of rice price changes on household nutrition is because the calorie elasticity with respect to the price of rice is small (-0.06 in urban areas and 0.03 in rural areas). Rice is the major traditional diet, consumed in almost every meal in Vietnam and providing about 60 percent of calorie consumption. Thus, dietary habits make rice demand rather inelastic, compared to some other foods. For example, the calorie elasticity with respect to pork price is -0.11 in urban areas, and -0.13 in rural areas. A 50 percent increase in the price of pork causes a 27 percent increase in undernutrition rate, 29 percent in rural areas and 20 percent in urban areas, 19 percent among the poorest quintile and 24 percent among the richest quintile.

The above analysis suggests that nutrition intakes of households in rural areas are more responsive to changes in expenditure than are households in urban areas. Likewise, the impacts of income changes are more significant for lower-income households than for higher-income households. On the other hand, urban and richer households are more responsive in lowering their calorie consumption when food prices increase than are rural and poorer households, respectively. These simulations show that both the magnitude and the distribution of income growth are important in reducing undernutrition in Vietnam. Pro-poor growth strategy would contribute significantly to reducing malnutrition since poor people are more responsive to increasing their calorie consumption as their income increases. At the same time, household calorie consumption is highly responsive to food price changes. In fact, an equal magnitude increase in both real expenditures and food prices results in a net negative effect on household nutrition. A 10-percent increase in both real expenditure and food prices raises the undernutrition rate by about 2 percent, while a 50 percent increase raises it by about 12 percent. Therefore, policies aimed at curbing food price inflation, particularly in the prices of pork, will help to improve household nutrition status.

5.5. Expenditure Elasticities of Protein and Micronutrients

The finding that households tend to consume calorie-expensive foods when their income increases, suggests that they increasingly prefer some other characteristics of food as their income rise. One possibility is an increasing preference for protein and micronutrients. To investigate this possibility, this section estimates expenditure elasticities of protein and micronutrients, which together with the above analysis of calorie demand gives a more complete picture of the relationship between household income and nutrition.

Although there have been many studies on the income/expenditure elasticity for calories, there are few studies of protein and/or micronutrient income/expenditure elasticities. Available studies show a wide range of estimates of micronutrient elasticities. For example, Pitt and Rosenzweig (1985) reported very low nutrient income elasticities, all below 0.03 for a wide variety of nutrients (calories, protein, fat, carbohydrates, calcium, phosphorus, iron, vitamin A and vitamin C) for Indonesian farm households. In contrast, Bouis and Novenario-Reese (1997)'s study on Bangladesh estimated an elasticity of 0.8 for vitamin C, and of 0.27 for iron. To the author's knowledge, there have been no estimates of micronutrient expenditure elasticities for Vietnam.

Micronutrient deficiency is serious problem in Vietnam. For example, Khan (2006) estimated that about 15 percent of under five-year-old children suffered from Vitamin A deficiency. Nhien et al (2008) estimated that nearly 80 percent of under six-year-old children in their sample had deficiency in two or more micronutrients. Hop (2003) stated that approximately 53 percent pregnant women, 40 percent of non-pregnant women, and 45 percent of under five-year-old children suffered from iron-deficiency anemia in 1995.

This study estimates household consumption of protein and micronutrients, based on the food quantity consumption data in the 2006 VHLSS. Food quantity is converted to protein and micronutrient intakes using the conversion tables developed by the National Institute of Nutrition [NIN] (1995). The total intakes of protein and micronutrients are adjusted for food without quantity data, assuming that the prices paid for each unit of protein or micronutrient are the same for food items without quantity information as they are for the food items in the same group with quantity information.

Table 5.10 summarizes per capita intakes of protein and micronutrients. The rural population consumes less protein and less micronutrient than do urban households. There is a clear trend showing that consumption of protein and micronutrients increases when household per capita expenditure rises. A person in quintile 5 consumes more than a person in quintile 1 about 72 percent more of protein, 78 percent more of calcium, 61 percent more of iron, 240 percent more of Vitamin A, 110 percent more of vitamin B1, 130 percent more of vitamin B2, 58 percent more of Vitamin B3, and 154 percent more of Vitamin C.

Table 5.10 also reports the prevalence of malnutrition in Vietnam, in terms of the percentage of the population with less than the biologically required nutrient intake. The required nutrient intake is calculated based on the Vietnam's nutrient requirements as reported in NIN (1995). The table in NIN (1995) determines nutrient requirements based on age, sex and whether the work performed is light, moderate or heavy. Using this information, I calculate the nutrient requirements per capita based on the age and sex composition in the survey, assuming moderate work load. Table 5.10 indicates that malnutrition in Vietnam is severe, as over 70 percent of Vietnamese population consumes less than the required amounts of most micronutrients.

Table 5.10: Per Capita Daily Protein and Micronutrient Consumption

	Protein (g)	**Mineral**		**Vitamin**				
		Calcium (mg)	Iron (mg)	A (mcg)	B1 (mg)	B2 (mg)	B3 (mg)	C (mg)
Total	80.4	395.4	12.8	298.3	1.45	0.71	14.7	45.3
Rural	78.4	382.5	12.5	266.3	1.37	0.66	14.5	41.1
Urban	86.3	434	13.6	393.9	1.68	0.83	15.2	57.7
Red River Delta	81	416.2	13.6	292.1	1.59	0.73	15.1	60.4
North East	78.4	358.1	12.9	238.5	1.52	0.65	15.3	46.5
North West	65	293.4	10.9	147.3	1.17	0.5	13.5	41.1
North Central Coast	71.1	353.4	11.4	225.8	1.21	0.59	13.3	34
South Central Coast	76.6	378.5	12	287	1.27	0.67	13.8	36.5
Central Highlands	73.6	356.1	11.8	219.2	1.28	0.63	13.7	35.8
South East	87.1	448.1	13.5	408.9	1.68	0.84	14.9	51
Mekong River Delta	89.3	433	13.3	380.8	1.42	0.79	15.3	39
Quintile 1	58.7	285.8	9.8	138.1	0.96	0.44	11.3	27.8
Quintile 2	71.6	349.9	11.5	221.5	1.19	0.58	13.3	35.2
Quintile 3	80.7	392.2	12.8	285.8	1.41	0.68	14.7	41.4
Quintile 4	89.4	435.9	14	370.5	1.65	0.81	16.0	50.7
Quintile 5	100.7	509.6	15.8	470.1	2.02	1.01	17.9	70.6
Required amount	54.1	534.9	15.3	528.5	1.04	1.48	16.4	68.8
% of malnourished*	14.8	87.0	79.8	88.0	31.1	97.8	73.0	83.2

** defined as percentage of population who has less than the required nutrient intake.*

Table 5.11: Regressions of Protein and Micronutrient Intake

	Protein		Calcium		Iron		Vitamin A	
	Coef.	t	Coef.	t	Coef.	t	Coef.	t
Log of PCE	1.30	13.8	0.97	9.1	0.99	10.4	4.90	16.6
Log of PCE squared	-0.06	-9.9	-0.04	-6.0	-0.04	-6.9	-0.24	-14.2
Price of								
Rice	0.03	2.0	0.02	1.1	0.03	2.4	-0.01	-0.2
Staples	-0.03	-4.8	-0.02	-2.6	-0.03	-5.2	0.00	0.1
Pork	-0.12	-6.4	-0.12	-5.5	-0.12	-6.6	0.13	2.7
Other meats	-0.04	-4.4	-0.07	-6.4	-0.05	-5.1	-0.10	-3.8
Poultry	-0.02	-4.0	-0.03	-3.5	-0.03	-4.9	-0.01	-0.7
Fish	-0.07	-9.5	-0.03	-3.5	-0.04	-5.0	-0.20	-8.3
Vegetables	0.00	-0.5	-0.01	-1.0	0.00	0.5	0.00	-0.1
Fruit	0.00	-0.5	0.00	-0.7	0.00	0.7	0.02	1.8
Other foods	-0.03	-4.8	-0.01	-2.1	-0.02	-4.5	-0.06	-4.3
Drink	-0.02	-3.9	-0.02	-2.3	-0.01	-2.5	-0.01	-0.4
FAFH	0.10	2.1	0.13	2.4	0.06	1.2	0.06	0.5
Head's age	-0.02	-1.9	-0.02	-1.1	-0.02	-1.6	0.03	0.9
Household size	-0.13	-14.2	-0.20	-18.4	-0.14	-15.3	-0.19	-7.8
Head's schooling	-0.01	-2.4	0.00	-0.6	-0.01	-1.8	0.02	1.2
Women's schooling	-0.04	-7.5	-0.04	-5.8	-0.04	-7.9	-0.07	-4.7
Female head	-0.02	-2.2	-0.01	-0.8	-0.01	-1.5	-0.01	-0.7
Urban	0.01	1.0	0.01	0.7	0.00	0.1	0.12	5.8
Minority	0.05	6.0	0.00	0.0	0.06	6.2	-0.05	-1.8
Infant proportion	-0.26	-8.1	-0.11	-2.8	-0.28	-8.4	0.35	4.2
Children proportion	-0.05	-2.8	-0.04	-1.9	-0.06	-3.4	0.12	2.8
Elderly proportion	-0.10	-7.1	-0.11	-6.3	-0.12	-8.2	-0.03	-0.7
Female proportion	-0.05	-3.2	-0.05	-2.7	-0.05	-3.0	-0.06	-1.5
Farming members	0.03	11.7	0.03	9.2	0.03	11.8	0.00	0.6
Constant	-1.53	-3.7	1.64	3.6	-1.85	-4.5	-18.15	-14.0
Number of obs	8683		8683		8683		8682	
R-square	0.45		0.38		0.39		0.44	

Table 5.11 (continued)

	Vitamin B1		Vitamin B2		Vitamin B3		Vitamin C	
	Coef.	t	Coef.	t	Coef.	t	Coef.	t
Log of PCE	1.45	12.3	1.47	12.3	1.02	11.0	2.63	7.4
Log of PCE squared	-0.06	-8.4	-0.06	-8.2	-0.04	-7.2	-0.12	-5.7
Price of								
Rice (log)	0.07	4.1	0.04	2.4	0.03	2.2	0.09	2.2
Staples (log)	-0.01	-0.9	-0.01	-1.5	-0.03	-4.9	0.02	0.7
Pork (log)	-0.18	-7.9	-0.14	-5.8	-0.13	-7.0	-0.16	-2.7
Other meats (log)	-0.03	-2.9	-0.07	-6.7	-0.06	-6.6	-0.11	-4.1
Poultry (log)	-0.04	-6.1	-0.03	-4.8	-0.03	-4.9	-0.09	-4.8
Fish (log)	0.01	0.6	-0.03	-2.5	-0.05	-7.2	-0.04	-1.5
Vegetables (log)	0.01	1.3	0.00	-0.5	0.02	2.6	-0.03	-1.1
Fruit (log)	0.01	1.2	0.00	-0.5	0.00	-0.4	0.05	3.9
Other foods (log)	-0.02	-2.6	-0.01	-1.1	-0.02	-4.3	0.02	1.1
Drink (log)	-0.02	-2.1	-0.02	-3.0	-0.02	-4.2	0.05	2.4
FAFH (log)	-0.16	-2.8	0.05	0.9	0.06	1.4	-0.01	-0.1
Head's age	0.00	-0.3	-0.03	-1.7	-0.03	-2.0	0.02	0.5
Household size	-0.16	-14.5	-0.20	-18.0	-0.11	-12.8	-0.22	-8.3
Head's schooling	0.00	0.1	0.00	0.3	-0.01	-2.0	0.03	1.9
Women's schooling	-0.04	-6.3	-0.05	-7.6	-0.04	-7.3	-0.02	-1.1
Female head	-0.01	-1.1	-0.01	-1.1	-0.02	-3.3	0.02	1.0
Urban	0.03	3.2	0.03	3.0	-0.01	-1.5	0.12	4.9
Minority	0.07	5.9	0.02	1.7	0.08	8.4	-0.02	-0.5
Infant proportion	-0.11	-2.7	0.01	0.3	-0.33	-10.4	0.04	0.4
Children proportion	-0.03	-1.4	-0.01	-0.6	-0.06	-3.8	0.04	0.7
Elderly proportion	-0.08	-4.4	-0.08	-4.4	-0.11	-7.7	-0.13	-3.0
Female proportion	-0.04	-2.4	-0.04	-2.2	-0.06	-4.1	-0.04	-0.9
Farming members	0.02	5.4	0.02	6.3	0.04	14.8	0.03	3.4
Constant	-6.44	-12.5	-7.35	-14.1	-1.92	-4.7	-8.87	-5.t7
Number of obs	8683		8683		8683		8683	
R-square	0.47		0.51		0.41		0.31	

Table 5.11 reports OLS regressions of protein and micronutrient consumption. The signs of PCE are positive and significant in all regressions, implying a positive and significant relationship between expenditure and protein and nutrient consumption. The impact of the price of rice is positive and significant for most nutrients. There are three possible reasons for this. First, household may shift to buy less preferred staples such as corn and wheat, which are richer in calcium and iron than rice, resulting in an increase in the intake of iron and calcium. Second, rice has very little vitamins. Thus, an increase in the price of rice leads to a substitution toward meat, fish and vegetables, which are vitamin-rich. Third, a rise in the prices of rice might have an income effect on food consumption, as over half of all Vietnamese households, and most of Vietnamese rural households, grow rice. Several studies have reported similar results. Bouis and Novenario-Reese (1997) found that the price of rice had a positive impact on the rural households' iron intakes in Bangladesh. Pitt and Rosenzweig (1985) found that grain prices have positive impacts on the consumption of calories, calcium, iron, vitamin A and vitamin C of farm households in Indonesia, but the impact is significant only for calcium and vitamin C.

The price elasticities of meat, fish, other foods, and drinks with respect to various micronutrients are mostly negative and significant. The prices of pork and fish have the largest negative impact on the consumption of proteins, calcium and iron, while the prices of pork and other meats (mainly beef) have the largest negative impacts on vitamin intakes. The price elasticity of FAFH is found to be positive. Perhaps increasing the price of FAFH leads to more home cooking and better micronutrient nutrition. Yet, caveats should be kept in mind when interpreting the impact of the FAFH price because in this study, that price is just the provincial price deflator.

Household size has large, negative and statistically significant impacts on all micronutrient consumption. Most studies (for example Abdulai and Aubert 2004b) have found similar results, which is closely linked with the so-called Deaton and Paxson paradox that in most countries, and in particular in the poorest countries, food demand decreases with household size.

The schooling of the head has negative and significant impacts on protein and Vitamin B3, while women's schooling has negative and significant impacts on all micronutrients, except vitamin C. These results seem counter-intuitive since one expects that better educated households have better nutrition knowledge, and thus have better micronutrient status. Yet the evidence on the impact of household schooling on household nutrition is mixed. While Behrman and Wolfe (1984) found significant impact of women's schooling on micronutrient consumption, Behrman, Deolalikar and Wolfe (1988) admitted that "possible omitted variables bias the results and cause an upward estimate of the impact of mother's schooling. It is difficult to accurately observe and measure the range of women's endowments such as ability, motivation and knowledge." Abdulai and Aubert (2004b) found that women's schooling has positive and significant impacts on micronutrient intakes but the magnitudes of those impacts are small. In contrast, studies such as Pitt and Rosenzweig (1985), Ward and Sanders (1980), Bouis and Novenario-Reese (1997) and Hönicke et al (2006) found no significant impacts of education (either women's or the head's) on micronutrients.

There are some possible explanations for the negative relationship between nutrition and women's schooling in this study. First, better-educated households may prefer food taste or food convenience rather than nutritional content. Second, educated households may spend more on non-food items and less on food than less-educated households. Third, as nutrition is seldom taught in schools, higher years of schooling are not necessarily accompanied by better nutrition knowledge. Fourth, women with higher education are more likely to work away from home and so spend less time on cooking.

The age of the head of the household has a negative and significant effect on Vitamin B3 but not on other micronutrients and protein. Head's sex has a negative and significant impact on Vitamin B3 and protein but not on other micronutrients. The urban and minority variables generally have positive coefficients. More specifically, the urban dummy coefficient is significant and positive for vitamin A, vitamin B1, vitamin B2 and vitamin C, while the ethnic minority coefficient is significant and positive for protein, iron, vitamin B1, and Vitamin B3.

Households with higher shares of infants, children, elderly and women generally have lower micronutrient intakes per capita. The exception is vitamin A: households with higher proportion of children or infants have higher consumption of vitamin A. Since vitamin A deficiency is considered a serious issue for millions of children in the world, the positive relation between children and infant proportion with vitamin A may reflect that households with larger share of children/infant are more concerned about vitamin A intake than the others.

The number of farming household members positively and significantly affects the intakes of all micronutrients except vitamin A. As farming households may have more access to food than non-farming households (with all other factors controlled), they probably have better nutrition intake. Moreover, physically demanding farm work may require farmers to have more need for protein and certain micronutrients, such as iron.

Table 5.12 summarizes the expenditure and price elasticities of protein and micronutrients. The demand for protein and micronutrients is more elastic for households in rural areas than for those in urban areas, and for poorer households (relative to richer households). This trend is consistent with the general Engel curve which states that the demand for food of poorer households is more elastic than that of richer households. These estimates of micronutrient expenditure elasticities are much higher than those in Behrman and Wolfe (1984), and more in line with those reported by Bouis and Novenario-Reese (1992) and Abdulai and Aubert (2004b).

Table 5.12: Protein and Micronutrient Expenditure and Price Elasticity

	Protein	Minerals		Vitamins				
		Calcium	Iron	A	B1	B2	PP	C
Nutrient expenditure elasticity								
Total	0.17	0.34	0.33	0.80	0.46	0.49	0.35	0.67
Rural	0.18	0.35	0.34	0.88	0.48	0.51	0.37	0.71
Urban	0.15	0.30	0.29	0.57	0.40	0.43	0.31	0.56
Quintile 1	0.21	0.40	0.40	1.21	0.56	0.59	0.42	0.86
Quintile 2	0.19	0.36	0.36	0.97	0.50	0.53	0.38	0.75
Quintile 3	0.17	0.34	0.33	0.82	0.46	0.49	0.36	0.68
Quintile 4	0.16	0.31	0.31	0.65	0.42	0.45	0.33	0.60
Quintile 5	0.14	0.27	0.26	0.37	0.35	0.39	0.28	0.46
Nutrient price elasticity								
Rice	0.03	0.03	0.03	ins.	0.07	0.04	0.03	0.09
Staples	-0.03	-0.03	-0.03	ins.	ins.	ins.	-0.03	ins.
Pork	-0.12	-0.12	-0.12	0.13	-0.18	-0.14	-0.13	-0.16
Other meats	-0.04	-0.04	-0.04	-0.10	-0.03	-0.07	-0.06	-0.11
Poultry	-0.02	-0.02	-0.02	ins.	-0.04	-0.03	-0.03	-0.09
Fish	-0.07	-0.07	-0.07	-0.20	ins.	-0.03	-0.05	ins.
Vegetables	ins.	ins.	ins.	ins.	ins.	ins.	0.02	ins.
Fruit	ins	ins	ins	ins.	ins.	ins.	ins.	0.05
Other foods	-0.03	-0.03	-0.03	-0.06	-0.02	ins.	-0.02	ins.
Drink	-0.02	-0.02	-0.02	ins.	-0.02	-0.02	-0.02	0.05
FAFH	0.10	0.10	ins	ins.	-0.16	ins.	0.06	ins.

Note: ins. = statistically insignificant

5.6. Summary and Conclusion

This chapter has presented a comprehensive analysis of calorie and micronutrient consumption in Vietnam using the 2006 household survey data from that country. The data suggest that food insecurity is a major problem. Nearly 40 percent of the population are not meeting their calorie requirements. In addition, dietary diversity is low, as nearly two-thirds of calories are from cereals, primarily rice. Employing parametric and non-parametric estimation techniques, the chapter examines the relationship between household calorie consumption, per capita household expenditure, and food prices in Vietnam. The analysis indicates a positive and significant relationship between per capita expenditure and per capita calorie consumption. This is inconsistent with the view that income changes have little effect on nutrient intakes, as found in earlier studies such as Behrman and Wolfe (1984) and Bouis and Haddad (1992). The mean calorie elasticity is estimated at around 0.21-0.31 by different parametric methods and 0.20 by a non-parametric method. The finding of positive and statistically significant calorie elasticity implies that income growth can alleviate undernutrition, although its impact on undernutrition is much less than its impact on poverty. Lower-expenditure groups have relatively higher calorie elasticities in all models. Therefore, economic growth that is pro-poor will help to reduce undernutrition more effectively than a proportional increase of income by all groups. In a simulation, undernutrition is found to be very responsive to changes in income and in food prices. For example, a 10 percent increase in income reduces the undernutrition head count index in Vietnam by 9 percent.

Note that when income increases, households tend to replace cheap sources of calories for more expensive ones. As a result, the price of calories increases when income increases. This suggests that a household not only increases its calorie consumption with rising income, but also tends to buy more expensive foods, which have higher quality, better taste and/or higher amounts of micronutrients.

The impact of food prices on calorie consumption is negative and significant for most food items. The estimates imply that a 10 percent increase in all food prices would increase the undernutrition head count index by 11 percent. This suggests that lower food prices would increase calorie intakes. The remarkable exception is the price of rice, which has a positive net impact on calorie consumption. Rising rice prices have negative effects on the real income of many households, particularly urban consumers. However, higher rice prices also have positive impacts on farmers' income, resulting in increased calorie consumption in rural areas.

The chapter also estimates protein and micronutrient elasticities, an area often overlooked in previous empirical studies. Estimates of micronutrient elasticities are high, ranging from 0.3 for iron and calcium, to nearly 0.7 for vitamin C and 0.8 for vitamin A. These results imply that income growth leads to highly significant increase in micronutrient intakes, particularly for vitamin intakes.

This finding has important policy implications regarding the link between food prices and nutrition in Vietnam. Overall, this result implies that policies that raise income will considerably improve calorie consumption in Vietnam, particularly among poor households. Therefore, pro-poor growth and targeted measures toward poor households are important for improving the nutrition status of Vietnamese households. At the same time, curbing food price inflation is necessary to preserve the achievements in nutrition from recent economic growth in Vietnam. Yet, while overall food price increases can lead to substantial worsening in the households' nutritional situation, an increase in the price of rice price has very little effect on undernutrition prevalence, due to the "income effect". Many developing country governments use price control on staple foods to guarantee food and nutrition security. In Vietnam, the government uses price and export controls for rice with the view to preserve food security. My results indicate that an increase in rice price, in contrast, leads to higher calorie and micronutrient consumption, and has no negative impacts on the average household nutritional status. It even results in a slight reduction of the undernutrition prevalence rate among the poor households.

CHAPTER 6: IMPACTS OF RISING FOOD PRICES ON POVERTY AND WELFARE IN VIETNAM

With Paul Glewwe

Abstract

This paper examines the impacts of rising food prices on poverty and welfare in Vietnam. Increases in food prices raise the real incomes of those selling food, but reduce the welfare of net food purchasers. Overall, the net impact of higher food prices on an average Vietnamese household's welfare is positive. However, the benefits and costs are not spread evenly across the population. A majority of the population would be worse off from increases in food prices. More specifically, a uniform increase in both food consumer and producer prices would reduce the welfare of 56 percent of Vietnamese households. Similarly, a uniform increase in the price of rice would reduce the welfare of about 54 percent of rural households and about 92 percent of urban households. The reason why average household welfare increases is that the average welfare loss of the households whose welfare declines (net purchasers) is smaller than the average welfare gain of the households whose welfare increases (net sellers). A relatively small increase in food prices reduces poverty rate slightly because poorer households in Vietnam tend to be net sellers. However, a large food price increase, for example a 50 percent increase, may increase the poverty rate.

6.1. Introduction

Price data from Vietnam show that commodity prices in that country have fluctuated around a rising inflation rate since 2000. More recently, inflationary forces intensified in 2007; the rate of inflation increased from 6.6 percent in 2006 to 12.6 percent in 2007[32]. Even more worrisome is that official price statistics show that food prices are increasing much more rapidly than non-food prices. Food prices increased by 18.9 percent in 2007, and by 32.7 percent from January to September, 2008, higher than the rate of increase of the general price index of 12.6 percent in 2007 and 21.9 percent in the first nine months of 2008.

A key policy issue for Vietnam is the impact of these changes in food prices on household welfare and poverty in that country. The impacts of higher food prices on welfare are strongly influenced by the patterns of household incomes and expenditures. Higher food prices almost always have negative impacts on urban households because they are net purchasers of food. In contrast, the impacts on rural households are indeterminate. In rural areas, the majority of households are both producers and consumers of food, so the net effect will depend on whether the household is a net buyer or a net seller. Of particular interest is the impact of food prices on poverty. Clearly, the effect of increased food prices on poverty is determined by the location of net buyers and net sellers of food in the distribution of income, which may be very different in rural and urban areas. The existing literature gives mixed results. Ivanic and Martin (2008) examine the impacts of higher prices of staple foods on poverty in nine low-income

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[32] These inflation rates are price changes from December of the previous year to December of the current year.

countries. They show that increased food prices will lead to poverty increases in most of their surveyed countries. Deaton (1989) used non parametric techniques to study the effect of a hypothetical change in rice prices on the distribution of income in Thailand. He found that higher rice prices benefit rural households at all levels of income, especially middle-income rural households. Barrett and Dorosh (1996) also used non-parametric techniques to examine the effect of an increase in rice prices on household welfare in Madagascar. They found negative impacts on the rural poor because the gains to net rice sellers were concentrated among the higher income rice farmers. Ravallion and Van de Walle (1991) estimated the impact on poverty of food price increases in Indonesia. They found that a 10 percent increase in the price of food increased the rate of poverty.

Several studies have examined the effect of food prices on household welfare and poverty in Vietnam. Using the 1993 Vietnamese Living Standards Survey (VLSS), Minot and Goletti (2000) estimated that a 10 percent increase in the price of rice would, on average, increase household real income, since most Vietnamese households cultivated rice. However, they also found that such an increase in the price of rice would lead to a slight increase in the poverty rate. Using Vietnamese household surveys conducted in 1998 and 2004, Ivanic and Martin (2008) find that an increase in commodity prices, particularly in rice prices, reduces poverty in both 1998 and 2004.

The purpose of this paper is to analyze the impact of food prices on welfare and poverty in Vietnam, using the 2006 Vietnamese Household Living Standards Survey

(VHLSS), a national survey of about 9,200 households that was conducted in 2006[33]. The structure of the rest of this paper is as follows. Section 6.2 describes the methods used and the data. Section 6.3 summarizes the current situation regarding poverty and household welfare in Vietnam. Section 6.4 analyzes food production and consumption in Vietnam. Section 6.5 presents estimates of the impacts from a general increase in the prices of all food commodities, and from an increase in the price of rice on household welfare and poverty in Vietnam. The analysis pays particular attention to the impacts of rice prices, because rice is the most important food for Vietnamese households. In particular, rice is consumed by 99.9 percent, and produced by more than half, of Vietnamese households. Section 6.6 concludes the paper.

6.2. Methods and Data

This section presents the methods used in this paper to estimate the short-term effect of increased food prices on household welfare. It is useful at this stage to distinguish between food consumption and food purchases, and between food production and food sales. In many developing countries, food grown and consumed by households constitutes an important proportion of both food production and food consumption. After harvest, many households consume part of the food crops they produce, selling the rest. Other households purchase some food items to supplant their consumption from their own production. Therefore, there are significant differences between total food production and food sales and between food consumption and food purchases. This is

[33] The total sample size for the 2006 VHLSS was about 45,000 households, but of these only about 9200 completed the questionnaire that included detailed questions on consumption expenditures, which are used in this paper to measure household welfare.

especially true for rice, which is both produced and consumed by a majority of households in Vietnam.

In order to assess the impact of changes in food prices on household welfare, one must assess changes in households' real expenditure brought about by those food price changes. This implies that household food sales and food purchases are the main interest in this paper, rather than household food production and consumption. More specifically, the most important variable for assessing changes in household welfare is a household's *net* food sales, which is defined as food sales minus food purchases.

To assess the impact of changes in food prices on household welfare, this paper uses a simple methodology first used by Deaton (1989). The impact of price changes on household welfare is estimated by the household's compensating variation, i.e., the amount of money needed to keep the household's utility level equal to the level of utility it experienced before the increase in food prices. One can use a household profit function to represent a household's production activities, and an indirect utility function to characterize its level of welfare. When food prices increase, the (implicit) profits increase for a household that produces any amount of food. Yet to maintain its previous utility level, the household must also increase its spending on food. The welfare change of the household is calculated as the increase in the household's profits minus the change in expenditure level needed to maintain its previous level of utility in response to a change in food prices. The welfare change can be expressed as a percentage of household real expenditure. This paper considers two kinds of impacts of food prices on household welfare. The first is the immediate impact. The second is the short-run impact, which allows for quantity responses on the consumer side, such as switching among food items if their prices do not change at the same rates. However, responses from the producer side, such as increasing production are ignored. Although these changes can play an important role, they are relatively complicated and so are beyond the scope of this paper.

Following Deaton (1989), the paper uses the indirect utility function to express household welfare (utility)

$$U_h = \varphi(\omega T + b + \pi; p_c) \tag{6.1}$$

U_h is the utility of household h, which is a function of (total) income and a vector of prices of all goods purchased p_c; ω is the wage rate, T is the total time available to all household members, b is non-labor income, and π is the household's profit from its agricultural (or non-agricultural) household business.

The profit in equation (6.1) is, by standard economic theory, a function of the prices of both the inputs used and the outputs produced by the household's production activities. A standard property of the profit function is that small changes in prices of commodities produced by the household change profits in proportion to the amount sold:

$$\Delta\pi = y_i \Delta p_{pi} \text{ which implies } \Delta\pi / \Delta p_{pi} = y_i \tag{6.2}$$

where p_{pi} is the producer's price and y_i is the amount of commodity i sold by the household. The expression in equation (6.2) is the immediate change in profit for a one unit change in the price of the output y_i. The intuition is very simple. If the household is currently producing y kilograms of food, for example, a one thousand *Dong* (VND) increase in the price of rice will increase that household's profits by y thousand *Dongs*[34].

[34] In 2008, one U.S. dollar was equal to about 16,000 Vietnamese Dong at the official exchange rate, so in practice in Vietnam, a small change in a price is often considered to be a change of 1000 dong.

Next, consider what happens to profits from a change in the price of purchased goods.

$$\Delta\pi/\Delta p_{ci} \quad = \quad \Delta\pi/\Delta p_{pi} \times \Delta p_{pi}/\Delta p_{ci} = \; y_i \Delta p_{pi}/\Delta p_{ci} \qquad (6.3)$$

The fraction $\Delta p_{pi}/\Delta p_{ci}$ represents the relative change of producer's price to consumer's price. Many authors (for example, Deaton 1989) assume that $\Delta p_{pi}/\Delta p_{ci}$ equals to unity. However $\Delta p_{pi}/\Delta p_{ci}$ can differ from unity in certain circumstances, for example if the government uses price controls in the consumer market and/or the producer market. Thus, when examining data from any country, a one-to-one change in consumer and producer prices must be checked, and not simply assumed.

Roy's identity implies that

$$q_i = -(\Delta\varphi/\Delta p_{ci})/(\Delta\varphi/\Delta b) \qquad (6.4)$$

where φ is the household's utility function and q_i is the household's (gross) purchase of commodity *i*.

Making the standard assumption that the household maximizes its utility yields the following first order condition, which shows the impact of an increase in consumer's price of good *i* on household utility.

$$\frac{\Delta U_i}{\Delta p_{ci}} = \frac{\Delta\varphi}{\Delta b} \times \frac{\Delta\pi}{\Delta p_{ci}} + \frac{\Delta\varphi}{\Delta p_{ci}} = \frac{\Delta\varphi}{\Delta b}\left(\frac{\Delta\pi}{\Delta p_{ci}} - q_i\right) = \frac{\Delta\varphi}{\Delta b}\frac{(y_i \Delta p_{pi} - q_i \Delta p_{ci})}{\Delta p_{ci}} \qquad (6.5)$$

where the second equality is obtained using equation (6.4). Equation (6.5) implies that, if p_{ci} increases, utility can remain unchanged only if the household has a change in income, denoted by ΔB_i, sufficient to maintain its previous level of welfare (i.e. to keep its utility constant).

Therefore, equation (6.5) indicates that the change of total welfare needed to maintain previous utility from a change in the prices of *n* goods:

$$\Delta B = \Delta C - \Delta Y = \sum_{i=1}^{n}\left(q_i \Delta\, p_{ci} - y_i \Delta\, p_{pi}\right) = \sum_{i=1}^{n}\left(p_{ci}\, q_i \Delta \ln p_{ci} - p_{pi}\, y_i \Delta \ln p_{pi}\right) \quad (6.6)$$

in which ΔC is the change in expenditure and ΔY the change in production value brought about by changes in food price. The second equality in this expression is very intuitive. The amount of money needed to compensate for a change in the consumer price of good *i* and in the producer price of good *i* is the difference between the change in the money needed to maintain its initial consumption of that good minus the change in the value of the production. Summing over *i* goods, we have the equation (6.6)

And if we represent the change in income (ΔB) as a fraction of household expenditure (*X*), we have the net welfare change:

$$\Delta lnB = \sum_{i=1}^{n}(w_i \Delta lnp_{ci} - \left(\frac{p_{pi}\, y_i}{X}\right)\Delta \ln p_{pi}) \quad (6.7)$$

where w_i is the budget share of commodity *i* and ($p_{pi}\ y_i\ /X$) is the sales of *i* as a fraction of total household expenditures. In our estimation, w_i is the share of purchasing values of food item *i,* excluding consumption from own production. Equation (6.7) is similar to the result in Deaton (1989) but it is more flexible since it allows the change in purchasing price to differ from the change in the selling price.

However, equation (6.7) measures only the immediate effect from price changes. The cost of attaining the same level of utility will be lower if households can substitute away from goods whose prices have risen disproportionately. We call this impact the short-run impact. A second-order Taylor series expansion for the expenditure equation that allows for substitution behavior will have the following form for expenditure change:

$$\Delta C = \sum_{i=1}^{n} q_i \Delta p_{ci} + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} s_{ij} \Delta p_{ci} \Delta p_{cj} \quad (6.8)$$

where s_{ij} is the Slutsky derivative[35].

Equation (6.8) can be reformulated in terms of budget shares and proportional price changes, after some algebraic manipulation[36]:

$$\Delta lnC = \sum_{i=1}^{n} w_i \Delta lnp_{ci} + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} w_i \varepsilon_{ij} \Delta \ln p_{ci} \Delta \ln p_{cj} \quad (6.9)$$

where ε_{ij} is the compensated price elasticity of good *i* with respect to the price of good j.

Thus, from (6.6) and (6.9) the short-run effect of price change becomes:

$$\Delta lnB^{sr} = \sum_{i=1}^{n} \left(w_i \Delta lnp_{ci} - \left(\frac{p_{pi} y_i}{X}\right) \Delta \ln p_{pi}\right) + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} w_i \varepsilon_{ij} \Delta \ln p_{ci} \Delta \ln p_{cj} \quad (6.10)$$

If one only wants to assess the price impact of a sing good *i*, for example a change in the price of rice, equations (6.7) and (6.10) can be simplified to become:

$$\Delta lnB_i = w_i \Delta lnp_{ci} - \left(\frac{p_{pi} y_i}{X}\right) \Delta \ln p_{pi} \quad (6.11)$$

$$\Delta lnB_i^{sr} = w_i \Delta lnp_{ci} - \left(\frac{p_{pi} y_i}{X}\right) \Delta \ln p_{pi} + \frac{1}{2} \sum_{j=1}^{n} w_i \varepsilon_{ij} \Delta \ln p_{ci} \Delta \ln p_{cj} \quad (6.12)$$

To summarize, equations (6.7) and (6.11) show the immediate, direct impact, while equations (6.10) and (6.12) show the short-run or second-order effect. In practice, producers may also respond to food price changes by changing food production activities, such as by increasing the production of food items whose price increased and reducing

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[35] The Slutsky derivative, s_{ij}, is defined by the expression $s_{ij} = \partial x(p_{ci}, b)/(\partial p_{ci}) + x(p_{ci}, b) \times \partial x(p_{ci}, b)/\partial b$ where $x(p_{ci}, b)$ is the Walrasian demand function.

[36] For more detailed derivation of this estimate, see Friedman and Levinsohn (2002).

the production of items whose prices declined. To calculate the effect of price change on food production, however, one needs to know the supply price elasticity of different food crops. Besides, food price changes may also lead to changes in the prices of agricultural inputs such as fertilizers and agricultural wages, lowering the real income of food producers. For simplicity, the supply-side effect from food price increase is ignored in this paper. Thus, this paper examines only the immediate effect of changes in food prices on household welfare and the short-run effect that allows consumers to adjust their demands in response to the changes in food prices. Similar procedures have been used in Friedman and Levinsohn (2002) and in Minot and Goletti (2000), the latter concerning rice only.

Following Deaton (1989), in addition to the above calculations, this paper applies non-parametric methods to investigate the impact of changes in food price on welfare. As Deaton (1989) argued, non-parametric techniques such as density estimation and locally weighted regression provide intuitively clear graphical descriptions of the impacts of changes in food prices on different groups of households. Non-parametric techniques have also been used in, *inter alia*, Budd (1993) and Barrett and Dorosh (1996).

Finally, consider the data used. This paper uses the 2006 Vietnam Household Living Standards Survey (VHLSS) to assess the impact of changes in food prices on household welfare and poverty rates. The 2006 VHLSS is a nationally representation household survey with detailed information on household activities and characteristics. It includes 9,189 households, of which 6,882 were in rural areas and 2,307 were in urban areas. Seventy five percent of these households are engaged in farming activities, and 53 percent grow rice.

6.3. Poverty and Household Welfare in Vietnam

The poverty line used in this paper is the official poverty line, corresponding to the expenditure required to purchase 2,100 calories per person per day, plus a modest amount for essential non-food expenditures. This yields a poverty line of 2,560 thousand VND per person per year or about 213 thousand VND per person per month. This poverty line implies that about 15.9 percent of Vietnamese population, 3.8 percent of the urban population, and 20.3 percent of the rural population, were poor in 2006.

Table 6.1 presents estimates of poverty based on this poverty line for different groups of households using three poverty measures (Foster, Greer, and Thorbecke 1984). The first index, P0, is the head-count poverty index: the percentage of people who are poor. The second index, P1, is the (normalized) poverty gap, defined as the average gap between the income of the poor person and the poverty lines, where the non-poor are all assigned a gap of zero. This shows the depth of poverty. The third index, P2, is the poverty severity index, which is defined as the average of the squared poverty gap.

The figures in table 6.1 indicate that poverty in Vietnam is much more severe in rural areas than in urban areas. Although 73 percent of the population live in rural areas, 94 percent of the poor in Vietnam live in those areas. Comparing regions, the North West region has the highest rate of poverty; nearly 50 percent of that region's population are poor, more than three times the national average. The Central Highlands, the North Central Coast and the North East also have higher than average poverty rates: the rates in these regions range from 25 percent to 30 percent. The least poor region is the South East, which includes Ho Chi Minh City and the surrounding areas, with a poverty rate of 5.7 percent. The Red River Delta, which includes two large cities (Hanoi and Hai Phong), the fertile rice-growing Mekong River Delta, and the South Central Coast have poverty rates that are lower than the national average, ranging from 9 percent to 12 percent.

Poverty is much more common among ethnic minorities: the poverty rate among this group is 52.2 percent. In contrast, the poverty rate among the ethnic majority (the Kinh and the Chinese) is only 10.2 percent.

This chapter defines the farm population as people who live in households in which one or more members participate in farming activities, even if some or most of the household's income is from non-farm activities. The farm population represents about 71 percent of Vietnam's population but accounts for more than 90 percent of poverty in Vietnam. The poverty rates for the farm population and for the rural population are 20.4 percent and 20.3 percent, respectively. This implies that the non-farm population in rural areas, who account for 2.3 percent of Vietnam's population, are only slightly better-off than the farm population. The poverty rate of the farm population that grows rice is higher than that of the overall farm population (23.4 percent versus 20.4 percent). Rice farmers are more likely to be poorer than the farmers who grow non-rice agricultural products (fruit, vegetables, industrial crops etc.). About 75 percent of rice farmers produce less than 3.3 tons of paddy rice or 8.4 million VND (US$ 550) worth of rice during the year. The household expenditures per capita of farming households that do not grow rice are as much as 1.3 to 1.5 times higher than those of rice farming households.

The last column in Table 6.1 is the mean of real expenditure per capita for each group. The real expenditure per capita is the total (food and nonfood) household real expenditure divided by the number of persons in the household. Vietnam's urban population has, on average, a much higher standard of living than its rural population.

The average expenditure per capita of the former is almost twice that of the latter. The urban population can be further divided into the population in the largest cities and the other urban population. The four largest cities are Ho Chi Minh City, Ha Noi, Hai Phong and Da Nang. The average expenditure per capita of the urban population in these cities is about 2.7 times higher than that of the rural population. When the population is divided by regions, the South East and the Red River Delta are the wealthiest while the North West region is the poorest. The gap in living standards between regions is remarkable; the average expenditure per capita in the richest region (South East) is 2.4 times that of the population in the poorest (North West).

Large discrepancies are also observed by ethnic group and by occupation. The ethnic majority is much better-off than ethnic minorities, and the non-farm population has a much higher standard of living than the farm population. Among per capita expenditure quintiles, the disparity in living standards between the richest quintile and the poorest quintile is a six fold difference.

Table 6.1: Poverty Measures and the Distribution of Poverty

	Share of population	Poverty Index			Contribution to national poverty			Per capita expenditure
		P0	P1	P2	P0	P1	P2	,000 VND/month)
All	100.0	15.9	3.8	1.4	100.0	100.0	100.0	491
Location								
Rural	73.3	20.3	4.9	1.8	93.6	94.7	96.0	396
Urban	26.7	3.8	0.8	0.2	6.4	5.3	4.0	774
Region								
Red River Delta	21.6	8.8	1.5	0.4	12.0	8.6	6.6	531
North East	11.5	25.0	5.6	1.8	18.1	16.9	15.6	412
North West	3.2	49.0	15.6	6.4	9.9	13.1	15.2	296
North Central Coast	13.2	29.1	7.6	2.9	24.1	26.4	28.0	382
South Central Coast	8.5	12.4	2.6	0.9	6.6	5.9	5.4	494
Central Highlands	6.0	28.4	8.8	3.6	10.7	13.8	16.0	432
South East	15.9	5.7	1.4	0.5	5.7	5.9	6.4	700
Mekong River Delta	20.1	10.2	1.8	0.5	12.9	9.5	7.0	494
Ethnic								
Ethnic majorities	86.5	10.2	2.0	0.6	55.6	45.4	38.5	531
Ethnic minorities	13.5	52.2	15.4	6.2	44.4	54.6	61.5	264
Occupation								
Non-farmer*	29.0	5.0	1.1	0.3	9.1	8.1	7.3	726
Farmer	71.0	20.4	4.9	1.8	90.9	91.9	92.7	399
Not growing rice**	46.9	7.5	1.7	0.6	22.0	21.5	21.0	643
Growing rice	53.1	23.4	5.6	2.0	78.0	78.5	79.0	354
Income groups								
Quintile 1	20.0	79.6	19.0	6.8	100.0	100.0	100.0	176
Quintile 2	20.0	0.0	0.0	0.0	0.0	0.0	0.0	280
Quintile 3	20.0	0.0	0.0	0.0	0.0	0.0	0.0	385
Quintile 4	20.0	0.0	0.0	0.0	0.0	0.0	0.0	544
Quintile 5	20.0	0.0	0.0	0.0	0.0	0.0	0.0	1060

**includes agricultural workers*
***includes both farmers and non-farmers*

Figure 6.1: Density Distribution of Living Standards

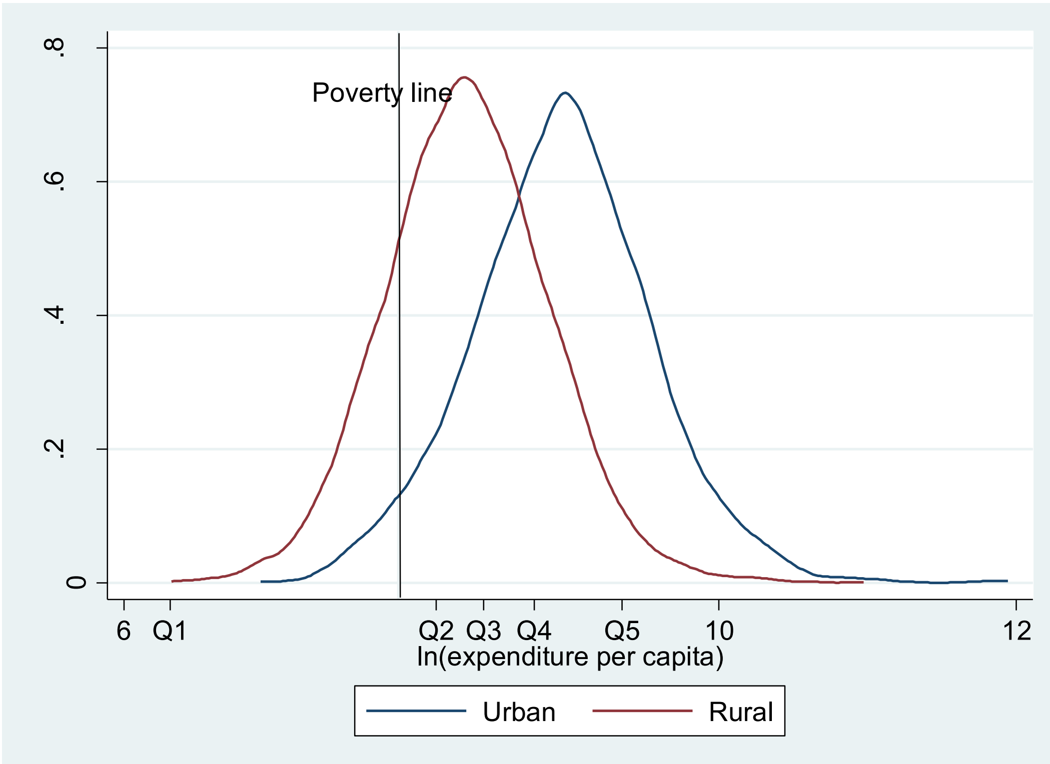


Figure 6.1 shows the distribution of living standards, as measured by per capita expenditures, separated for households in urban and rural areas. The graphs are the density functions of the logarithm of real expenditure per capita, estimated by kernel smoothing. As in Deaton (1989), the chapter uses the logarithmic transformation of real expenditure per capita because the distribution of real expenditure per capita is strongly positively skewed. The standard of living in the urban areas is, on average, much higher than in the rural areas.

6.4. Food Production and Consumption in Vietnam

6.4.1. Overall Food Production and Consumption Patterns

Table 6.2 provides information on the prevalence of farming and rice-farming in Vietnam. About 72 percent of Vietnamese households are farming households, and 53 percent of Vietnamese households grow at least some rice. Eighty six percent of the rural population are farmers, and two-thirds are rice farmers. In terms of regions, the North West has the highest percentage of both farming households and rice farming households: nearly 93 percent are engaged in farming activities and 77 percent grow rice. In contrast, in the South East, which includes Ho Chi Minh City, only 44 percent of the households are farmers and only 15 percent grow rice.

Based on the expenditure quintiles, the poor households are more likely to be farmers and rice farmers than the better off households. In the poorest quintile, 90 percent of the households are farmers and 76 percent are rice farmers, while in richest quintile, only 40 percent of households are farmers and 18 percent are rice farmers.

Ethnic minorities are more likely to be farmers and rice farmers than ethnic majority households; 94 percent and 81 percent of ethnic minority households are farmers and rice farmers, respectively. In contrast, 68 percent and 47 percent of ethnic majority households are farmers and rice farmers, respectively.

Table 6.3 presents food consumption, production, selling and purchasing patterns for Vietnamese households. The 2006 VHLSS data show that food constitutes 50 percent of households' real expenditure, about 47 percent for the non-poor population and 67 percent for the poor population. The percentage of total expenditure devoted to food is largest for the poorest quintile and smallest for the richest quintile. More specifically, food accounts for 65 percent of real expenditure for the first quintile (the poorest 20 percent of the population) but only 37 percent for the fifth quintile (the wealthiest 20 percent). For the population as a whole, food purchases constitute 72 percent of total food consumption, and self-produced food constitutes the other 28 percent. The poorest households depend least on purchased food (52 percent), while the richest quintile relies the most (88 percent).

Table 6.2: Distribution of Farming and Rice Farming Households

	Percentage who are farmers	Percentage who are rice farmers
All	71.9	52.5
Rural	86.2	66.0
Urban	29.3	12.3
Red River Delta	76.7	67.6
North East	84.0	70.3
North West	92.8	77.2
North Central Coast	80.9	66.1
South Central Coast	65.5	55.2
Central Highlands	86.6	41.1
South East	43.8	15.1
Mekong River Delta	65.1	37.3
Quintile 1	89.8	75.6
Quintile 2	84.8	69.4
Quintile 3	79.5	59.0
Quintile 4	66.2	41.5
Quintile 5	39.9	17.9
Ethnic majority	68.0	47.4
Ethnic minority	94.3	81.1
Non-poor	68.5	48.1
Poor	90.4	76.7

Table 6.3: Annual Food Production and Consumption by Household Groups (million VND and %)

	Food budget*	Food production	Food consumption	Food sale	Food purchase	NFS*	NFS for net sellers	NFP* for net purchasers	Percentage of net sellers
All	50.4	15.4	10.2	11.9	8.4	3.5	19.6	-9.1	43.8
Rural	53.7	18.3	9.2	14.0	6.6	7.4	18.5	-5.9	54.4
Urban	40.8	6.6	12.9	5.8	14.1	-8.3	34.2	-14.1	11.9
Red River Delta	49.4	13.9	9.9	9.9	7.7	2.2	15.5	-8.6	44.8
North East	55.2	12.7	9.5	7.1	6.1	1.0	7.9	-7.0	53.5
North West	61.7	13.1	8.3	6.6	4.3	2.3	5.6	-5.4	69.9
North Central Coast	51.8	11.2	8.4	7.2	6.0	1.3	9.3	-6.1	47.7
South Central Coast	47.3	13.1	10.1	10.7	9.1	1.6	21.9	-9.4	35.1
Central Highlands	51.9	12.7	10.7	9.6	8.7	0.9	14.3	-8.0	40.0
South East	43.1	10.2	12.4	9.2	14.0	-4.8	29.1	-14.1	21.4
Mekong River Delta	50.5	26.7	10.7	24.2	9.3	14.9	41.5	-8.6	46.9
Quintile 1	64.7	9.9	6.5	5.5	3.5	2.1	5.6	-3.1	59.3
Quintile 2	56.0	13.3	8.0	9.0	5.4	3.6	10.7	-4.7	54.1
Quintile 3	51.2	16.1	9.4	12.2	7.3	4.9	17.0	-6.5	48.5
Quintile 4	44.7	18.9	11.4	16.0	10.1	5.8	30.5	-9.7	38.7
Quintile 5	36.6	18.3	15.2	16.6	15.8	0.8	72.8	-15.7	18.7
Ethnic majority	48.2	15.7	10.4	12.8	9.2	3.6	23.1	-9.7	40.5
Ethnic minority	63.2	13.2	8.5	7.1	4.5	2.6	6.7	-4.1	62.4
Non-farmer*	43.7	5.7	12.2	5.6	13.3	-7.7	102.6	-13.3	4.9
Farmer	53.1	19.1	9.4	14.4	6.6	7.8	16.9	-5.3	58.9
Not growing rice	45.5	11.3	11.4	10.5	11.8	-1.2	48.0	-11.5	17.3
Growing rice	54.9	19.1	9.0	13.1	5.4	7.7	13.1	-3.6	67.7
Non-poor	47.4	16.4	10.9	13.2	9.4	3.7	23.5	-9.9	40.7
Poor	66.5	9.6	6.3	5.2	3.2	2.0	5.1	-2.9	60.2

**NFS: Net food sale, NFP: Net food purchase; **including households who catch or raise aquaculture products. Food budget is defined as a percentage of total household expenditure.*

Food production can be divided into the growing of rice, other staple crops (e.g. corn, potatoes, and cassava[37]), vegetables, fruit, livestock, and aquaculture products (fish, shrimp etc.). For Vietnam as a whole, the value of food production is about 1.5 times the average value of food consumption. This reflects the fact that Vietnam is a major exporter of food products[38]. More specifically, an average Vietnamese household produces about 15.4 million VND, and consumes 10.2 million VND, worth of food products each year. In terms of purchasing and selling values, an average household sells 11.9 million VND of food and buys 8.4 million VND, resulting in a net food sale of 3.5 million VND annually. The difference between net food sale (3.5 million VND) and net food production (5.2 million VND) reflects household self-produced consumption, storage, use for animal feed, crop loss after harvest, use as seeds, and other household uses (gifts, lending, payment, etc.).

An average urban household is a net food purchaser, buying 8.3 million VND worth of food per year, while an average rural household is a net food seller, selling 7.4 million VND. However, only 44 percent of Vietnamese households are net food sellers. Even in rural areas, only 54 percent of the households are net food sellers. In urban areas, an even smaller fraction, 12 percent, of households are net food sellers.

Turning to regional patterns, almost all the other regions are net producers and net sellers of food, the sole exception being the South East. The fertile Mekong River Delta is the major net food seller. A typical household in the Mekong River Delta has net food

[37] Corn and cassava are often used as animal feed.

[38] In 2006, Vietnam produced 197 trillion VND (about $12 billion) worth of agricultural products and exported $6.3 billion worth of those products, including 4.7 million tons of rice exports, valued at $1.3 billion (GSO data).

sales of 14.9 million VND, while an average household's net food sale in the other main agricultural region- the Red River Delta- is only 2.2 million VND. Yet, the region with most net food sellers is the North West: only 47 percent of households in the Mekong River Delta, and 45 percent in the Red River Delta are net food sellers, while in the North West nearly 70 percent of households are net sellers.

Among quintiles, all quintiles are net food sellers, on average, with the average net sales value being lowest in the richest quintile. Although the net food sales value per a household in the poorest quintile is relatively small (2.1 million VND compared with the overall average of 3.5 million VND), the percentage of households with positive net food sales among this quintile is the largest: 59 percent of the households in the poorest quintile are net food sellers. Table 6.3 breaks down the figures into rural and urban areas for quintiles and poverty groups. The net food sales value per household in the poorest quintile who live in rural areas is 2.3 million VND, compared to 21.5 million VND for an average rural household from the richest quintile. However, 62 percent of the rural households in the poorest quintile are net food sellers, compared to 38 percent of the rural richest quintile. This implies that although rural poor households are largely net sellers, their net sales are small and therefore their benefits from increased food producer prices will be small. On the other hand, the average net sales of the richest households in rural areas are very large, implying that these households will gain very much from the increase in food producer prices. Yet, while 38 percent of the richest rural households gain very much from being food producers, the rest of the richest rural households are net purchasers[39] and thus see their welfare decline from an increase in the prices of food.

Regarding occupations, 59 percent of farmers and 68 percent of rice farmers are net food sellers. This indicates that rice farmers are more likely to be net food sellers than non-rice farmers, who may grow industrial crops such as tobacco, tea or coffee. On average, a poor household has net food sales of 2 million VND, much smaller than the average non-poor household's net food sales of 3.7 million VND. Yet 60 percent of poor households, 62 percent of the rural poor and 26 percent of the urban poor, are net food sellers, compared to 41 percent of the non-poor households. Therefore, an increase in the price of food will benefit a greater percentage of poor households than of non-poor households. Yet, in absolute terms and in the percentage of household expenditure, the average effect on poor households is smaller than the average effect on non-poor households.

The fact that the majority of the rural poor are net food sellers is rather surprising since, in some countries, the rural poor are more likely to be net food purchasers than net food sellers. One reason for the rural poor being net food purchasers in those countries is that many poor households are landless, and thus they must be net food purchasers. In Vietnam, however, most of the rural poor have some cultivated land, as a result of the land policies in the socialist era. About 90 percent of the poor produce food, and for many of them, farming is the major household activity. Another possible reason why the poor in developing countries are often net food purchasers might be that the indebted poor are more likely to sell their crops early in order to pay debts and cannot store them

[39] Only 5 households in the whole sample (of 9189 households) are neither net purchasers nor net sellers of food, and all of them are in quintiles 1 and 2.

for future sale at higher prices. In contrast, in Vietnam, there is no significant relationship between borrowing and being net food seller among the poor. About 50 percent of the indebted poor are net food sellers and 50 percent of the poor without debt are net food sellers.

6.4.2. Rice Consumption and Production Patterns

Table 6.4 summarizes rice consumption and production patterns among Vietnamese households, as measured by the 2006 VHLSS. Because households often sell paddy rice and buy processed rice in the market, the quantity of rice produced and sold has been adjusted using a conversion rate of 0.67 from paddy rice to milled rice[40]. The gap between average implied purchasing price of 4,560 VND per kilogram and the average implied selling price of 3,540 thousand VND per kilogram reflects processing and marketing costs and traders' profits. It is also important to clarify the relationship between the quantity consumed and the quantity produced. Rice produced by households is not only consumed or sold by the household but also includes crop losses after the harvest, animal feed, seeds, storage and other household uses (gifts, lending, payment etc). The gap between production and consumption also reflects the fact that Vietnam is usually the world's second largest rice exporter after Thailand, with total rice exports of over 4.5 million tons in 2007.

[40] Conversion rates can vary between 0.62 to 0.7 depending on technology and dryness of paddy. However, the choice of conversion rates affects only the *quantities* of rice production and rice sales and does not affect the analysis on net sales value and net sales ratio.

Table 6.4: Rice Production and Consumption, in kg (Q) and thousand VND (V)

	Production (Q)	Consumption (Q)	Sales (Q)	Purchase (Q)	Production (V)	Consumption (V)	Sales (V)	Purchases (V)	Net sales (V)
All	1247	582	689	261	4518	2421	2442	1190	1252
Rural	1562	630	851	221	5667	2531	3020	966	2053
Urban	308	439	208	379	1087	2093	717	1857	-1140
Red River Delta	971	535	294	141	3922	2233	1206	664	542
North East	845	663	99	155	3424	2765	412	739	-327
North West	1009	782	155	168	4018	3202	663	814	-151
North Central Coast	1000	602	273	210	3660	2359	1018	925	94
South Central Coast	761	528	268	223	2661	2043	951	993	-42
Central Highlands	656	687	231	415	2343	2864	842	1876	-1034
South East	460	489	344	410	1605	2264	1201	1971	-770
Mekong River Delta	2917	568	2427	383	9880	2361	8322	1667	6655
Quintile 1	1041	712	314	202	3880	2759	1131	824	307
Quintile 2	1353	653	621	207	5017	2576	2250	879	1371
Quintile 3	1614	597	972	250	5840	2437	3418	1096	2322
Quintile 4	1341	539	884	311	4793	2321	3099	1439	1659
Quintile 5	877	413	642	331	3032	2022	2255	1695	560
Ethnic majority	1250	545	746	275	4504	2291	2648	1261	1387
Ethnic minority	1226	790	371	182	4591	3151	1275	788	487
Non-farmer	0	414	0	405	0	1964	0	1925	-1925
Farmer	1733	648	959	205	6280	2599	3394	903	2491
Not growing rice	0	465	0	455	0	2137	0	2094	-2094
Growing rice	2375	688	1314	85	8605	2678	4651	372	4279
Non-poor	1294	556	769	273	4664	2354	2718	1266	1453
Poor	996	718	264	193	3735	2775	963	786	177

Table 6.5: Rice Production and Consumption as Percentages of Total Household Real Expenditure

	Production ratio	Consumption ratio	Sales ratio	Purchase ratio	Net sales ratio	Percentage of Net sellers	Percentage of Net purchasers	Percentage of Self-sufficient	% of food expense
All	26.0	14.6	12.3	6.0	6.3	30	63.8	6.2	27.5
Rural	33.0	16.7	15.5	5.8	9.7	37.8	54.5	7.7	30.2
Urban	5.2	8.2	3.0	6.7	-3.7	6.8	91.8	1.4	19.6
Red River Delta	26.2	13.4	8.7	3.0	5.7	41.6	51.9	6.5	26.2
North East	24.0	18.5	2.8	4.0	-1.2	26.1	57.2	16.7	31.9
North West	35.3	27.0	5.3	5.1	0.2	28.9	49.0	22.1	41.9
North Central Coast	26.5	16.7	7.2	5.7	1.4	35.4	60.9	3.7	31.1
South Central Coast	17.3	11.7	6.0	4.6	1.5	31.5	65.4	3.1	24.1
Central Highlands	15.7	16.8	5.5	9.9	-4.4	17.4	80.8	1.8	31.0
South East	7.3	9.8	5.3	8.2	-3.0	10.1	87.9	2.0	22.0
Mekong River Delta	44.1	12.7	36.8	9.0	27.8	34.0	64.7	1.3	24.7
Quintile 1	37.9	28.0	10.6	8.5	2.2	35.1	52.7	12.2	42.7
Quintile 2	34.8	18.0	15.5	6.2	9.3	40.5	52.0	7.5	32.6
Quintile 3	30.8	13.2	17.6	5.9	11.7	36.9	57.7	5.4	26.6
Quintile 4	19.1	9.1	12.2	5.5	6.7	26.5	70.5	3.0	21.4
Quintile 5	8.1	5.1	5.8	4.1	1.6	11.5	85.7	2.8	15.0
Ethnic majority	24.5	12.7	13.1	6.0	7.1	29.7	66.5	3.8	25.5
Ethnic minority	34.6	25.4	8.0	6.0	2.0	31.6	48.5	19.9	39.3
Non-farmer	0.0	8.9	0.0	8.4	-8.4	0.0	98.0	2.0	19.5
Farmer	36.2	16.8	17.2	5.1	12.0	41.7	50.5	7.8	30.7
Not growing rice	0.0	10.5	0.0	10.0	-10.0	0.0	98.5	1.5	22.2
Growing rice	49.6	18.3	23.5	2.4	21.1	57.2	32.5	10.3	32.4
Non-poor	23.8	11.8	12.9	5.5	7.3	29.2	66.0	4.8	24.5
Poor	38.1	29.4	9.6	8.6	1.0	34.4	52.2	13.4	44.0

Rice plays a very important role in Vietnam. The 2006 VHLSS shows that it is grown by over 52 percent of Vietnamese households and 65 percent of rural households. About 26 percent of real household expenditure comes from rice production. Among rice farming households, rice production equals 50 percent of real household expenditure (Table 6.5). An average household produces 1861 kg of paddy each year, and an average rice farmer produces 3545 kg of paddy each year. About 55 percent of this quantity (1029 kg of paddy) is sold in the market, giving the household about 2.4 million VND in receipts. The distribution of rice production is highly skewed; the 5 percent of farming households that produce the most paddies produce 33 percent of total paddy production value in the 2006 VHLSS. Most of these highly productive rice farming households are in the Mekong River Delta; more specifically, 90 percent are in the Mekong River Delta and 5 percent are in the South East.

On the consumption side, rice is the main food item consumed, accounting for about 15 percent of household food expenditure and 69 percent of calorie intake. The average annual value of rice consumption for an average household is 2.4 million VND, of which half is purchased in the market and a half is self- produced.

Across regions, rice farming households in the Mekong River Delta are the most productive and the most commercialized. An average household in this region produced an amount of rice worth 9.9 million VND in 2006, an almost more than twice the national average. A typical Mekong River Delta rice farming household sells 84 percent of its production compared to the average ratio of 50 percent. On average, a household in the Mekong River Delta has a net rice sales value of 6.7 million VND, while the average net rice sales value is 1.3 million VND for the whole country and only 0.5 million VND in the Red River Delta.

Among the eight regions, five are net purchasers of rice in terms of value: the North East, the North West, the South Central Coast, the South East and the Central Highlands. The Central Highlands, which grows mostly industrial crops such as coffee and tea, is particularly vulnerable to increases in rice prices. An average household in this region is a net purchaser of an amount of rice worth over 1 million VND in 2006, equivalent to an average of 4.4 percent of that household's real expenditure. However, in terms of net sales as a percentage of household real expenditure (Table 6.6), there are three regions with negative net sales: the North East, the South East and the Central Highlands. The fact that the figures in column 9 of Table 6.4 are negative while the figure in column 5 of Table 6.5 is positive for North West and South Central Coast implies that, on average, households with positive net rice sales have higher living standards than those with zero or negative net rice sales in these two regions. As a result, average net rice sales as a percentage of household real expenditure are positive, while average net rice sales in absolute value are negative in these two regions[41].

The average household in Vietnam is a net seller of rice; the average net amount sold being 428 kg of rice, the value of which is 1.25 million VND. Categorized by standard of living, on average all quintiles are net sellers of rice, although the average net amounts are lower for the lowest and the highest quintiles. However, these numbers can be misleading if one ignores the distribution of rice consumption and production

[41] Let NS be the net sales per household in money value, and Y the household's real expenditure; the average net sales in Table 6.5 is equal to $(\sum_i NS_i)/n$, while the average net sales as a percentage of household real expenditure in Table 6 is equal to to $(\sum_i NS_i/Y_i)/n$, where is the number of households in the group.

patterns. Table 6.5 summarizes rice production, consumption, purchases and sales as percentages of total household real expenditure. The 'net sales' column indicates whether the average household is a net purchaser (negative number) or net producer (positive number) of rice. Other things being equal, the average net sales of 6.3 percent imply that a 10 percent increase in the price of rice will increase the real income of an average household by 0.63 percent.

Column six in Table 6.5 shows, for each group, the percentage of households who are net rice sellers. Only 30 percent of Vietnamese households are net rice sellers. Even among the rice farmers, about 43 percent of rice farmers are either net buyers or self-sufficient farmers. The regional distribution shows that the South East has the lowest percentage of net rice sellers. Only 10.1 percent of the region's households are net rice sellers. Even in the most important rice growing region, the Mekong River Delta, only 34 percent of households are net rice sellers. This appears surprising because this region is the main rice production area in Vietnam. However, it should be noted that in Mekong River Delta, the distribution of land has become somewhat unequal, resulting in production concentration among some large producers. Only 37 percent of the households in the Mekong River Delta are farmers, but an average household in this region produces three times (in terms of quantity) higher than an average household in the second important rice farming region, the Red River Delta. This reflects the fact that the cultivated area per household in the Mekong River Delta is six times higher than in the Red River Delta.

Poor households have a slightly higher percentage of net rice sellers than the non-poor. Note that the poor also have a higher percentage of self-sufficient households (i.e. neither net sellers nor net purchasers of rice) than non-poor households. About 13 percent of poor households are self-sufficient in terms of rice consumption, while only 5 percent of non-poor households are.

In order to understand better rice consumption and production patterns, non-parametric methods can be used. Figure 6.2 presents non-parametric regressions of the percentage of household per capita expenditure spent on rice on the logarithm of household per capita expenditure, using kernel smoothing. The downward slopes in Figure 6.2 are consistent with Engel's Law; the share of budget spent on rice declines as living standards increase. For the poorest households in both rural and urban areas, nearly half of the household budget is spent on rice. In the contrast, the share is very small, less than 5 percent, for the richest quintile. The curves are steeper at low levels and flatter at higher levels of per capita expenditure, indicating that poor households are more sensitive to income increases than rich households.

Figure 6.2: Density Estimation of Share of Household Expenditure Spent on Rice

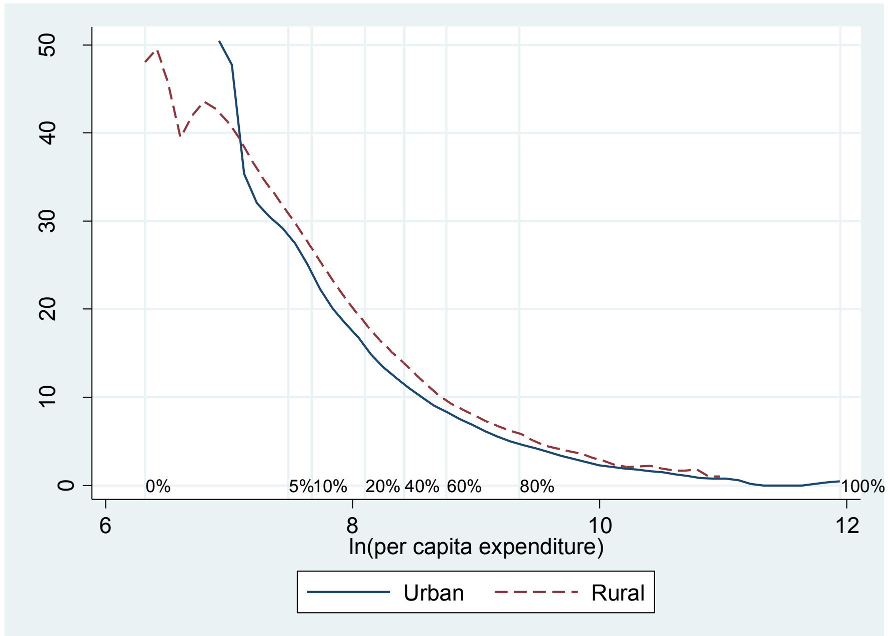
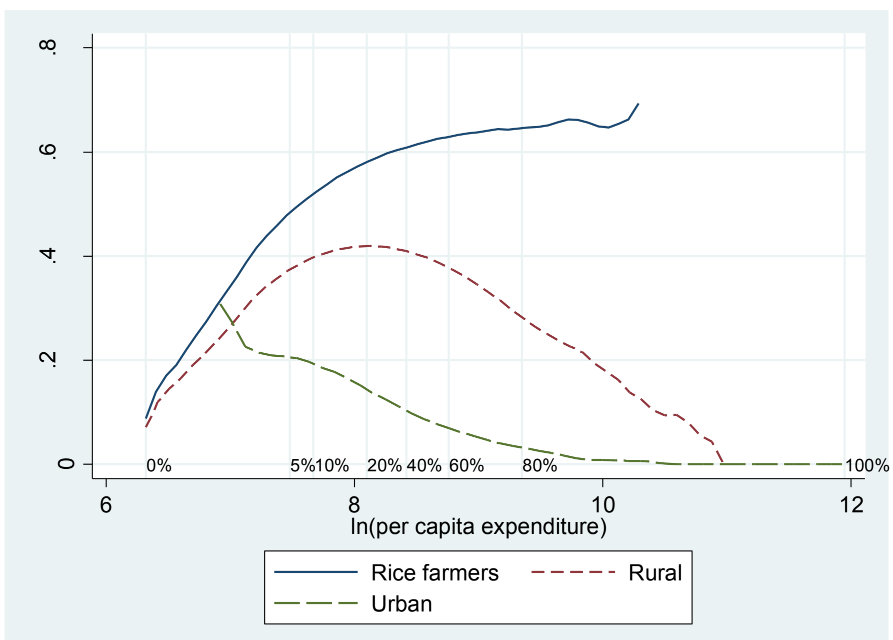


Figure 6.3: Probability for a household to be a net rice seller (bandwidth=0.3)



Now turn to the production side. Figure 6.3 estimates the probability that a household is a net rice seller, conditional on the household engaging in rice production, or on living in a rural or urban area. Figure 6.3 indicates that rich rice farmers are almost always more likely to be a net rice seller than poor rice farmers. Therefore, an increase in the price of rice tends to benefit rich farmers more than poor farmers. However, the pattern for rice farmers is not the same as that for all rural households. As its standard of living increases, the probability that a rural household is a net rice seller initially increases but then decreases when household's income is around the quintile 2. Perhaps better-off households are more likely to participate in some more profitable farming or non-farming activities instead of growing rice. Therefore, rice price increases benefit mostly middle-income rural households. For urban households, the probability of being a net rice seller is very small, less than 0.2, and decreases as income increases. Thus, the probability of being a net rice seller for an urban household in quintile 1 is about 0.15, but that for an urban household in quintile 5 it is close to zero.

These results suggest that large rice farmers are more likely to benefit from an increase in the price of rice than small rice farmers; middle-income rural households are more likely to have benefits than very rich or very poor rural households; and rich urban households are more likely to experience welfare declines than poor urban households. However, almost all urban households face welfare declines.

The fact that 64 percent of Vietnamese households are net buyers implies that an increase in the price of rice will have adverse effect on the welfare of a majority of

Vietnamese households regardless of the *average* positive welfare effect for the population as a whole.

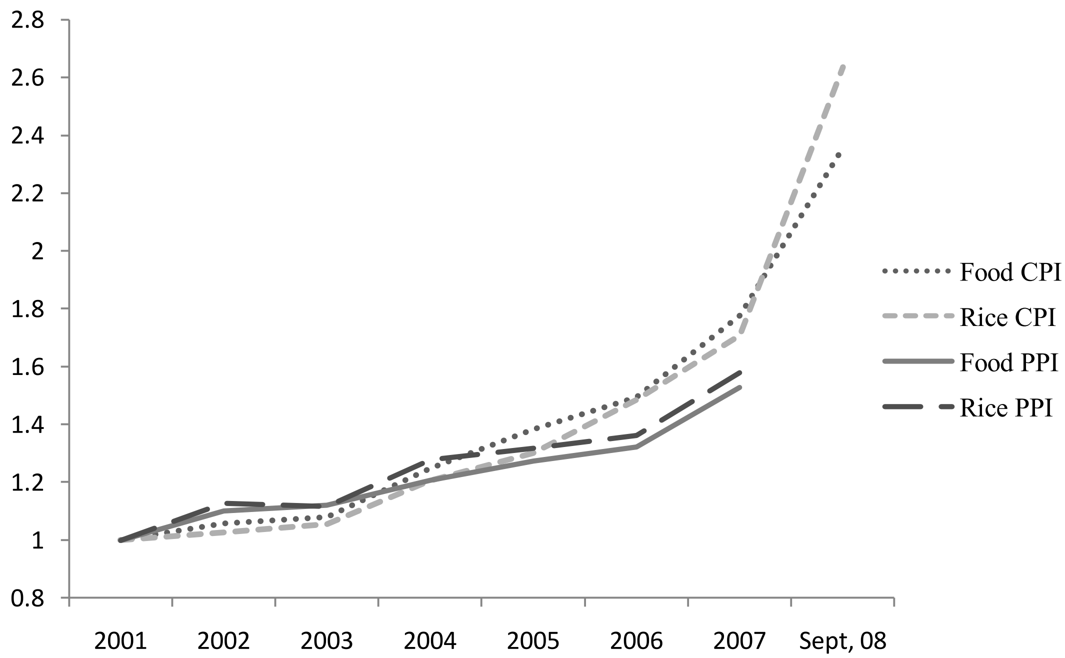
The next section examines the distributional effects of price changes for food in general, and for rice in particular.

6.5. Changes in Food Prices and Household Welfare

6.5.1. Food Prices and Household Welfare

Figure 6.4 shows Vietnam's consumer price index (CPI) and producer price index (PPI), both for food in general and for rice in particular, for the period 2001-2007. Setting the year 2001 as the initial period, the food PPI was higher than the food CPI from 2001 to 2003, but was lower than the food CPI from 2004 to 2007. Turning to rice alone, the rice PPI was higher than the rice CPI during the period 2001-2004 but was lower than the rice CPI from 2005 to 2007. The gap between the consumer and producer food price indices has been large in recent years, although that gap has been smaller for rice than for food in general. During the first nine months of 2008, the food CPI increased by 33 percent and the rice CPI increased by 54 percent, compared to an increase of 19 percent for the food CPI and 15 percent for the rice CPI for all of 2007. The rapid increase in the price of food in 2008 will have a bigger effect on households' welfare than the price change during 2007.

Figure 6.4: Consumer Price Index and Producer Price Index for Food and Rice 2001-2008



This section uses the 2006 VHLSS to examine the impacts of changes in food prices on household welfare and poverty. It does so for six scenarios. The first scenario (1a) examines the direct impacts on household welfare and poverty of a hypothetical 20 percent increase in the prices of all food products. This scenario assumes that producer and consumer prices increase by the same amount, which is also assumed by Deaton (1989), Minot and Goletti (2004), and Ivanic and Martin (2008). The second scenario (1b) assumes that producer prices for food products increase faster than the increase in consumer prices, so that consumer prices increase by 20 percent while producer prices increase by 24 percent. The third scenario assumes that the producer prices increase less than consumer prices so that consumer prices increase by 20 percent while producer prices increase by 16 percent. Scenarios 2a, 2b and 2c replicate these scenarios but with consumer prices for food products increasing by 50 percent while producer prices increase by 50 percent, 60 percent and 40 percent, respectively.

More specifically, the following six scenarios for food prices are examined:

(1) Consumer price increases by 20 percent

(1a) Producer price increases by 20 percent

(1b) Producer price increases by 24 percent

(1c) Producer price increases by 16 percent

(2) Consumer price increases by 50 percent

(2a) Producer price increases by 50 percent

(2b) Producer price increases by 60 percent

(2c) Producer price increases by 40 percent

Since the consumer prices of all food items are assumed to increase at the same rate, there is no substitution effect in consumer demand. The impacts of these scenarios on household welfare are presented in Table 6.6. Table 6.6 shows that a hypothetical uniform food price increase of 20 percent would raise the real annual income of an average household in Vietnam by 3.4 percent. A uniform price increase of 50 percent would raise the income by 8.5 percent. Yet, the size and direction of the impact depends on whether producer prices increase the same as, or more or less than, consumer prices. If producer prices rise faster than consumer prices, the welfare impact would be large. For example, if the food consumer prices rise by 20 percent, while the food producer prices increase by 24 percent, average household welfare would rise by 5.6 percent. Yet, if food producer prices rise at 16 percent, household income would rise by only 1.3 percent.

Table 6.6: Household Welfare Change due to Food Price Increases (%)

	Welfare change (%)						Percentage of worse-off (%)		
+ Consumer price	20%			50%					
+ Producer price	20% (1a)	24% (1b)	16% (1c)	50% (2a)	60% (2b)	40% (2c)	(1a & 2a)	(1b & 2b)	(1c & 2c)
All	3.4	5.6	1.3	8.5	13.4	3.1	56.2	53.1	61.0
Rural	6.0	8.6	3.4	15.0	21.5	8.5	45.5	41.8	51.3
Urban	-4.4	-3.6	-5.2	-11.0	-8.90	-13.0	88.1	86.9	89.7
Red River Delta	3.5	5.5	1.4	8.8	13.8	3.7	55.1	51.9	59.8
North East	2.2	3.8	0.5	5.4	9.60	1.3	46.5	42.4	52.8
North West	4.2	6.1	2.3	10.4	15.2	5.6	30.1	27.3	37.3
North Central Coast	2.1	3.8	0.3	5.2	9.50	0.8	52.1	48.6	57.7
South Central Coast	1.5	3.4	-0.3	3.8	8.40	-0.8	64.9	61.4	72.2
Central Highlands	1.1	2.9	-0.7	2.8	7.20	-1.7	60.0	56.5	64.3
South East	-2.5	-1.1	-3.8	-6.1	-2.78	-9.5	78.5	76.9	81.1
Mekong River Delta	10.0	13.7	6.3	25.0	34.3	15.8	53.0	50.5	56.1
Quintile 1	3.6	5.7	1.5	9.1	14.3	3.8	40.4	36.7	47.5
Quintile 2	4.5	6.9	2.1	11.2	17.1	5.3	45.8	41.9	51.8
Quintile 3	4.6	7.1	2.2	11.6	17.7	5.4	51.4	47.4	56.1
Quintile 4	4.1	6.5	1.8	10.3	16.1	4.4	61.3	58.9	66.0
Quintile 5	0.2	1.6	-1.3	0.4	4.10	-3.3	81.3	80.1	83.0
Non-farmer	-5.2	-4.5	-6.0	-13.0	-11.2	-14.9	94.9	94.6	95.2
Farmer	6.8	9.5	4.1	16.9	23.7	10.2	41.1	36.9	47.6
Not growing rice	-1.5	-0.1	-3.0	-3.8	-0.14	-7.4	82.6	81.2	84.6
Growing rice	7.9	10.6	5.1	19.6	26.6	12.7	32.3	27.7	39.6
Poor	3.4	5.5	1.2	8.4	13.8	3.0	59.2	56.3	63.6
Non-poor	3.6	5.7	1.5	9.0	14.2	3.8	39.4	35.9	46.6
Rural poor	4.0	6.1	1.9	10.0	15.4	4.7	37.4	33.8	45.0
Rural non-poor	6.5	9.2	3.8	16.2	23.0	9.5	47.4	43.7	52.9
Urban poor	-3.3	-2.1	-4.6	-8.4	-5.22	-11.5	73.4	72.2	74.7
Urban non-poor	-4.4	-3.6	-5.2	-11.1	-9.06	-13.1	88.6	87.4	90.2

These scenarios have different impacts on urban and rural areas. On average, the welfare of rural households increases while that of urban households decreases. For example, Scenario 1a (uniform 20% price increase) shows that an average rural household would experience a 6.0 percent increase in its standard of living, while an average urban household would suffer a reduction of 4.4 percent.

On average, middle-income groups gain the most (in percentage terms) from increased food prices. The welfare of households in quintiles 2, 3 and 4 would see their welfare increase between 4.1 and 4.7 percent in Scenario 1a, and between 10.3 and 11.6 percent in Scenario 2a. In contrast, the richest quintile has almost no gain in either scenario, and even loses in Scenarios 1c and 2c. The poorest quintile, as a whole, gains from food price increases, but the gains are less than those experienced by the middle-income groups.

The welfare of both poor and non-poor households increase in these scenarios, but the relative increase is slightly higher for non-poor households. For example, in Scenario 1a, the poor's household income increases by 3.4 percent, less than the rise in non-poor's household income (3.6 percent). If we further divide the poor and non-poor into urban and rural groups, the implications are more interesting. The rural non-poor gain more than the rural poor, while the urban non-poor lose more than the urban poor.

In terms of regions, only the most urbanized region- the South East- suffers a decline in average household income in all scenarios. The South East and the Central Highlands are particularly vulnerable to food price increases since they consume more than they produce, and may exhibit welfare decline if food consumer price increases faster than producer prices. Among the other regions, the Mekong River Delta is the biggest winner, which is not surprising since it produces far more food than it consumes. Average household income in this region may increase by 10 percent for a uniform 20 percent price increase, and by 25 percent for a uniform 50 percent price increase.

The impacts reported in previous paragraphs are averages for each group, and they reveal nothing about variation within groups. To examine the variation in welfare changes *within* groups, columns 8, 9 and 10 shows the percentages of households whose welfare declines. These percentages would be the same for Scenario 1a and 2a, 1b and 2b, 1c and 2c since the price changes in these scenarios are proportional. Overall, from 53 percent to 61 percent of Vietnamese households will experience welfare declines from increases in food prices. Nearly 90 percent of urban households will suffer a welfare decline, while from 40 to 50 percent of rural households would experience welfare reductions.

In terms of regions, the South East region is the most negatively affected: around 80 percent of households in this region would suffer reductions in their welfare in each of these scenarios. Although the Mekong River Delta is the most productive agricultural region in Vietnam, even in this region, over 50 percent of households experience a welfare decline. This is not surprising since nearly 40 percent of the households in this region are not engaged in any household farming activity. The region with the greatest percentage of households benefiting from an increase in food prices is the North West: only 27-37 percent of this region's households would be worse off under these scenarios. This is not surprising because, as shown in Table 6.2, 93 percent of the households in the North West are farmers, much higher than the national average of 72 percent. Table 6.3 also shows that the North West has the highest percentage of net food sellers (69 percent).

Grouping households by welfare quintiles, the poorest quintile has the lowest percentage of households whose welfare declines (37 to 48 percent) while the richest quintile has the highest (over 80 percent). Categorized by poverty status, from 36 to 47 percent of poor households would experience a welfare reduction; while from 56 to 64 percent of non-poor households would suffer a decline in welfare.

Most non-farmers (about 95 percent) would experience welfare reductions under all scenarios. The other five percent of non-farmers experience welfare increases because they are engaged in fishing activities, and sell more food than they purchase. As for farmers, 37-48 percent of farmers would have lower welfare than before. This occurs because many Vietnamese farmers are small food producers, and the welfare improvement from higher food producer prices may not offset the negative effect brought about by higher food consumer prices.

The impacts of increases in food prices on poverty are summarized in Table 6.7. Increases in food prices of different rates do not necessarily have the same effects. A food price increase by 20 percent for both consumer and producer prices would reduce the national poverty headcount rate by 0.8 percentage points. Yet, if food prices increase uniformly by 50 percent, the poverty rate would increase by 0.3 percentage points. Since food prices increased by 12-15 percent in 2007, and 40-50 percent in 2008, the impacts of food price changes could be poverty-reducing in 2007 but poverty-increasing in 2008. The intuition for this change in sign is simple. When food prices increase moderately, rural poverty would reduce significantly while urban poverty would increase mildly. The net effect is a reduction in the national poverty rate. However, as food prices increase dramatically, urban poverty would rise sharply, and bring about an increase in the national poverty rate.

More particularly, rural poverty falls in all five of those scenarios, the exception being Scenario 1c, while urban poverty increases in all scenarios. A uniform food price increase of 20 percent will reduce headcount poverty in rural areas by 1.4 percentage points, but raise it in urban areas by 0.8 percentage points. Yet if food prices increase by 50 percent uniformly, the rural poverty headcount rate falls by only 0.8 percentage points but urban poverty headcount rises by 3.3 percentage points. More interestingly, a food consumer price increase of 50 percent, together with a food producer price increase by 40 percent (Scenario 2c) would increase poverty in both urban and rural areas, since many farmers are in the edge between being net food sellers and net food consumers.

Measured by the headcount poverty ratio (P0), about 13 percent of the poor would escape of poverty in Scenario 1a, 24 percent in Scenario 2a. In contrast, about 1.5 percent of the non-poor would fall into poverty in Scenarios 1a, and 4.9 percent in Scenario 2a.

Table 6.7: Poverty Impacts of Food Price Increases

+ Consumer price		*0%*	*20%*			*50%*		
+ Producer price		*0%*	*20%*	*24%*	*16%*	*50%*	*60%*	*40%*
			(1a)	*(1b)*	*(1c)*	*(2a)*	*(2b)*	*(2c)*
All country	P0	15.9	15.1	14.6	15.8	16.2	15.3	17.7
	P1	3.8	3.6	3.5	3.8	4.1	3.8	4.4
Rural poverty	P0	20.3	18.9	18.3	19.8	19.5	18.3	21.5
	P1	4.9	4.6	4.4	4.8	5.0	4.6	5.4
Urban poverty	P0	3.8	4.6	4.5	4.9	7.1	6.9	7.4
	P1	0.8	1.0	0.9	1.0	1.7	1.6	1.7
Non farmer	P0	5.0	6.6	6.5	6.6	11.5	11.4	11.7
	P1	1.1	1.5	1.4	1.5	2.8	2.8	2.9
Farmer	P0	20.4	18.5	18.0	19.6	18.2	16.8	20.2
	P1	4.9	4.5	4.3	4.8	4.6	4.2	5.0
Non-rice farmer	P0	7.5	8.7	8.6	8.9	12.8	12.6	13.5
	P1	1.7	2.0	2.0	2.1	3.3	3.2	3.4
Rice farmer	P0	23.4	20.7	20.0	21.9	19.2	17.6	21.5
	P1	5.6	5.0	4.8	5.3	4.8	4.4	5.3
Non-poor	P0	0.0	1.5	1.5	1.7	4.9	4.7	5.5
	P1	0.0	0.1	0.1	0.1	0.6	0.6	0.6
Poor	P0	100	86.5	84.1	90.6	75.9	71.2	82.4
	P1	23.9	22.4	21.4	23.4	22.6	21.0	24.4
Rural poverty	P0	20.3	18.9	18.3	19.8	19.5	18.3	21.5
	P1	4.9	4.6	4.4	4.8	5.0	4.6	5.4
Urban poverty	P0	3.8	4.6	4.5	4.9	7.1	6.9	7.4
	P1	0.8	1.0	0.9	1.0	1.7	1.6	1.7
Red R.D.	P0	8.8	7.2	6.6	7.8	7.0	6.4	8.3
	P1	1.5	1.3	1.2	1.4	1.4	1.2	1.5
North East	P0	25.0	23.1	22.6	24.3	21.5	20.1	24.4
	P1	5.6	5.1	4.9	5.4	5.0	4.6	5.5
North West	P0	49.0	46.2	45.1	47.7	41.2	37.4	46.1
	P1	15.6	13.8	13.2	14.4	12.0	11.0	13.3
N. C. Coast	P0	29.1	26.3	26.0	27.4	26.2	23.9	27.6
	P1	7.6	7.0	6.7	7.3	7.1	6.6	7.7
S. C. Coast	P0	12.4	12.7	12.1	13.4	14.4	14.0	15.9
	P1	2.6	2.7	2.5	2.8	3.3	3.0	3.5
C. Highlands	P0	28.4	28.1	27.3	29.1	29.1	28.2	31.5
	P1	8.8	8.4	8.1	8.8	8.7	8.1	9.5
South East	P0	5.7	6.6	6.6	6.8	9.6	9.4	10.1
	P1	1.4	1.7	1.6	1.7	2.7	2.6	2.8
Mekong R.D.	P0	10.2	10.3	10.2	11.0	14.8	14.2	15.8
	P1	1.8	2.0	1.9	2.1	3.3	3.2	3.5

Turning to regional patterns, some regions would have lower poverty rates, while others would experience higher poverty rates. Poverty rates would rise in the South Central Coast in all scenarios except 1b, and the South East in all scenarios. Poverty rates would also rise in the Central Highland if food prices increase by 50 percent, or if food producer prices increase significantly less than food consumer prices. More interestingly, except under Scenario 1b, the poverty rate increases in the Mekong River Delta- the most agriculturally productive region. A relatively high percentage of non-farmers in this region (35 percent) contribute to that result. Food price increases would reduce poverty in the North West, North Central Coast, Red River Delta and North East regions.

The normalized poverty gap index (P1) decreases slightly by 0.2 percent in Scenario 1a, but increases by 0.3 percent in Scenario 2a, implying a mixed direction as well in the poverty gap index of poverty.

6.5.2. Rice Prices and Household Welfare

Rice prices have increased sharply in international commodity markets since late 2007. The export price of Vietnam 5-percent broken rice almost tripled during one year, from $303/ton in April 2007 to $875/ton in April 2008. In the domestic market, the increase in the price of rice is less dramatic but it is still considerable. The price of grains, which are mostly rice, increased by 38 percent during the same period.

To study the effect of rice prices alone, assume that the prices of other foods are unchanged. This allows one to examine both the immediate effect and the short-run effect changes in rice prices, the latter of which allows consumers to substitute to other foods. Two scenarios will be examined: a uniform rice price increase of 20 percent and a uniform rice price increase of 50 percent[42].

Therefore, there are two scenarios:

(1) A uniform increase in the price of rice of 20 percent for both consumers and producers.

(2) A uniform increase in the price of rice of 50 percent for both consumers and producers.

We divide the effects into the immediate or first-order effect (1a and 2a) and the short-term or second-order effect (1b and 2b)[43].The estimation is based on equations (6.11) and (6.12) and on the compensated own- and cross- price elasticities that were estimated in Chapter 4 (Table 4.7).

The results are presented in Tables 6.8 and 6.9. On average, household welfare increases immediately by 1.3 percent in Scenario 1a, and 3.1 percent in Scenario 2a. Allowing for food substitution, the second-order effect is very small, less than 0.1 percent in Scenario 1b and 0.2 percent in Scenario 2b, because the demand for rice is price inelastic. Household welfare increases a little bit more in the short-term, but that difference between the short-term and the immediate effect is small. Even for a 50 percent increase in the price of rice, the difference is less than 0.2 percent. Overall, the short-term effect improves household welfare by about 0.1-0.2 percent more than the immediate effect.

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[42] The inclusion of differing consumer and producer prices of rice would make the analysis more complicated and hard to follow, especially since both the immediate effect and the short-run effect (which allows for food substitution) are examined.

[43] Thus, when Scenario *1* is mentioned, it implies both *1a* and *1b*.

In rural areas, household welfare increases by 1.9 percent and 4.8 percent, respectively, in response to a 20 percent and 50 percent price increase. In urban areas, household welfare decreases by 0.7 percent and 1.8 percent, respectively. If we divide the income quintiles into urban and rural areas, some interesting patterns emerge. In rural areas alone, the rural households in quintile 3 have the largest welfare increases: 2.9-3.0 percent in Scenario 1, and 7.2-7.4 percent in Scenario 2.[44] In contrast, the poorest quintile (quintile 1) in rural areas has the lowest welfare increases among rural households: 0.6-0.7 percent in Scenario 1, and 1.4-1.7 percent in Scenario 2. In urban areas, all quintiles experience lower welfare due to higher rice prices, but the welfare reductions are lowest for quintile 3: 0.4-0.5 percent in Scenario 1, and 1-1.2 percent in Scenario 2, and highest for quintile 1: 1.5-1.7 percent in Scenario 1, and 3.8-4.2 percent in Scenario 2. Therefore, the rural middle-income groups appear to receive relatively high benefits from an increase in the price of rice. In the contrast, the poorest households in rural areas receive small average benefits, while the poorest households in urban areas suffer the largest welfare reductions (relative to their previous welfare) from an increase in the price of rice.

Regionally, the Mekong River Delta has the largest welfare increase: 5.5-5.6 percent in Scenario 1, and 13.7-14.0 percent in Scenario 2. In contrast, the North East, Central Highlands and South East regions experience reductions in average welfare. The Central Highlands has the largest welfare reductions: 0.8-0.9 percent in Scenario 1, and 1.9-2.1 percent in Scenario 2. Rice farmers' welfare increases by 4.2 percent in Scenario 1, and 10.4-10.5 percent in Scenario 2. Households that do not grow rice

[44] The lower figures denote immediate effect (1a and 2a), while the higher figures imply the short-term effect (1b and 2b).

experience an average welfare reduction of 1.9-2.0 percent in Scenario 1, and 4.7-5.0 percent in Scenario 2.

Non-poor households have higher relative welfare increases than poor households: 1.4-1.5 (Scenario 1) and 3.6-3.8 percent (Scenario 2) for non-poor households, compared to 0.1-0.3 percent (Scenario 1), and 0.5-0.7 percent (Scenario 2) for poor households.

Columns 5 of Table 6.8 shows the percentages of households whose welfare falls, which are the same in both scenario since uniform increases of consumer and producer prices are assumed. This column shows the immediate effect but the short-term effect is almost the same in terms of the percentage of worse-off households. About 64 percent of Vietnamese households as a whole, 54 percent in rural areas and 92 percent in urban areas, are made worse-off by increases in the price of rice. Turning to welfare quintiles, about half of quintiles 1, 2 and 3 in rural areas are worse-off. The percentages are higher for quintile 4 and 5 in rural areas, where 60 percent of households in quintile 4 and 71 percent of households in quintile 5 are worse-off. Perhaps the rich households in rural areas are more likely engaged in non-farming activities than other rural households are. In urban areas, about 80 percent of households in quintile 1 and 2 are worse-off, while 94-96 percent of households in quintiles 4 and 5 are worse-off. Fifty-two percent of poor households have lower welfare than before, while 66 percent of non-poor households experience a reduction in welfare. Finally, half of farming households and about one-third of rice farming households have lower welfare than before.

Table 6.8: Household Welfare Change due to Rice Price Increases

	Scenario 1 (20%)		Scenario 2 (50%)		
	Immediate (1a)	Short-term (1b)	Immediate (2a)	Short-term (2b)	% of worse-off
All	1.25	1.31	3.12	3.28	63.8
Rural	1.91	1.97	4.78	4.93	54.4
Urban	-0.73	-0.66	-1.83	-1.65	91.8
Red River Delta	1.12	1.15	2.80	2.88	51.9
North East	-0.23	-0.19	-0.57	-0.47	57.2
North West	0.03	0.09	0.08	0.22	49.0
North Central Coast	0.28	0.35	0.71	0.86	60.8
South Central Coast	0.29	0.34	0.72	0.84	65.4
Central Highlands	-0.87	-0.76	-2.18	-1.91	80.8
South East	-0.58	-0.50	-1.46	-1.24	87.9
Mekong River Delta	5.50	5.59	13.74	13.99	64.7
Rural					
Quintile 1	0.57	0.66	1.43	1.65	51.0
Quintile 2	2.13	2.19	5.32	5.47	49.0
Quintile 3	2.89	2.95	7.22	7.36	51.6
Quintile 4	2.38	2.44	5.96	6.09	59.9
Quintile 5	1.62	1.66	4.05	4.15	70.8
Urban					
Quintile 1	-1.65	-1.50	-4.13	-3.75	78.1
Quintile 2	-0.84	-0.72	-2.10	-1.80	79.4
Quintile 3	-0.49	-0.39	-1.22	-0.97	86.9
Quintile 4	-1.00	-0.92	-2.50	-2.30	93.4
Quintile 5	-0.55	-0.50	-1.37	-1.26	95.7
Non-farmer	-1.65	-1.56	-4.14	-3.91	98.0
Farmer	2.38	2.43	5.95	6.09	50.5
Not growing rice	-1.98	-1.87	-4.95	-4.68	98.5
Growing rice	4.17	4.19	10.42	10.48	32.5
Non-poor	1.44	1.50	3.61	3.76	65.9
Poor	0.18	0.28	0.46	0.69	52.4

The South East and the Central Highlands have very high percentages of households whose welfare declines: 88 percent of households in the South East and 81 percent of households in the Central Highlands have welfare reductions. Only in the North West -- the region with the highest percentage of net rice sellers -- is the number of households whose welfare increases higher than the number of households whose welfare falls. Although, on average, households in the Mekong River Delta have the highest average welfare increase, almost two-thirds of the households in that region have lower welfare than before after an increase in the price of rice. About 52 percent of the poor would be worse-off and 48 percent would be better-off (or would be unaffected) from the change in the price of rice.

Table 6.9 shows that rice price increases have little effect on poverty. For a 20 percent increase in the price of rice, the effect is a reduction of the poverty headcount rate by 0.2 percentage points. When rice prices increase by 50 percent, the poverty headcount index is unchanged, but falls by 0.1 percentage points after short-term demand adjustments. While rice price increases would lower the poverty index in rural areas slightly, by 0.4 percentage points in Scenario 1, they would raise poverty in urban areas mildly, by a small amount, 0.3-0.4 percentage points.

Previous studies found mixed results regarding the impacts of rice price increases on household welfare. Using an international poverty line, Ivanic and Martin (2008) found that a 10 percent increase in the price of rice would reduce poverty by 0.5 percentage points in 1998 and 0.7 percentage points in 2004. In contrast, Minot and Goletti (2004) found that a 10 percent increase in rice prices would raise the (headcount) poverty rate by 0.3 percentage points immediately (before households' responses to prices) and by 0.2 percentage points after households' responses to prices. Note that the poverty headcount ratio defined in this chapter is different from those of both Minot and Goletti (2004) and Ivanic and Martin (2008). Minot and Goletti (2004) used the poverty measures defined by the population in the bottom 25 percent in terms of real per capita consumption expenditures; while Ivanic and Martin (2008) used the standard "dollar-a-day" expenditure-based measures of poverty from the 2007 World Bank *World Development Indicators.* The findings in this chapter imply that rice price changes have insignificant impacts on national poverty in Vietnam, and have little effect on both rural and urban areas. The impact of the increases in rice prices on the normalized poverty gap index (P1) for the country is also very close to zero in Scenario 1, and 0.2 percentage points in Scenario 2, indicating neither improvement nor worsening of the poverty gap in Scenario 1, and a slight increase in poverty depth in Scenario 2.

Table 6.9: Poverty Impacts of Rice Price Increases, under Three Different Scenarios

	0%		20% Immediate (1a)		20% Short-term (1b)		50% Immediate (2a)		50% Short-term (2b)	
	P0	P1	P0	P1	P0	P1	P0	P1	P0	P1
All	15.9	3.8	15.7	3.8	15.7	3.8	15.9	4.0	15.8	4.0
Rural	20.3	4.9	19.9	4.9	19.9	4.9	20.0	5.1	19.8	5.1
Urban	3.8	0.8	4.2	0.8	4.1	0.8	4.9	1.0	4.8	1.0
Red River Delta	8.8	1.5	7.7	1.4	7.7	1.4	7.2	1.3	7.2	1.3
North East	25.0	5.6	25.0	5.6	25.0	5.6	25.3	5.7	25.1	5.6
North West	49.0	15.6	49.9	15.6	49.9	15.5	51.1	15.7	51.1	15.7
North Central Coast	29.1	7.6	29.1	7.6	29.1	7.6	27.8	7.8	27.6	7.7
South Central Coast	12.4	2.6	12.5	2.6	12.5	2.6	12.2	2.7	11.8	2.7
Central Highlands	28.4	8.8	28.7	9.1	28.7	9.1	30.4	9.9	30.4	9.8
South East	5.7	1.4	5.8	1.5	5.8	1.5	6.7	1.7	6.6	1.7
Mekong River Delta	10.2	1.8	10.1	1.9	9.9	1.9	11.1	2.3	10.9	2.3
Non-farmer	5.0	1.1	5.6	1.2	5.6	1.2	6.8	1.6	6.6	1.6
Farmer	20.4	4.9	19.9	4.9	19.8	4.9	19.7	5.0	19.6	5.0
Not growing rice	7.5	1.7	8.4	2.0	8.3	2.0	10.1	2.6	9.9	2.5
Growing rice	23.4	5.6	22.2	5.4	22.2	5.4	21.1	5.3	21.0	5.3
Non-poor, rural	0.0	0.0	0.8	0.0	0.7	0.0	2.2	0.1	2.0	0.1
Poor, rural	100.0	24.2	95.1	24.2	95.0	24.1	89.7	24.8	89.5	24.7
Non-poor, urban	0.0	0.0	0.4	0.0	0.4	0.0	1.2	0.1	1.1	0.0
Poor, urban	100.0	19.9	99.5	21.8	99.5	21.7	98.1	24.7	98.1	24.3

Figure 6.5 presents non-parametric regressions of the net sales ratio (defined as the value of net sales of rice divided by household expenditure) on the logarithm of household expenditure per capita, for urban and rural areas. Thus, it indicates the magnitude of the possible welfare increase or reduction for households at different levels of welfare. Figure 6.5 shows that the net sales ratio in rural areas increases with household's living standards until the logarithm of expenditure per capita is around 9, (equivalent to an average expenditure per capita of 675 thousand VND per month). The curve then declines as the standard of living rises. The ratio is negative for very poor rural households, which implies that these households are harmed by increases in the price of rice. In urban areas, households are adversely affected at all welfare levels, but the poorest households are most adversely affected.

Figure 6.5: Nonparametric Estimation of Rise Net Sales Ratio for Urban and Rural Households (Bandwidth=0.2)

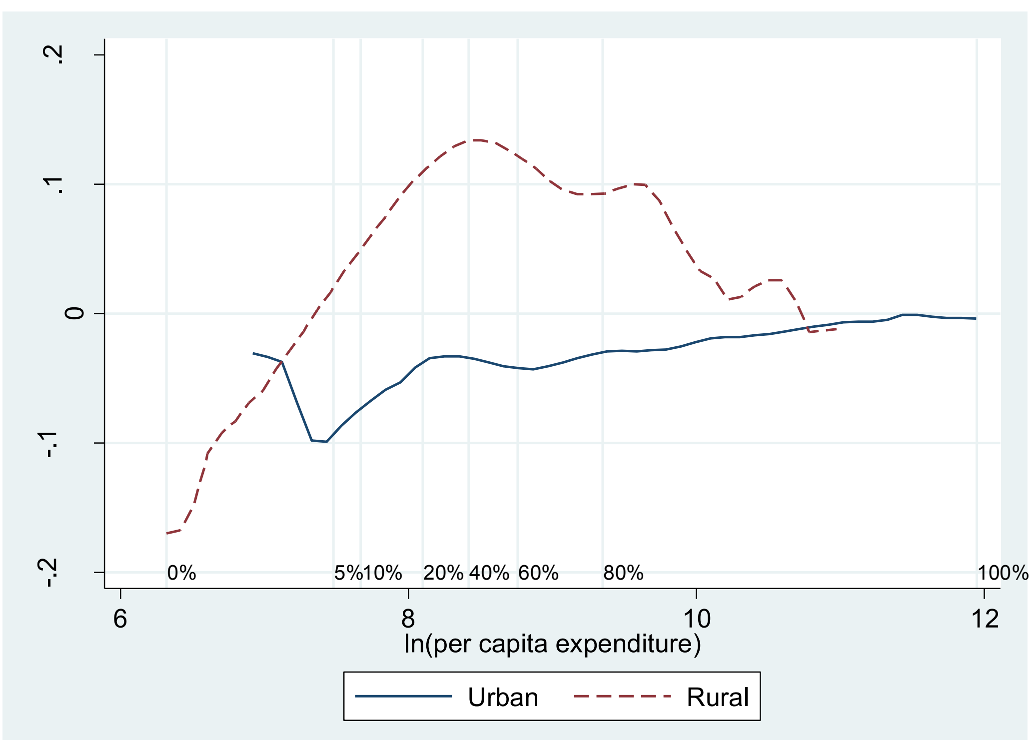

Figure 6.6: Nonparametric Estimation of Rise Net Sales Ratio for Households at Different Levels of Welfare

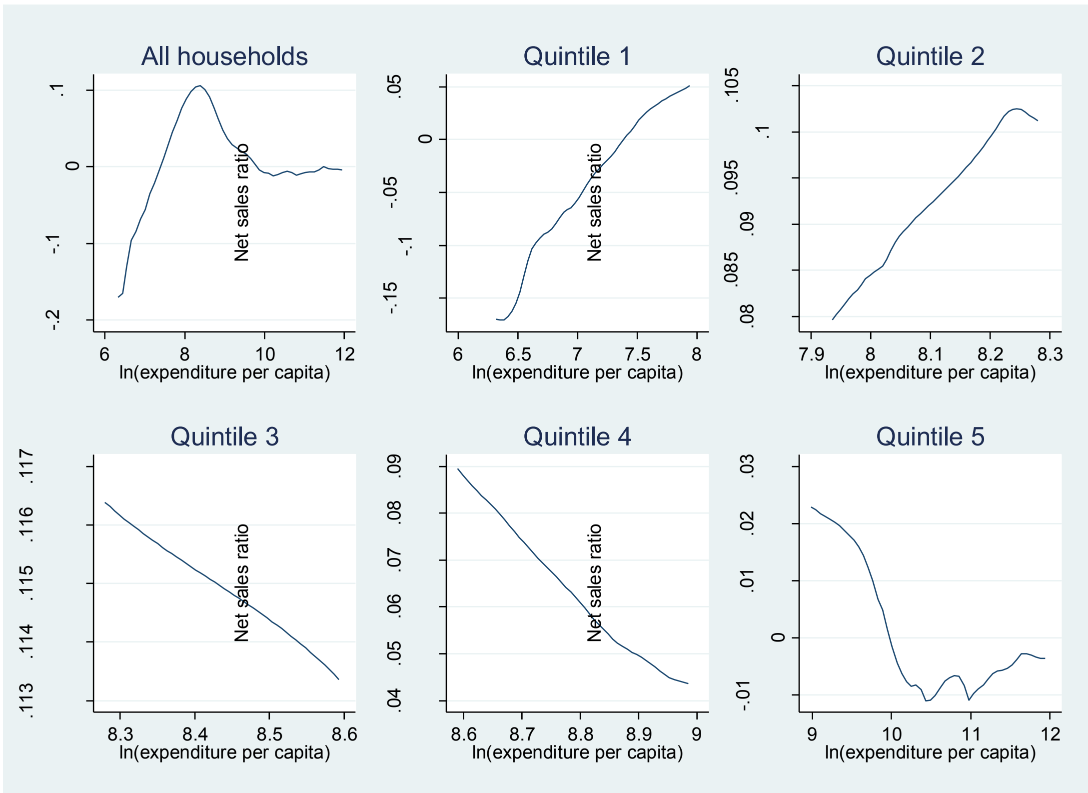

Figure 6.6 shows regressions of the net sales ratio on the logarithm of household per capita expenditure for each quintile. Increases in the price of rice primarily benefit quintiles 2 and 3, while the benefits are lowest for quintiles 1 and 5. This is consistent with theory, since the poorest households spend a relatively larger share of their budget on rice. Among the rich, only a minority of the rich households are rice farmers and net rice sellers: 18 percent of households in the fifth quintile grow rice compared to 53 percent for the whole population. Similarly, only 11.5 percent of households in the fifth quintile are net rice sellers, compared to 30 percent of all Vietnamese households.

Therefore, an increase in the price of rice will provide few benefits to the richest; instead it will primarily raise the cost of their consumption.

The average net sales ratios for all quintiles are positive, implying that a price change would increase the average welfare of all quintiles. Yet, although average welfare levels increase, a majority of households in all quintiles, especially quintiles 4 and 5, would experience a decrease in their standard of living. These results are striking even in the Mekong River Delta, the major rice production area; over 64 percent of households are worse-off following a uniform increase in the price of rice. The reason for this is the concentration of rice production in this region. Although it is the biggest rice producing area, a majority of households in the region do not produce any rice and thus are worse-off due to an increase in the price of rice. More specifically, only 37 percent of households in this region grow rice[45], less than the national average of 53 percent.

6.5.3 The Impacts of Food Price and Rice Price Changes in 2007-2008.

In this sub-section, we estimate the impacts of the cumulative food price and rice price changes that occurred from Jan, 2007 to Sept, 2008, using the price data from Vietnam's General Statistics Office. Since the producer price index in 2008 is not available, we assume that prices received by producers increase at the same rate as the food consumer price index in 2008. That assumption implies the price changes during 2007 and 2008 that are shown in Table 6.10.

[45] About 28% of the households in this region are non-rice farmers and 35% are non-farming households (including 9% who earn income from aquaculture activities).

Table 6.10: Changes in Food Consumer and Producer Prices, 2007 and 2008.

	2007	2008 (Jan-Sept)
Consumer prices		
Food	18.9	57.8
of which		
staples	15.4	78.1
non-staples	21.2	50.1
drink	6.78	18.1
Producer prices		
Food	18.1	56.7
of which		
staples	15.9	78.9

In chapter 4, the analysis divided food into eleven categories: rice, other staples, pork, poultry, other meats, fish and seafood, vegetables, fruit, other foods, drink and food away from home (FAFH). Yet, the GSO data provides price indices only for food of which: staples (including rice), non-staples foodstuff, and drink and tobacco. Thus, one must assume that the price index of FAFH is the general food price index. More generally, there are four price indices, corresponding to 11 food categories: the price index of rice and staples (categories: rice, staples), of non-staples foodstuffs (categories: pork, poultry, other meats, fruit, vegetables, and other foods), of drink (category: drink), and general food price index (category: FAFH).

These price indices are used to calculate the first-order effect (without demand adjustment) and the second-order effect (with demand adjustment) on household welfare (equations 7 and 10, respectively). The compensated price elasticities used to calculate second-order effect have been calculated in Chapter 4.

However, the second order effect is again very small. In all cases, the second order effect on welfare is less than one percent of the welfare change induced by the first-order effect. More specifically, Table 6.11 reports the immediate impact (first-order effect) and the short-term effect (both first-order and second-order effect) on household expenditure from food/rice price changes. It indicates that the second-order effect is negligible. Thus, this result is different from Friedman and Levinsohn (2002), who find the difference between the immediate impact and the short-term impact to be quite pronounced in Indonesia during the financial crisis. One reason for the difference between this study and Friedman and Levinsohn is that the aggregate data of food prices in this study do not provide detailed information about how prices of different food commodities changed. In contrast, Friedman and Levinsohn (2002) have detailed price data with considerable variation. In practice, the substitution effect might be more important if the rise in the prices of different foods differs significantly or if one has more exact data on different food items. Moreover, this study does not include non-food in the demand system, while Friedman and Levinsohn (2002) include non-food items. The inclusion of non-food items may result in larger estimates of second-order effects.

Table 6.11: Percentage Increase in Food/Rice Expenditure Due to Food/Rice Price Increase 2007/08

	2007		**2007-08**	
	Immediate	Short-term	Immediate	Short-term
Food price	18.90%	18.85%	57.80%	57.75%
Rice price	15.40%	15.64%	78.10%	77.48%

Table 6.12: Household Welfare Change (%) Due to Increases in Food and Rice Prices, 2007/08

	Food price change		Rice price change	
	2007	2007-08	2007	2007-08
All	2.78	9.23	1.02	4.97
Rural	5.16	16.66	1.55	7.58
Urban	-4.32	-12.93	-0.55	-2.84
Red River Delta	2.91	9.59	0.91	4.44
North East	1.73	5.83	-0.16	-0.88
North West	3.55	11.49	0.05	0.17
North Central	1.60	5.49	0.25	1.16
South Central Coast	1.06	3.88	0.25	1.17
Central Highlands	0.69	2.72	-0.64	-3.36
South East	-2.59	-7.46	-0.42	-2.24
Mekong River Delta	8.72	27.91	4.41	21.76
Quintile 1	3.00	9.90	0.38	1.77
Quintile 2	3.76	12.30	1.49	7.28
Quintile 3	3.88	12.68	1.86	9.15
Quintile 4	3.41	11.21	1.08	5.25
Quintile 5	-0.14	0.07	0.28	1.30
Non-farmer	-5.08	-15.28	-1.27	-6.46
Farmer	5.85	18.80	1.92	9.43
Not growing rice	-1.72	-4.78	-1.52	-7.73
Growing rice	6.86	21.91	3.32	16.45
Non-poor	2.74	9.12	1.17	5.73
Poor	3.00	9.86	0.19	0.79
Rural non-poor	5.60	18.03	1.85	9.11
Rural poor	3.37	11.03	0.29	1.30
Urban non-poor	-4.35	-13.03	-0.51	-2.66
Urban poor	-3.41	-9.99	-1.53	-7.84

Table 6.13: Change in Poverty Due To Increases in Food and Rice Prices 2007- 2008 (Percentage Points)

	Food price change				Rice price change			
	2007		2007-08		2007		2007-08	
	P0	P1	P0	P1	P0	P1	P0	P1
All	-0.64	-0.15	1.07	0.56	-0.22	0.00	0.31	0.51
Rural	-1.18	-0.28	-0.14	0.32	-0.39	-0.02	-0.06	0.55
Urban	0.83	0.19	4.41	1.23	0.25	0.06	1.33	0.43
Red River Delta	-1.36	-0.24	-1.21	-0.06	-0.91	-0.11	-1.52	-0.19
North East	-1.33	-0.37	-3.01	-0.48	-0.08	0.00	0.38	0.21
North West	-2.64	-1.58	-8.37	-3.73	0.73	-0.03	2.53	0.36
North Central	-2.49	-0.55	-2.44	-0.31	-0.04	-0.03	-2.68	0.45
South Central Coast	0.29	0.06	2.87	0.93	0.04	-0.02	-0.43	0.25
Central Highlands	0.20	-0.26	1.30	0.27	0.36	0.27	2.54	1.93
South East	0.91	0.27	4.91	1.68	-0.09	0.07	1.46	0.62
Mekong River Delta	0.16	0.16	5.79	2.13	-0.21	0.04	2.57	1.12
Non-farmer*	1.45	0.36	7.93	2.36	0.53	0.14	2.91	0.94
Farmer	-1.50	-0.36	-1.73	-0.17	-0.52	-0.05	-0.75	0.34
Not growing rice	1.22	0.28	6.77	2.09	0.73	0.22	4.15	1.42
Growing rice	-2.29	-0.53	-3.95	-0.79	-1.06	-0.18	-3.08	-0.28
Non-poor	1.48	0.07	6.01	0.84	0.49	0.01	2.97	0.24
Poor	-11.87	-1.31	-25.01	-0.90	-3.98	-0.01	-13.74	1.96
Rural non-poor	1.65	0.07	6.38	0.86	0.59	0.01	3.59	0.28
Rural poor	-12.28	-1.62	-25.71	-1.80	-4.22	-0.11	-14.38	1.57
Urban non-poor	1.10	0.06	5.17	0.79	0.28	0.00	1.56	0.14
Urban poor	-5.87	3.25	-14.78	12.29	-0.52	1.43	-4.47	7.59

In short, because the differences between the immediate (first-order) and the short-term (second-order) effects are very small, this chapter reports only the immediate effect. Table 6.12 presents the percentage change in welfare and Table 6.13 summarizes the impacts on poverty. Table 6.12 indicates that average household welfare increased by 2.8 percent from Jan, 2007 to Dec, 2007, and by 9.2 percent from Jan, 2007 to Sept, 2008 due to increases in food prices. Rice price alone leads to a 1 percent increase in household welfare in 2007 and 5 percent increase in the period Jan, 2007- Sept, 2008. While rural households gain substantially from food price increases, urban households experience welfare reductions. The middle-income groups are more likely to gain from food price increases than the lowest and the highest income households. In rural areas, non-poor households gain proportionately more than the poor, while in urban areas, the non-poor lost proportionately more than the poor.

Table 6.13 presents estimates of the impacts of poverty from increases in food and rice prices. In 2007, food price increases reduced the rate of poverty headcount by 0.6 percentage points. However, the sharp increase in 2008 leads to a reverse impact on poverty, and the total impact on poverty from the food price increases from Jan, 2007 to Sept, 2008 is to increase poverty rate by 1.1 percentage points. The increase in rice prices alone is responsible for about 0.3 percentage point increase in the poverty rate during 2007-08.

Yet, the above analysis does not take into account the complexity of the rice market in Vietnam. In practice, the increase in producer food prices may be significantly lower than the increase in consumer food prices, especially for small farmers. One reason is that in Vietnam, the export market is still dominated by a few large State-owned monopolies. Moreover, small farmers are less able to store their harvest and may need to sell their harvest at lower prices immediately after the harvest. As shown in table 6.6 above, the average welfare benefit would be substantially reduced if the increase in producer prices is significantly lower than the increase in consumer prices of food. Moreover, the medium-term and long-term welfare effects would also be lower if food price increases lead to increases in the prices of agricultural inputs, such as wages and prices of fertilizers.

6.6. Summary and Conclusion

This chapter demonstrates that the impacts of recent food price increases, especially rice price increases, on Vietnamese households are complicated. About 44 percent of Vietnamese households are net food sellers and 30 percent are net rice sellers. In rural areas, 54 percent of Vietnamese households are net food sellers and 38 percent are net rice sellers. The net food sellers will naturally benefit from increases in food prices.[46] However, the magnitude of the benefits depends on the relative changes of producer prices and consumer prices. If changes in these prices are uniform, an increase in food prices will induce an increase in the average level of household welfare. When food prices increase uniformly by 20 percent, average household welfare increases by 3.4 percent and the national poverty rate falls by 0.8 percentage points. When rice prices increase (uniformly) by 20 percent, the average household's welfare increases by 1.3 percent and the national poverty rate falls by 0.2 percentage points. However these impacts are sensitive to the relative changes of producer and consumer prices. If consumer prices increase at a lower rate than producer prices, welfare benefits are higher and poverty reduction is greater. On the other hand, if consumer prices rise faster than producer prices, the positive impacts of the price changes on welfare and poverty reduction are smaller. Examining the price changes that actually occurred in 2007-2008, this chapter finds that average household welfare increased by 9.2 percent relative to what it would have been had food prices not changed. Yet, poverty increased by 1.1 percentage points, again relative to no changes in food prices. In addition, increases in

[46] Yet, if the food consumer prices increase faster than the food producer prices, some net food sellers may still experience a decline in welfare because their increased food revenues are less than their increased food costs.

rice price alone raised average household welfare by 5 percent in relation to the situation where rice prices were unchanged, but the poverty (headcount) rate increased by 0.3 percentage points over what would have occurred without a change in rice prices.

Moreover, it is important to note that the benefits and costs are not spread evenly across the population. A uniform increase in both consumer and producer food prices would make 56 percent of households worse off, and similarly, a uniform increase in rice prices alone would make 64 percent of households worse off. In particular, a uniform increase in the price of rice would make about 54 percent of rural households and 92 percent of urban households worse off. Regionally, the South East and Central Highlands would be hit the hardest; with 80-90 percent of the population experiencing lower welfare. In the rural areas, rural middle-income households would gain the most while the poorest rural households would gain the least from an increase in the price of rice. On the other hand, in the urban areas, the poorest households lose the most (relative to their welfare) from higher rice prices. This indicates that support programs should target the poorest quintile in urban areas, as well as the poor people in regions that are hit the hardest from an increase in price such as the South East, and the Central Highlands. While the Mekong River Delta, which produces about 90 percent of Vietnam's marketable rice, certainly gains much from an increase in the price of rice, only about one-third of the households in this region are better-off due to rice price increases. This indicates that some kind of assistance to poor people, including those in the regions gaining much due to price changes, is necessary to offset the negative impacts of rice price increases.

Note that the analysis provided in this chapter takes into account the substitution effect in demand. Calibrating the simulations of a price increase with 2007-08 data for Vietnam reveals that the substitution effect is negligible in this case due to low cross-price demand elasticities.

Finally, it should be pointed out that there are several limitations of this chapter. First, the analysis does not examine the production response to increases in food and/or rice prices. As rice prices increase, farmers may response by expand their production. On the other hand, the price of agricultural inputs may also increase, reducing farmers' disposable income.[47] Second, data limitations do not allow one to fully explore the relationship between consumer and producer prices in different regions. The analysis indicates that the welfare and poverty effects are sensitive to the relative changes of consumer and producer prices, and generally the effects are more beneficial if producer prices increase faster than consumer prices. However, food producer prices are often unavailable or not updated as often as food consumer prices.[48] More sophisticated analysis, based on reliable and up to date regional consumer and producer price data would be useful for further research.

[47] According to the Prime Minister's Report to Vietnam's National Assembly in May 2008, in the Mekong River Delta, pesticide costs increased by 49.2 percent, irrigation costs by 66.3 percent, fertilizers costs by 42-360 percent, and labor costs by 31.4 percent in the Winter- Spring 2008 harvest, compared to the same period one year earlier. On average, farmers' net profits are 2,000 to 2,500 VND to one kilogram of rice. The average domestic rice price in May, 2008 is about 10,000 VND per one kilogram.

[48] The General Statistics Office collects producer price index (PPI) but publishes it only annually, while the consumer price index (CCI) is published monthly. The available PPI and CPI data do not list specific index for individual food and foodstuff items such as rice, maize, beef etc. On the other hand, the Ministry of Agriculture collects and publishes the local market prices for several food and foodstuff items, but does not publishes producer (or farm-gate) prices of these items.

CONCLUSION

This dissertation includes five essays on several aspects of food production and consumption in Vietnam. Specifically, it examines productivity and efficiency in Vietnamese agriculture; farm-level technical and scale efficiency in rice production in Vietnam; food demand system; income elasticities of calorie and micronutrient demand; and the welfare consequences of food price changes. This chapter summarizes the major findings.

First, this study shows that Vietnam's market reforms were followed by a period of high rate of growth in agricultural and rice production. Farmers evidently responded to market incentives by increasing their productivity and efficiency. Yet, in recent years, agricultural productivity growth has slowed as the benefits from a one-off round of incentive reforms have been fully realized. Government investment in improving agricultural research and development (R& D) and extension support is necessary if farmers are to sustain productivity growth in future years. This study also indicates that education plays an important role in improving farmers' technical efficiency. The labor force in Vietnam is relative well-educated, with literacy rates much higher than in the majority of countries at similar stages of development. This is an advantage that will help Vietnam continue to improve its agricultural productivity and efficiency.

Second, this study indicates that a relatively equal distribution of land is a key factor in reducing poverty. In Vietnam, landless rural labor is a very small proportion of the rural population, at around 2 percent (Minot and Goletti 2000). Most farmers in Vietnam are small-holders, and even the majority of poor rural population are net food sellers. Thus, an increase in rice price would generally lead to an increase in the income of most poor farmers. In contrast to studies in other countries (for example Deaton 1989 on Thailand), poor Vietnamese farmers can gain significantly from an increase in food prices in general, and in rice prices in particular. However, the relatively equal allocation of land among rural households in Vietnam has a negative impact on rice production efficiency, as shown in Chapter 3.

Third, this study indicates that rice export liberalization would lead to an increase in general welfare in Vietnam, while can still be consistent with food security. Policymakers have been worried that lifting rice export quotas would create food insecurity and worsen the nutrition situation among the population. This study demonstrates that modest increases in rice prices lead to higher welfare among poor people and do not lead to increases in poverty or undernutrition rates.

There are some limitations in this study that should guide future research. On the production side, further studies that extend chapter 2 by explicitly studying the role of incentives in improving agricultural productivity and efficiency would complement this study. In that chapter, fertilizers were dropped from the analysis due to incomplete data, which may lead to certain bias in the results. In addition, other methods such as growth accounting and stochastic production functions to study agricultural productivity in Vietnam may shed more light on this issue and thus complement this study. On the consumption side, using panel data from several household surveys would help alleviate some biases present in this study. In chapter four, the quadratic almost ideal demand system (QAIDS) may be a better model than the AIDS model used in this study. In chapter six, including the supply response effects may incorporate the medium-term and long-run effects from food price changes. For example, Ravallion (1990b) and Ivanic and Martin (2008) studied both the direct impacts of food price on consumers and producers and the indirect impacts via induced changes in agricultural wages.

I look forward to exploring these aspects more effectively in my future scholarly endeavors.

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APPENDIX

Appendix A1: Bootstrapping Procedure for Technical Efficiency (CRS Case) as in Simar and Wilson (1998, 2000)

i. Calculate the DEA efficiency scores under constant returns to scale (CRS) for each farm among N farms as in equation (1), denoted as $\hat{\theta}_i$ for the i[th] farm.

ii. Let $\beta_1^*,....\beta_k^*$ be a simple bootstrap sample from $\hat{\theta}_1,...\hat{\theta}_k$. Generate a random sample of size k for the random generator:

$$\tilde{\theta}_i^* = \begin{cases} \beta_i^* + h\varepsilon_i^* & \text{if } \beta_i^* + h\varepsilon_i^* \leq 1 \\ 2 - \beta_i^* - h\varepsilon_i^* & \text{otherwise} \end{cases}$$

where h is the bandwidth of a standard normal kernel density and ε_i^* is a random deviation from the standard normal.

iii. To correct the variance of the generated bootstrap sequence when kernel estimators are used, construct another sequence

$$\theta_i^* = \overline{\beta}^* + \frac{1}{\sqrt{1 + h^2 / \hat{\sigma}_\theta^2}} (\tilde{\theta}_i^* - \overline{\beta}^*) \text{ where } \overline{\beta}^* = (1/n) \sum_{i=1}^{N} \beta_i^* .$$

Thus, the sequence θ_i^* is obtained by the smoothed bootstrap. It has better properties than the simple bootstrap sequence in the sense that the variance of θ_i^* is asymptotically correct.

iv. For i=1,..,N, a pseudo data set of $(x_{i,b}^*, y_{i,b}^*)$ where $x_{i,b}^* = (\hat{\theta}_i / \theta_i^*) x_i$ and $y_{i,b}^* = y_i$ with x_i , y_i the original input and output vectors of the *ith* farm, respectively.

v. Calculate the new DEA score $\hat{\theta}_i^*$ for each farm by taking the pseudo data as reference

vi. Repeat step (i) to (iv) for B times to yield B new DEA technical efficiency scores $\hat{\theta}_i^*$ for i=1,…,N.

vii. Calculate the bootstrap bias estimate for the original estimator $\hat{\theta}_i$ as

$$\widehat{bias}_B(\hat{\theta}_i) = B^{-1} \sum_{b=1}^{B} \hat{\theta}_i^* - \hat{\theta}_i \ .$$

The bias-corrected estimator of $\hat{\theta}_i$ can be computed as $\hat{\hat{\theta}}_i = \hat{\theta}_i - \widehat{bias}_B(\hat{\theta}_i)$.

viii. The percentile method is involved in constructing confidence interval. The confidence interval for the true value of $\hat{\theta}_i$ can be established by finding value a_α, b_α such that Prob $(-b_\alpha \leq \hat{\theta}_i^* - \hat{\theta}_i \leq -a_\alpha) = 1-\alpha$. Since we do not know the distribution of ($\hat{\theta}_i^* - \hat{\theta}_i$), we can use the bootstrap values to find $\hat{a}_\alpha, \hat{b}_\alpha$ such that Prob $(-\hat{b}_\alpha \leq \hat{\theta}_i^* - \hat{\theta}_i \leq -\hat{a}_\alpha) = 1-\alpha$. It involves sorting the value of ($\hat{\theta}_i^* - \hat{\theta}_i$) for b =1,…, B in increasing order and deleting ($(\alpha/2) \times 100$ percent of the elements at either end of this sorted array and setting $-\hat{a}_\alpha$ and $-\hat{b}_\alpha$ at the two endpoints, with $\hat{a}_\alpha \leq \hat{b}_\alpha$.

In our empirical work, we set B=2000 to ensure the low variability of the bootstrap confidence intervals. The value of bandwidth of the density estimate *h* is found by Simar and Wilson (2000)'s method of minimizing an approximation to the mean weighted integrated square error.

Appendix A2: Food Items and Calorie Conversion Rate (Calorie per 1000 grams)

Food code	Food type	Conversion rates	Food group	Mishra & Ray
101	Ordinary rice	3530	Rice	3570
102	Glutinous rice	3550	Rice	2760
103	Corn/maize	3640	Staples	3560
104	Cassava	1560	Staples	1090
105	Potatoes	1088	Staples	760
106	Bread, wheat, flour	3015	Staples	3340
107	Noodle, pho noodle, instant rice soup	3580	Staples	2130
108	Rice noodle	3400	Staples	3600
109	Vermicelli	1285	Staples	3640
110	Pork	3956	Pork	2200
111	Beef	1233	Other meats	1500
112	Buffalo's meat	1233	Other meats	1500
113	Chicken	1759	Poultry	1220
114	Duck and other poultry meat	1260	Poultry	2910
115	**Other meat***		Other meats	
116	Processed meat	3259	Other meats	2330
117	Fat and oil	9270	Other foods	9020
118	Fresh fish, shrimp	900	Fish	420
119	Dried and processed fish and shrimp	2409	Fish	1610
120	Other seafood (crab, snails etc.)*		Fish	
121	Chicken or duck eggs	78 (per one)	Other foods	1390
122	Tofu	980	Other foods	2190
123	Peanuts, sesame seeds	5445	Vegetables	5730
124	Beans	3142	Vegetables	3410
125	Fresh peas	735	Vegetables	--
126	Water morning glory	210	Vegetables	300
127	Kohlrabi	300	Vegetables	230
128	Cabbage	370	Vegetables	190
129	Tomatoes	370	Vegetables	170
130	Other vegetables*	176	Vegetables	190
131	Oranges	430	Fruits	340
132	Bananas	830	Fruits	600
133	Mangoes	290	Fruits	450
134	Other fruits*	402	Fruits	170
135	Fish sauce and dipping sauce	332	Other foods	1000
136	Salt	0	Other foods	20
137	Spices, powdered soup	0	Other foods	--
138	Food seasoning	0	Other foods	--
139	Sugar, molasses*		Other foods	
140	Cakes, jams, sweets	4026	Other foods	4600
141	Condensed milk, powdered milk	3544	Other foods	610
142	Ice creams, yoghurts*	500	Other foods	610
143	Fresh milk	868	Drinks	610
144	Liquor	470	Drinks	2950
145	Beer	470	Drinks	2950

146	Bottled& canned refreshment	470	Drinks	390
147	Fruit juices	470	Drinks	390
148	Purified water	470	Drinks	390
149	Tonic water	1290	Drinks	--
150	Instant coffee*	--	Drinks	--
151	Powdered coffee	1290	Drinks	560
152	Powdered tea/instant tea*	0	Drinks	--
153	Dried tea*		Other foods	--
154	Cigarettes, tobacco	0	Other foods	--
155	Belter leaf	0	Other foods	--
156	Outdoor meals*	--	FAFH	--
157	Others*	--	Other foods	--

*Food without quantity information. The derivation of calorie intakes are based on the calorie "price" of the food groups.

Appendix A3: Review of Deaton's Approach

This section draws extensively from Deaton (1990), Huang and Lin (2000) and Niimi (2005). Deaton's approach is based on two equations: one is the budget share equation and the other is the unit value equations. For household i, good j, in commune c, we have the following equations:

$$w_{ijc} = \alpha_j + \beta_j \, ln\, x_{ic} + \gamma_j z_{ic} + \sum_h \theta_{jh} ln\, p_{hc} + f_{jc} + u_{ijc} \qquad \text{(A2.1)}$$

$$ln\, v_{ijc} = \alpha_j^* + \beta_j^* \ln x_{ic} + \gamma_j^* z_{ic} + \sum_h \varphi_{jh} ln\, p_{hc} + u_{ijc}^* \qquad \text{(A2.2)}$$

where w_{ijc} is the budget share of good *j* in the household *i*'s budget, x_{ic} is total food expenditure of household *i* the commune *c*; z_{ic} is a vector of household characteristic; p_{hc} is the price of good *h* in the total of *n* goods; f_{jc} is a commune-fixed effect for good i, to represent unobservable taste variation among different clusters but are shared by all households in each commune; and u_{ijc} and u_{ijc}^* are random errors.

Since the market price variable p_{hc} is unobservable in the model, it is impossible to estimate (A2.1) and (A2.2) directly. Deaton suggested a two-stage procedure to overcome this problem. The idea of this method is to link the price effect with the estimated residuals from the model without price variables.

In the first stage, it is assumed that there is no price variation in the same commune. Both equations are estimated separately by OLS with cluster means subtracted from all data. In the resulting equations, both the commune-fixed effect f_{jc} and the unobservable prices are removed as in the following:

$$w_{ijc} - w_{jc} = \beta_j (ln\, x_{ic} - ln\, x_c) + \gamma_j (z_{ic} - z_c) + (u_{ijc} - u_{jc}) \qquad \text{(A2.3)}$$

$$(ln\, v_{ijc} - ln\, v_{jc}) = \beta_j^* (\ln x_{ic} - \ln x_c) + \gamma_j^* (z_{ic} - z_c) + (u_{ijc}^* - u_{jc}^*) \qquad \text{(A2.4)}$$

Based on the estimated residuals from (A2.3) and (A2.4), one can estimate the matrices of covariance in each equation and across equations as $\Omega = Cov(u_{ijc}^* - u_{jc}^*)$ and $\Gamma = Cov[(u_{ijc} - u_{jc}), (u_{ijc}^* - u_{jc}^*)]$, respectively.

In the second stage, the between-commune information is used to estimate the price response. The effects of total expenditure and household characteristics are netted out to obtain the covariance matrices of price components and residuals. More specifically, we define the residuals netted out the expenditure and household characteristics as follows:

$$\varepsilon_{jc} = w_{jc} - \beta_j \, ln\, x_c - \gamma_j z_c = \alpha_j + \sum_h \theta_{jh} ln\, p_{hc} + f_{jc} + u_{ijc} \qquad \text{(A2.5)}$$

$$\varepsilon_{jc}^* = ln\, v_{jc} - \beta_j^* \ln x_c - \gamma_j^* z_c = \alpha_j^* + \sum_h \varphi_{jh} ln\, p_{hc} + u_{ijc}^* \qquad \text{(A2.6)}$$

The matrices of covariance associated with these residuals are calculated as:

$$S = Cov(\varepsilon_{jc}^*, \varepsilon_{jc}^*) = \psi M \psi' + (1/n)\Omega \qquad \text{(A2.7)}$$

$$R = Cov(\varepsilon_{jc}, \varepsilon_{jc}^*) = \psi M \Theta' + (1/n)\Gamma \qquad \text{(A2.8)}$$

where M is the covariance matrix of the unobservable market price, ψ is the covariance matrix of φ_{jh}, and Θ is the covariance matrix of θ_{jh}.

From the matrices S, R, Ω, and Γ, it is possible to deduct a matrix B, which is defined as

$$B = [S - (1/n)\Omega]^{-1}[R - (1/n)\Gamma] = (\psi M \psi')^{-1}\psi M \Theta' = (\psi')^{-1}\Theta' \quad \text{(A2.9)}$$

Finally, using matrix B, it is possible to derive information on the price effects by the following matrix:

$$E = [D^{-1}(w_j)B' - I][I - D(\xi_j)B' + D(\xi_j)D(w_j)]^{-1} \quad \text{(A2.10)}$$

where E is the matrix of owned- and cross-price Marshallian elasticities, I is an identity matrix, $D^{-1}(w_j)$ is a diagonal matrix with $(1/w_j)$'s as entries, $D(\xi_j)$ is a diagonal matrix with $(1/\xi_j)$ as entries, in which ξ_j is defined as $\xi_j = \beta_j^*/[(1 - \beta_j^*)w_j + \beta_j]$.

The expenditure elasticities are calculated as

$$e_j = 1 - \beta_j^* + \beta_j D^{-1}(w_j) \quad \text{(A2.11)}$$