Nutrition, Labour Productivity and Food Security in Thailand

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Abstract

Many households in less developed countries suffer from food insecurity which is unreliable access to a sufficient quantity of nutritious food. It is a major cause of malnutrition, and may lead to reduced worker capacity and low productivity. This study examines the impact of nutrient intake on the productivity of rice-producing households in Thailand. There are three objectives: first, to analyse the relationship between nutrient intake and labour productivity; second, to examine factors affecting the nutrition-labour productivity relationship; and third, to study the links between nutrition, labour productivity and food security.

Agricultural household models are used to examine decision-making behaviour, namely production, consumption, and labour allocation. The efficiency wage hypothesis is also examined where an increase in nutrient consumption increases labour productivity. Accordingly, labour is determined by caloric consumption, and nutrition affects productivity. The empirical study adopts econometric methods with data from Thailand's Socio-Economic Survey for 2011 for 2,781 rice-farming households. A semi-log wage equation and a Cobb-Douglas production function are estimated; and a logit model is used to examine the determinants of food security on the production-consumption relationship.

Results from the wage equation show that increasing consumption of calcium, vitamin A, vitamin C and iron increase household income, while increasing calorie intake reduces income. An increase in the consumption of grains and starches reduces income, whereas extra consumption of meat and poultry, fruits, vegetables and nuts lead to an increase in income. Male household heads earn more than female heads. Higher levels of education, age, the dependency ratio, and farm size increase income. In the production function, all nutrients affect farm productivity positively which supports the efficiency wage hypothesis. The logit results show that income, education, food expenditure, owning livestock, production for own-consumption, farm size, fertiliser use, and the use of family labour improve food-security; while household size, the dependency ratio, and total household expenditure do not.

In conclusion, enhancing micronutrient intake is an investment for improving productivity. The Thai government should focus on building awareness of nutrition in diet and provide dietary guidelines. Food quality and safety standards should be promoted to improve accessibility to nutritious foods. Policies on vitamin and mineral fortification of processed foods, including cooking oils, flours, salt, and sweetness additives, could be designed to improve nutrient-content.

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Table of Contents

List of Tables

List of Figures

Chapter 1 Introduction

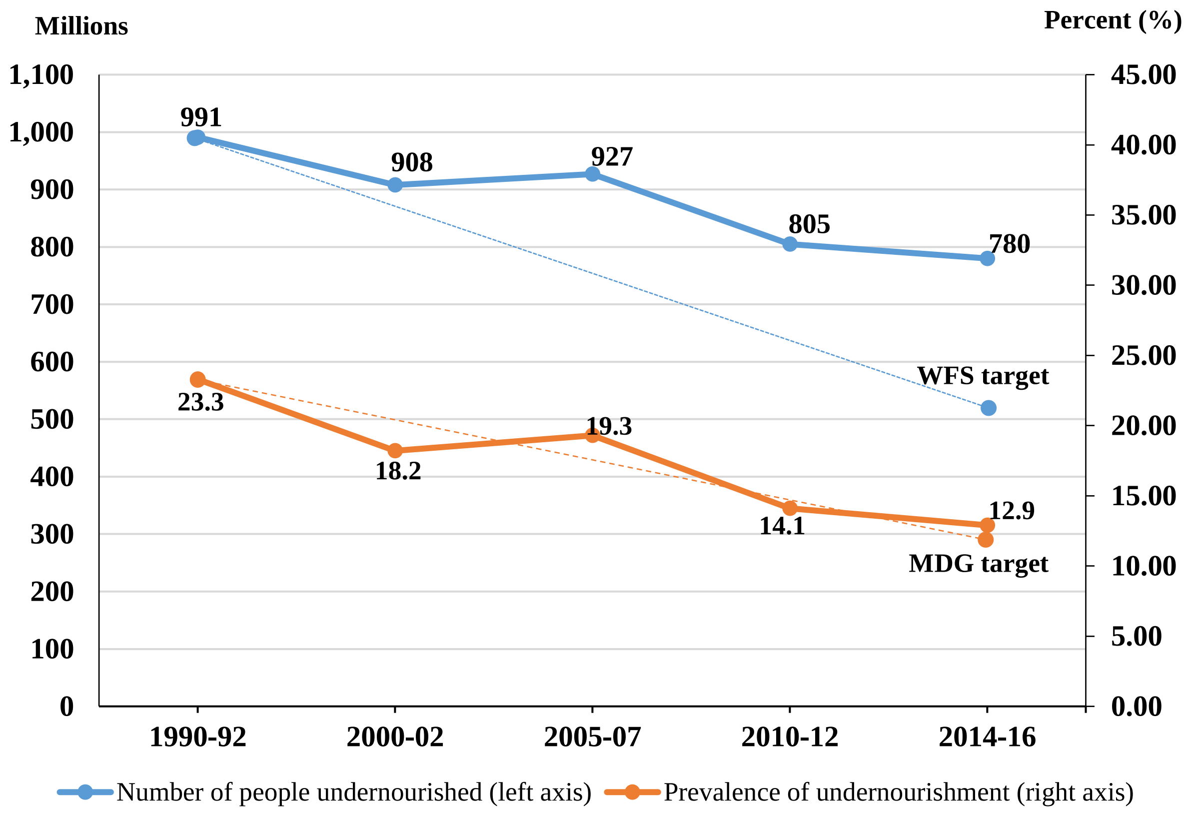
Food security and insecurity are often described in terms of whether people have access to a sufficient quantity of nutritious food or not. They are influenced by factors such as population growth, poverty, food supply shortage, food prices, political stability, economic crises, health issues, and natural disasters. Almost one billion people around the world are estimated to live without sufficient daily food consumption, especially those in developing countries (Hammond and Dube, 2011; the Food and Agriculture Organisation of the United Nations (FAO), the International Fund for Agricultural Development (IFAD) and the World Food Programme (WFP) (FAO/IFAD/WFP), 2015). Improving food security status is one of the most challenging issues for the global reduction of hunger and poverty, and for economic development.

In recognition of this challenge, the World Food Summit (WFS) sponsored by FAO (2002) adopted the definition of food security as "*Food security exists when all people, at all times, have physical, social, and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life*". This definition can be divided into four main pillars: food availability, food accessibility, food utilisation, and food stability (FAO, 2008). Food availability is explained in terms of the consistence of sufficient quantities of food available for all individuals through domestic food production, food imports, and food aid. Food accessibility is defined as an adequate supply of appropriate foods for a nutritious diet at the household and individual levels. Food utilisation is commonly understood as biological use of food consumed to provide sufficient energy and essential nutrients through food storage and preparation, feeding practices, potable water, and adequate sanitation. Food stability refers to the ability to maintain the other three dimensions over time.

Regarding the reduction of hunger, the WFS set a target for hunger reduction by eradicating the proportion of undernourished people by 50% by 2015. This is similar to the hunger target of the Millennium Development Goals (MDGs) of cutting by half the proportion of people who suffer from hunger, particularly in developing countries (FAO/IFAD/WFP, 2015). These two targets are internationally recognised by more than 180 countries, and are monitored by FAO using the three-year period 1990-92 as the starting point (FAO/IFAD/WFP, 2015). The estimated reduction of MDGs' target nearly reached the required point in 2014 – 16, while the number of people undernourished globally is still higher than the WFS's target (see Figure 1.1). The World Food Programme (WFP) (2015) also supports these targets by providing the Zero

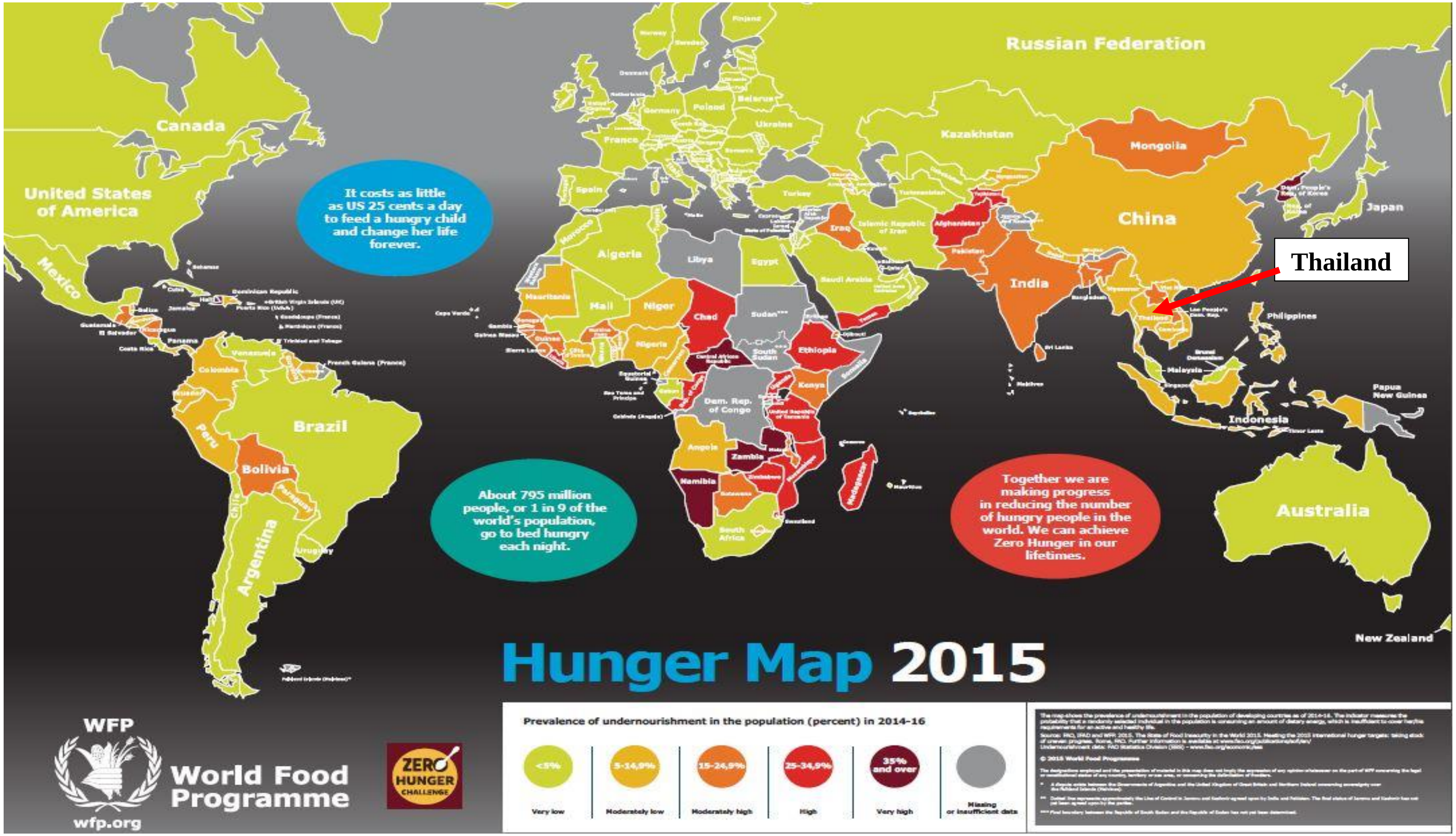
Hunger programme to end global hunger. The purpose of this proramme is to eradicate the number of hungry people around the world to zero or at least to be less than 5%. Figure 1.2 shows the Hunger Map which is measured by the prevalence of undernourishment in the population in 2015. The map reveals that there are many developing countries still suffering from undernourishment, and this includes Thailand. Although Thailand is a food surplus country, food accessibility is still problematic for low-income households.

Figure 1.1 The Proportion of Undernourishment in Developing Regions: Actual and Projected Progress towards the MDG and WFS Targets



Source: Adapted from FAO/IFAD/WFP (2015).

Figure 1.2 The Hunger Map, 2015



Source: WFP (2015).

Thailand is an agrarian country with more than 50% of its population in the labour force, of which around 40% are involved in agriculture, particularly in rice production (Office of National Economic and Social Development Board (NESDB), 2013). From the First (1961-1966) to the Eleventh National Economic and Social Development Plan (NESDP) (2012-2017), Thailand has rapidly shifted from a subsistence agrarian economy to a newly industrial country with about 40% of gross domestic product (GDP) absorbed by manufacturing (NSEDB, 2013). Socio-economic indicators have also steadily developed. The percentage of poor declined from 33% in 2002 to 13% in 2010 (NESDB, 2012). Likewise, the proportion of undernourishment fell from 35% in 1990-92 to 7% in 2014-16 (FAO/IFAD/WFP, 2015). Per capita income has risen by approximately 22% from 104,792 baht in 2009 to 127,395 Baht in 2012 (NESDB, 2013). Conversely, the average total monthly income of farm workers has been not changed between 2001-11: it is 14,000 Baht/month compared with the national average monthly income of 23,000 Baht/month. This level of income is a half that of self-employed and non-farm workers and three times lower than that of blue-collar workers (National Statistical Office (NSO), 2011).

Approximately 35% of the average expenditure of a Thai household is spent on food and beverages (NSO, 2011), with 60% of dietary energy consumption (DEC) acquired from food purchase (NSO and Office of Agricultural Economics (OAE) (NSO/OAE), 2012). The report of NSO and OAE on food security and nutrition status in Thailand of NSO and OAE which is collaborated with FAO (NSO/OAE, 2012) reveal that an average DEC of low-income households, including farm households in Thailand is 1,760 kcal/person/day, which is lower than the national minimum dietary energy requirement (MDER) of 1,882 kcal/person/day (NSO/OAE, 2012). The main source of energy intake is macronutrients which consist of protein, fat and carbohydrates. If low-income households have insufficient income for food, they suffer inadequate food access and malnutrition. The malnutrition may lead to poor health and reduced physical capability and worker capacity (Latham, 1990; Jha *et al.*, 2011; Croppenstedt and Muller, 2000). Eventually, this can lead to lower productivity and food insecurity. This thesis aims to examine the impact of nutritional intake on the productivity of rice-farming households in Thailand, which typically have low incomes, towards achieving food security. The objectives are: first, to analyse the relationship between nutrient intake and labour productivity; second, to examine factors affecting the nutrition-labour productivity relationship; and third, to study the links between nutrition, labour productivity and food security.

This research is the first application which estimates the nutrition-labour productivity link in Thailand, and it is also the first to estimate the determinants of food security among Thai rice-farming households. Empirical models are derived to test theories and research hypothesises on the nutrition-labour productivity link and food security. The findings of this research provide an evidence-based understanding of the relationship between nutrition, labour productivity and food security, make recommendations on enhancing labour productivity, overcoming undernourishment, and achieving the status of food security among low-income households, especially rice-farming households. The research should be of interest to the Thai government in identifying policies for supporting farm labour and improving agricultural household productivity.

The thesis is organised into eight chapters. Chapter 2 provides an overview of agriculture, nutrition and food security in Thailand. The chapter begins with a background of the country and its economy and then the agricultural sector is described. We also discuss the status of national nutrition and food security as well as current food security policies.

Chapter 3 presents a literature review of nutrition status and labour productivity. It discusses economic theories, econometric approaches and literature that relate to the relationship between nutritional status and labour productivity. We first discuss agricultural household models (AHM) in which production, consumption and labour supply decisions are jointly determined. The AHMs are the theoretical main framework of this study. Then, we review the literature on the AHMs and the nutrition-labour productivity link. Econometric approaches are then examined. Finally, we review the literature on labour productivity and nutritional status in Thailand.

Chapter 4 provides a theoretical framework of the nutrition-labour productivity relationship for rice-farming households in Thailand. We present the decision-making behaviour of farm households which is used as the theoretical framework for constructing an econometric model of the nutrition-labour productivity relationship at the household level. We introduce fundamental concepts of the utility function and the production and income functions of farm households. Then the decision-making behaviour of the farm household is discussed, and we distinguish between subsistence, commercial, and semi-commercial farm families, and some comparative static propositions are examined. We also introduce the labour efficiency function based on the efficiency wage hypothesis. Then, the empirical model of the relationship is developed using the AMH and the efficiency wage hypothesis. A semi-log wage equation and a Cobb-Douglas production function are chosen to examine the nutrition-labour productivity link.

Chapter 5 explains the econometric approaches that are used to estimate the nutrition-labour productivity links of rice-farming households. We first introduce the causes of endogeneity, particularly the reverse-causality problem which commonly occurs. Then, two-stage least squares (2SLS), which is used to solve the endogeneity problem, is presented. We also present two-step quartile regression (2SQR) which is applied to address the endogeneity problem at different quartiles. Next, we discuss non-linear two stage least square (NL2SLS) which is used to examine non-linear relationships. Finally, we specify two empirical models for estimating the nutrition-labour productivity relationship, namely a semi-log wage equation using 2SLS and 2SQR and a Cobb-Douglas production function using NL2SLS.

Chapter 6 describes the cross-sectional data of National Statistical Office (NSO), 2011, Thailand which is used in this study, and its limitation. The chapter also presents the results of the nutrition-labour productivity relationship which are separated into two main parts. First, we present the results of descriptive statistics and the 2SLS semi-log wage equation, then the results are explored at different quartiles using 2SQR method. Second, the NL2SLS results of Cobb-Douglas production function are presented.

Chapter 7 examines the food security status of rice-farming households. We review the literature on food security, focusing on the definition of food security and its determinants at the household level. We discuss and estimate a binary logit (logistic) model.

Chapter 8 summarises, draws some conclusions and provides policy implications. The contribution and limitations of the study are indicated and some potential issues for further research are recommended.

Chapter 2 Agriculture, Nutrition, and Food Security in Thailand

2.1 Introduction

This chapter describes agriculture, nutrition and food security in Thailand. Agriculture is an important sector and is the largest source of employment for the rural population, especially rice-farming households (Isvilanonda and Booyasiri, 2009). Agriculture not only plays a significant role in export earnings, but also contributes significantly to domestic food supply and nutritional security. Nutritious foods are key to ensuring good health and well-being. A lack of access to nutritious foods leads to malnutrition and undernourishment with related health problems. On the other hand, the rise of over-nutrition, resulting from changes in lifestyle and eating patterns, has a negative impact on nutrition and health. Understanding these problems and how the agriculture-nutrition interaction affects productive capacity is an important step towards overcoming food and nutritional insecurity. This chapter is organised as follows: Section 2.2 provides an overview of Thailand, including the economy; Section 2.3 describes Thailand's agriculture; Section 2.4 discusses the status of national nutrition; Section 2.5 describes food security; Section 2.6 discusses national food security policies; and Section 2.7 summarises.

2.2 Overview of Thailand

Thailand is a country of 514,000 square km with 2,420 kilometres of coast line. It is located on the Indochina peninsula of Southeast Asia and is bordered by Burma (Myanmar), Laos People's Democratic Republic, Cambodia and Malaysia (see Figure 2.1). Thailand is divided into five regions - Northern, Southern, Northeast, Eastern, and Central regions. Bangkok is the capital.

Figure 2.1 Map of Thailand

Source: www.maps-thailand.com.

Thailand’s population increased from 46m in 1980 to 64m in 2012 with 40% residing in rural areas (NESDB, 2012). Approximately 95% of the population is Buddhist and the official language is Thai. Since 1980, the annual population growth rate has reduced from 3.2% to 1.2% in 2011. Likewise, the average household size has fallen from 3.8 to 3.2 over the last decade because of extensive family planning programmes. More than 50% of the population formed the labour force in 2011, and 38% worked in agriculture (Table 2.1).

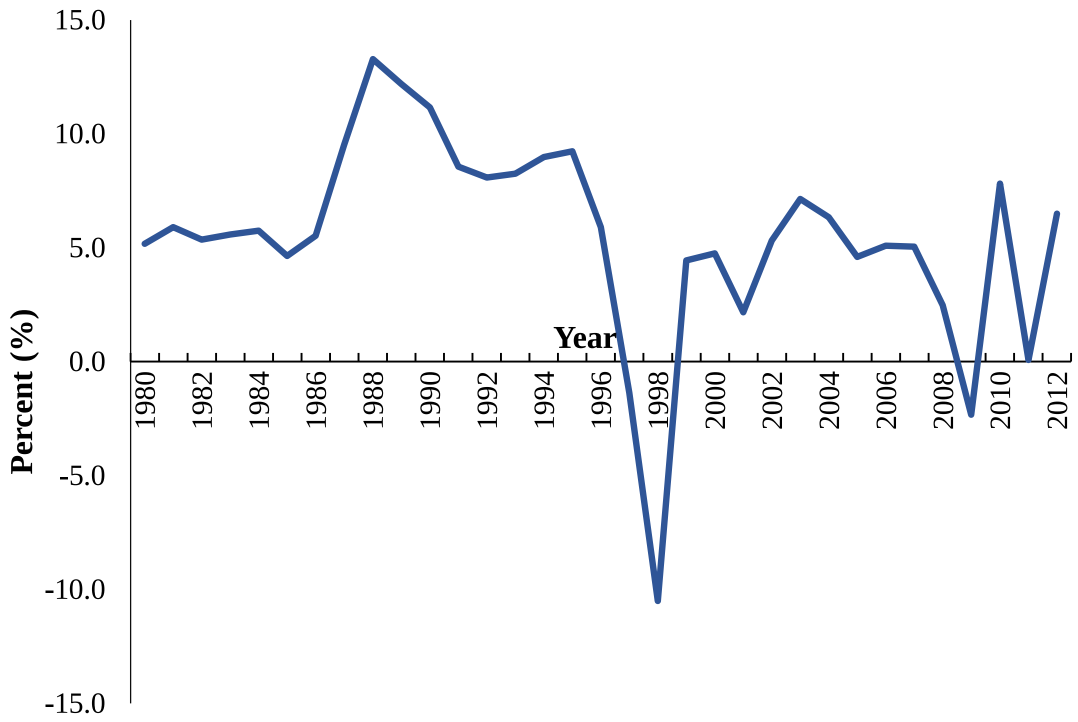
Table 2.1 Number and Percentage of Employed Persons (1,000 persons) by Industry, 2011

Industry	Number	Percentage
Agricultural (agriculture, forestry, and fishing)	14,883.10	38.24
Non-Agricultural	23,581.55	60.59
1. Mining and quarrying	49.96	0.13
2. Manufacturing	5,301.37	13.62
3. Electricity, gas and air conditioning	101.29	0.26
4. Water supply, water and sewage management	88.78	0.23
5. Construction	2,371.90	6.09
6. Wholesale and retail trade, repair of motor vehicles motorcycles and personal and household goods	6,037.02	15.51
7 Transport, storage and communication	937.32	2.41
8. Hotel, restaurants and service	2,545.71	6.54
9. Financial intermediation and insurance	395.45	1.02
10. Social and communication	181.42	0.47
11. Real estate, renting and business activities	105.83	0.27
12. Science and technology	268.18	0.69
13. Administrative and support service	394.34	1.01
13. Public administration and defence compulsory social security	1,596.39	4.10
14. Education	1,287.40	3.31
15. Art and entertainment	230.11	0.59
16. Health and social work	671.01	1.72
17. Other community, social and personal service activity	739.56	1.90
18. Private households with employed persons	247.29	0.64
19. Extra-territorial organisations and bodies	3.24	0.01
20. Unknown	28.02	0.07
Total	**38,921.50**	**100.00**

Source: NSO (2012).

Thailand is a developing country with more than 60% of GDP dependent on exports (NESDB, 2012). In Figure 2.2, real GDP growth was around 5% between 1980 and 1985. It raised to 13% in 1986/87 and dropped subsequently to -10% in 1998 as a result from the national financial crisis of 1997 before recovering. Since the the global financial crisis in 2009, real GDP growth declined to -2%, and once again in 2011 due to Thai floods. Since 1980, economy grew 6% on average.

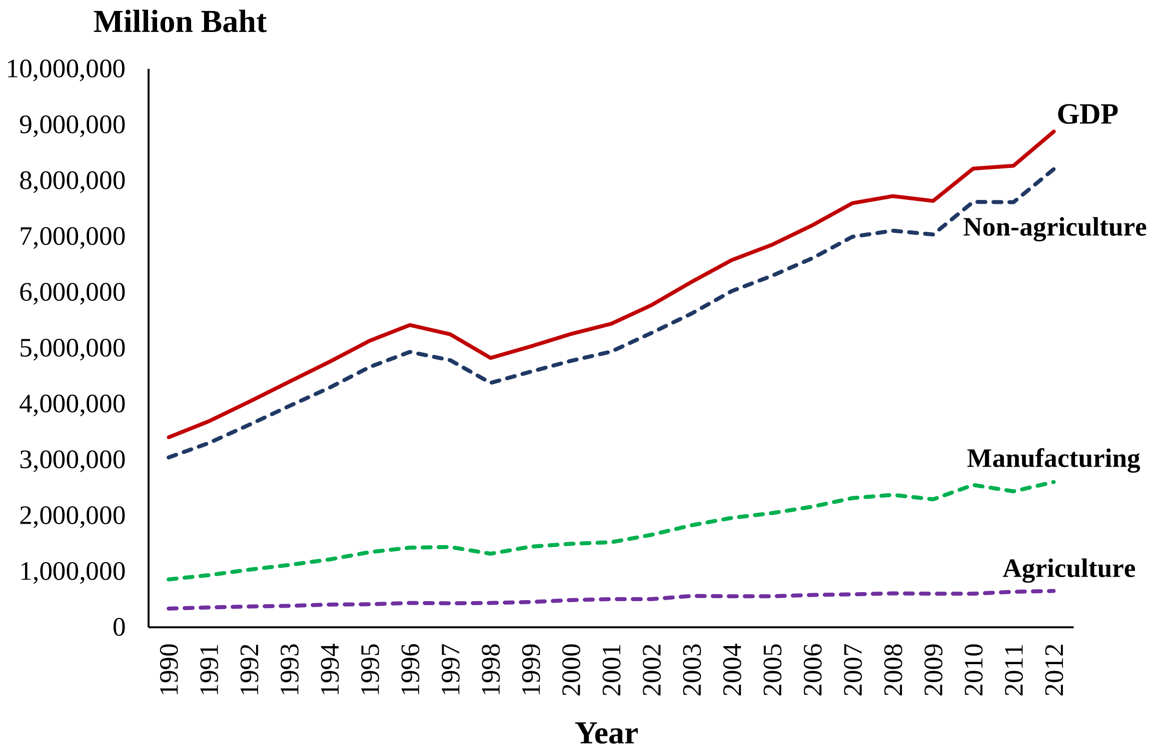
Figure 2.2 Real GDP Growth Rate, 1980-2012



Source: World Bank (2015).

The structure of GDP has shifted from being agriculture-based to manufacturing and non-agriculture. Figure 2.3 shows that the real GDP of non-agriculture products was eight times higher than that from agriculture in 1990 and this increased to 12 times in 2012. Important exports are motor vehicles and machinery and equipment, electronics and computer equipment, rubber and plastic products, chemicals and chemical products and canned seafood (NESBD, 2012). Although agricultural production accounted for only 8% of GDP in 2012, it is important since the majority of the population earn their living from this sector (NESBD, 2012). The main agricultural exports are natural rubber, rice and rice products, sugarcane, fishery and seafood products, processed chicken, and cassava (OAE, 2012a).

Figure 2.3 Real GDP , 1990–2012

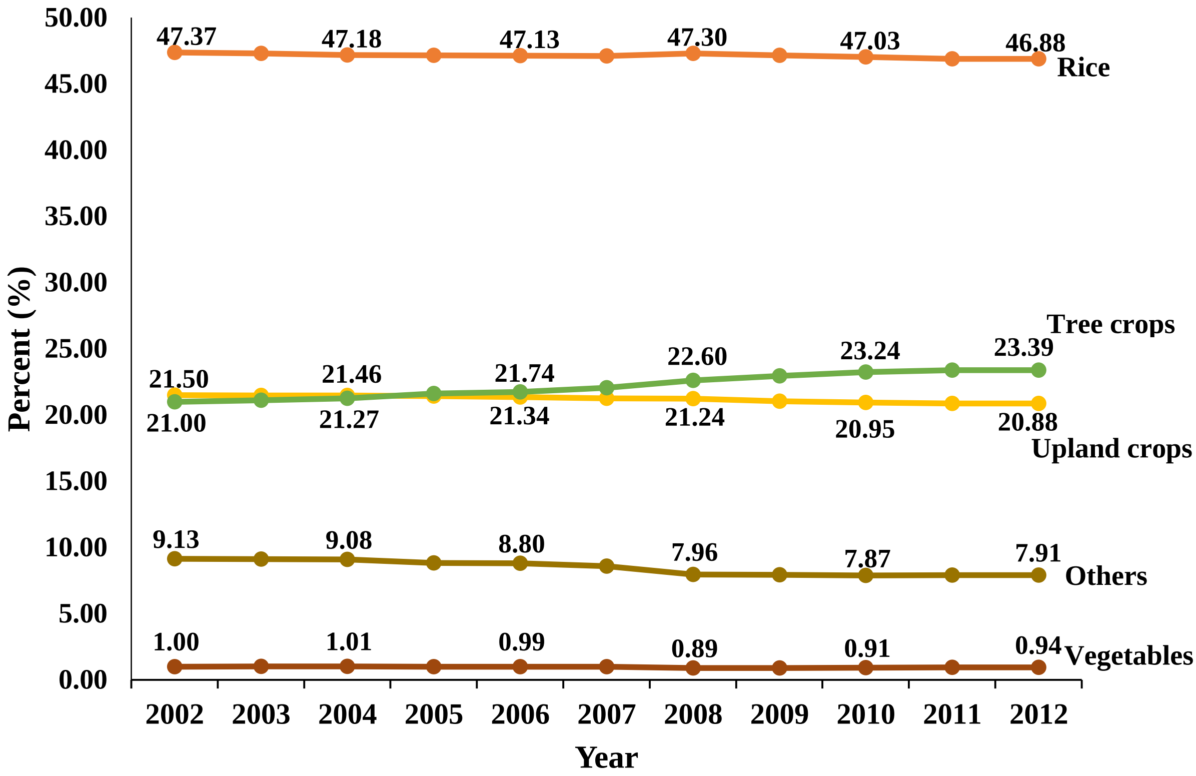


Source: NESDB (2012).

2.3 Thailand's Agriculture

In the first National Economic and Development Plan (NEDP) (1961-1966), Thailand made steady progress in food production and economic development (Tontisirin *et al*., 2013). Food production mainly focused on expanding agricultural areas to increase productivity. Around 43% of the total land area is used for agriculture, 37% is forest and 20% is unclassified (FAOSTAT, 2013). Almost 50% of agricultural land is used for rice paddy (Figure 2.4). The percentage of cultivated land for rice declined by 1% between 2002–2012, while that of tree crops, including rubber, increased from 21% to 24%. Other important crops are maize, cassava, sugarcane and oil palm.

Figure 2.4 Share of Total Agricultural Land Use by Crops, 2002-2012



Source: Calculated from OAE (2012b).

Rice is the main staple food which is produced both for domestic consumption and export. It is grown throughout the country, especially in lowland areas (Isvilanonda and Bunyasiri, 2009). The largest share of rice area and production is in the Northeastern region, 50% and 35% respectively (OAE, 2012a). Household rice production in this region is mostly for self-sufficiency, and the surplus is sold. Commercial rice production is in the Central and lower Northern regions, and rice exports mostly comes from these areas (Isvilanonda and Bunyasiri, 2009).

Table 2.2 shows that rice production increased by 32% between 2002 –2012. The harvested area also increased from 60,335 to 75,266 thousand rais.[1] In 2004, 35% of rice production was exported but this proportion fell to 18% in 2012 due to the strong Thai Baht compared to trading competitors such as India and Vietnam (Isvilanonda and Bunyasiri, 2009; NESDB, 2012). Only 2% of the total GDP is accounted for by rice exports (NESDB, 2012).

[1] 1 rais = 0.16 hectares.

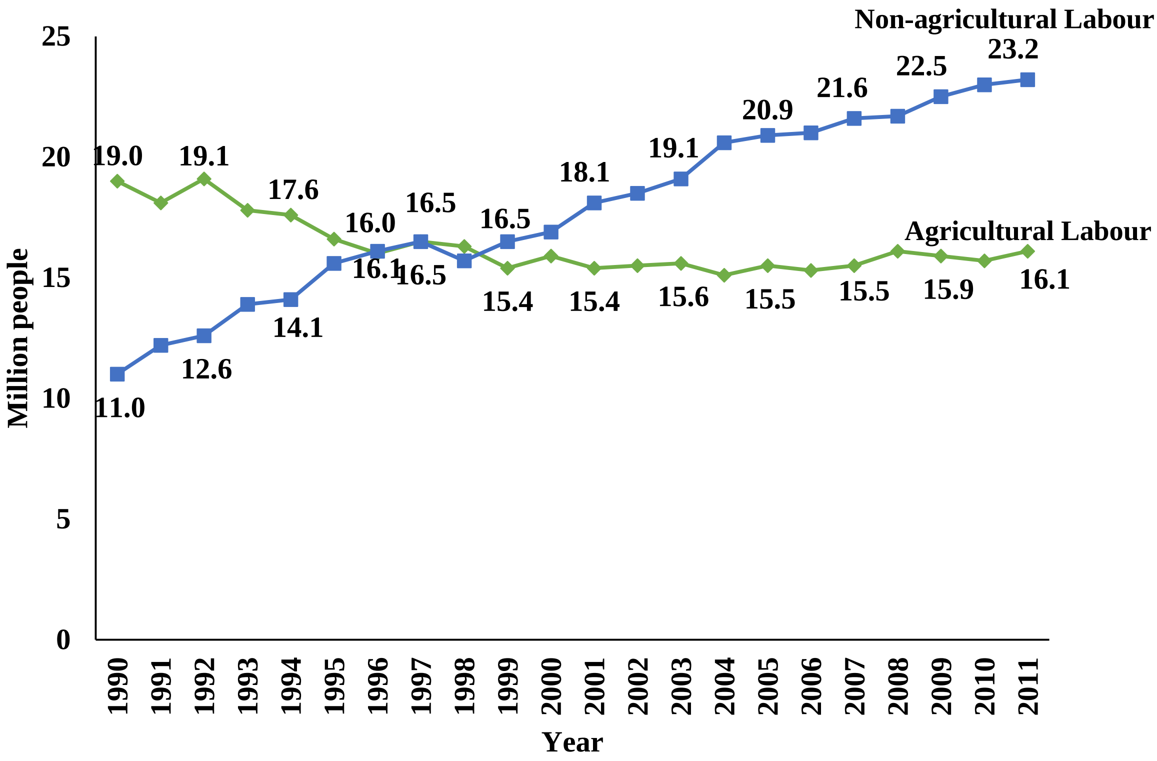
Table 2.2 Rice Production, Areas and Export, 2002-2012

Year	Planted area (1000 rais)	Harvested area (1,000 rais)	Total rice production (1000 tonnes)	Total rice export (1000 tonnes)	% of export to total production
2002	66,440	60,335	27,992	7,334	26.2
2003	66,404	63,524	29,823	7,346	24.6
2004	66,565	62,455	28,873	9,977	34.6
2005	67,677	63,906	30,649	7,496	24.5
2006	67,616	63,532	29,994	7,494	25.0
2007	70,187	66,681	32,482	9,193	28.3
2008	69,825	66,772	32,020	10,216	31.9
2009	72,720	69,626	32,396	8,620	26.6
2010	80,676	75,747	36,004	8,940	24.8
2011	83,329	74,652	38,091	10,712	28.1
2012	79,754	75,266	36,854	6,734	18.3

Source: OAE (2012a).

In Figure 2.5, agricultural labour declined from 19m in 1990 to 16m in 2011, while that of non-agricultural labour increased from 11m to 23m. *Per capita* income of agricultural workers is lower than that of other workers and this is one factor influencing the changing structure of the agricultural population (NSO, 2012). In addition, MOAC (2011) reports that agricultural labour lacks protection and secure welfare which may push farm workers into the non-agricultural sector.

Figure 2.5 Labour Force in Thailand, 1990–2011



Source: NSO (2012).

In 2010, the agricultural sector comprised of 4.7m farm households which are engaged in rice farming (OAE, 2012b). Most of them are smallholders with an average land holding of around 22 rais (or 3.5 hectares), and grow a single crop (OAE, 2012b; Piotrowski et al., 2013). Additionally, average household members decreased from 4.1 to 3.7 persons between 2003–2008 (NSO, 2010). Approximately 75% of rice farmers has an educational level at elementary level or lower (NSO, 2012). The agricultural population is aging: household members aged over 65 years increased from 5.2% in 2001 to 9.4% in 2010 (MOAC, 2011), while the proportion of the agricultural workforce aged between 15–65 years fell from 74% to 69%. The average annual income of agricultural workers including rice farmers in 2010 was 196,389 Baht (5,692 US$) per household (or 49,719 Baht (1,441 US$) per individual). This is a half that of self-employed, non-farm workers and three times lower than that of blue collar workers (NSO, 2011). Thus, rice-farming households are classified as a low-income households. More significantly, NSO/OAE (2012) report that low-income households have an average dietary energy consumption (DEC) of 1,760 kcal/person/day which is lower than the average national minimum dietary energy requirement (MDER) of 1,882 kcal/person/day. This may contribute to malnutrition and food insecurity for rice-farming households, and low incomes may also lead to poor living conditions.

2.4 National Nutrition

Until to the third NEDP (1972–1976), nutrition was not recognised as an issue for national development. In the late 1970s, undernutrition, nutrition deficiency and diseases were highly prevalent and became major medical and public health concerns (Tontisirin *et al*., 2013). To stress the social importance of nutrition for economic development, subsequent NEDPs incorporated "Social" and became National Economic and Social Development Plans (NESDPs) (Tontisirin *et al*., 2013), and the health sector focused on providing preventive measures on nutrition challenges. Further, health experts realised that controlling and preventing nutritional deficiencies requires multi-sectoral approaches (Kachondham *et al*., 1992; Tontisirin *et al*., 2013), and in 1977 the first Food and Nutrition Plan (FNP) was included in the fourth NESDP (Tontisirin *et al*., 2013). It aimed at tackling seven major nutrition problems: protein-calorie malnutrition, vitamin A deficiency, iron deficiency, riboflavin (vitamin B2) deficiency, thiamin (vitamin B1) deficiency, phosphorous deficiency (urinary bladder stone disease), and iodine deficiency (goitre), (Winichagoon, 2013). Also, it aimed at preventing malnutrition, mainly undernutrition, and improving nutritional status (Tontisirin *et al*., 2013).

In the fifth NESDP (1982–1986), malnutrition was considered as a symptom of poverty, and the Poverty Alleviation Plan (PAP) was designed to alleviate malnutrition and poverty by encouraging multi-sectoral planning to cover FNP and Primary Health Care plan (PHC)[2] (Tontisirin and Kiranandana, 1990; Tontisirin *et al*., 2013). Nutrition was an indicator in implementing the PAP as a part of multi-sectoral efforts at the community level with a focus on improving basic minimum needs of nutrition (Kachondham *et al*., 1992). The success of implementing the community-based approach produced large reductions in protein-energy malnutrition (PEM) and micronutrient deficiency over the last two decades, especially in children and pregnant women (Tontisirin *et al*., 2013; Winichagoon, 2013).

In 1992, the national School Lunch Programme (SLP) and School Milk Programme (SMP) were introduced to provide high quality diets not only in terms of energy but also protein, calcium and other micronutrients needed for growth among school children (Tontisirin *et al*., 2013). Tontisirin *et al*. (2013) report that these programmes have had a positive impact on child nutrition. This is also beneficial to local farmers who provide milk for the programmes. In 1998, government policy on decentralization, which allocates budgets for local administration, was gradually implemented according to the Thai King's Sufficiency Economy Philosophy for

[2] PHC is the policy that focuses on enhancing health coverage and quality of care.

household food security. Food and nutrition issues were managed at local community level. Several tools for nutrition information, education and communication were developed and promoted for desirable eating practices and knowledge such as nutrition labelling and Food-Based Dietary Guidelines (FBDGs).

Figure 2.6 shows the nutrition status, policies and strategies of Thailand during 1st – 11th NESDPs. The proportion of PEM fell from over 50% in 1981 to 7% in 2012 (FAO, 2012). The percentage of vitamin B1 deficiency declined from 23% in 1960 to less than 1% in 1995 (Department of Health (DOH), 1960; DOH, 1995), and the proportion of vitamin B2 deficiency fell from 47% to less than 1% (DOH, 1960; DOH, 1995). Tontisirin *et al.* (2013) report that vitamin B1 and B2 deficiencies are no longer a public health issue. In addition, the percentage of low serum retinol occurrences diminished by more than 90% between 1960-2003 when only 2% of reproductive women were deficient (Bureau of Nutrition (BON), 2011a; Wanichagoon, 2013). The percentage of iron-deficiency anaemia in pregnant women fell from 57% to 10% over the past 40 years (DOH, 1960; DOH, 2005a), although iron is still deficient in rural areas and iodine has been deficient for the past 40 years (Tontisirin *et al.*, 2013). Although the goitre rate in children, which is used as an indicator of iodine deficiency, declined from 29% to around 1% between 1960-2003, the proportion of urinary iodine concentration (UIC) in pregnant women, which is also an indicator of iodine deficiency, was relatively high in over 40% of pregnant women in 2010 (BON, 2011b). Consequently, the universal salt iodisation (USI) strategy was implemented in 2011 (Tontisirin *et al.*, 2013).

Figure 2.6 The Nutrition Status, Policies and Strategies of Thailand during 1st – 11th NESDPs

Nutrition Situation	Thailand's Development Plans	Polices and Strategies
1960 - Anaemia in pregnant women: 57%, - B1 deficiency: 23% - B2 deficiency: 47% ……- Low serum retinal: 38% ……- Goitre in children: 29%	1960 – 1967: 1st NEDP	: Economic infrastructure, Sectoral plans
	1967 – 1972: 2nd NEDP	: Improvement of agriculture and infrastructure
	1972 – 1977: 3rd NEDP	
	1977 – 1982: 4th NESDP	: Social plan, FNP, PHC
1982 - PEM: >50%,	1982 – 1987: 5th NESDP	: PAP + integrated and implemented PHC +FNP and basic minimum needs indicators in rural communities
1986 - PEM: 30%, 1989 - Goitre in children: 29% 1991 - Anaemia in pregnant women: 18%	1987 – 1992: 6th NESDP	
1995 - B1 deficiency: <1% - B2 deficiency: <1%	1992 – 1997: 7th NESDP	: SLP and SMP
1996 - PEM: 15%, - Anaemia in pregnant women: 13%, - Goitre in children: 4%	1997 – 2002: 8th NESDP	
2003 - Goitre in children: 1% …… - Low serum retinal: 2% 2005 - Anaemia in pregnant women: 13% 2006 - PEM: 9%	2002 – 2007: 9th NESDP	
2007 - UIC in pregnant women: 61%, 2008 - UIC in pregnant women: 56% 2010 - UIC in pregnant women: 43%	2007 – 2012: 10th NESDP	: National Food Committee Act, : Voluntary fortification, : Strategic framework for food management (SFFM) approved by Cabinet
2012 – PEM: 7%	2012 – 2017: 11th NESDP	: Integration of SFFM and 11th NESDP, : Promote cooperation and integration of all relevant sectors, academia, business and NGOs to strengthen national food and nutrition security. : USI, : Triferidine tablet (iron+folate+iodine)

Source: Tontisirin *et al.* (2013).

During the same period, the prevalence of overweight and obese people increased in all age groups and this resulted in non-communicable diseases (NCDs) such as cardiovascular disease, cancer, hypertension, stroke and diabetes. In 2008, the incidence of death from diet-related NCDs was the highest among the ASEAN countries (WHO, 2011). One possible reason is dietary transition. Many factors can lead to changes in dietary patterns that affect nutrition status, including changes in socioeconomic status, urbanisation, food advertising, and food system changes (Kusolwat, 2002; Tontisirin, 2009; Tontisirin *et al*., 2013; Wanichagoon, 2013). Rapid growth in the agro-industry and food system during the last 30 years allowed greater access to a wider variety of foods, including more animal protein, sugary and fatty foods (NSO/OAE, 2012: Tontisirin *et al*., 2013). The National Food Committee (NFC) (2012) monitors these problems and provides strategic plans to strengthen national food and nutrition security.

2.5 Food Security Situation

Food security is commonly measured as food availability, food accessibility, food utilisation and food stability which are related to agricultural production and food consumption and nutritional intake. In terms of food supply, Thailand produces surplus food and non-food products for export. In Table 2.3, the quantity of domestic food supply is often greater than that of domestic utilisation. Cereals, including rice, and fruits contribute significantly to total food supply, followed by vegetables, alcoholic beverages, fish and seafood.

Table 2.3 Thailand's Supply Utilisation Account, 2011

Commodities	Domestic Supply (1000 Tonnes)					Domestic Utilisation (1000 Tonnes)					
	Production	**Import**	**Stock**	**Export**	**Total**	**Feed**	**Seed**	**Waste**	**Processing**	**Other use**	**Food**
Cereals (excluding beer)	28,259	2,372	633	11,621	19,643	7,000	649	1,829	1,280	-	8,884
Starchy roots	22,373	1,053	0	17,513	5,914	1,321	10	1,107	0	1,949	1,526
Sugar crops	95,950	-	-	0	95,950	-	-	960	92,000	-	2,991
Sugar and sweeteners	10,027	99	-492	6,935	2,699	-	-	-	1	1	2,696
Pulses	223	33	0	48	206	-	14	8	-	-	185
Tree nuts	76	36	0	53	59	-	-	-	-	-	59
Oil crops	1,860	2,212	-3	82	3,988	25	6	172	2,457	287	1,043
Vegetable oils	2,100	247	13	644	1,715	-	-	-	-	1,167	546
Vegetables	3798	430	0	594	3635	0	-	350	0	-	3279
Fruits	10759	584	67	4482	6930	-	-	651	91	-	6608
Stimulants	116	132	42	172	119	-	-	-	0	-	131
Spices	311	52		30	334	-	-	9	-	-	324
Alcoholic beverages	3006	83	0	307	2784	-	-	-	-	181	2603
Meat	2416	29	0	588	1857	-	-	25	0	-	1850
Offal	45	31	0	2	74	-	-	-	-	-	75
Animal fats	28	50	0	11	68	-	-	-	-	13	58
Milk (excluding butter)	985	1138	9	210	1922	-	-	30	-	2	1891
Eggs	996	2	-	9	990	-	152	50	0	-	788
Fish and seafood	2756	1769	45	2662	1909	416				0	1494

Source: FAOSTAT (2013).

Table 2.4 shows the food balance sheet between supply and utilisation of all agriculture and food which results in availability for domestic consumption. Cereals contribute substantially to overall food availability with rice dominating. Between 2004-2011, cereals show a small increase of 3%, and rice consumption increases from 7,786 to 9,457 thousand tonnes. Most food commodities show an increasing trend, but fruits which is the second most important commodity decreased by 9%. Fruit exports however increased by more than 70% between 2004-2011, and there is increasing fruit production for export.

Table 2.4 Food Availability/Supply in Thailand, 2005-2011

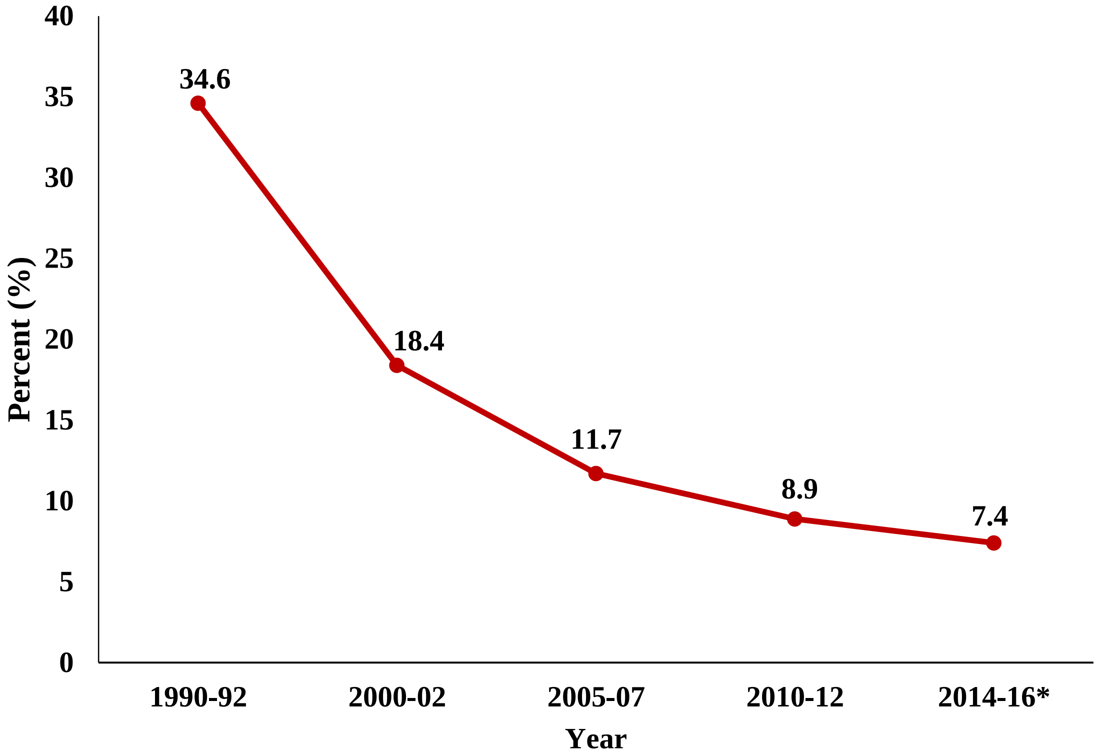
Commodities	Food Supply Quantity (1000 Tonnes)							
	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Cereals (excluding beer)	8,597	9,300	9,396	8,828	9,032	9,115	9,073	8,884
Starchy roots	1355	1,488	1,489	1,465	1,458	1,435	1,508	1,526
Sugar crops	2,946	2,290	2,282	2,922	3,317	3,098	3,120	2,991
Sugar and sweeteners	2,176	2,110	2,510	2,443	2,517	2,545	2,611	2,696
Pulses	179	156	147	155	142	145	197	185
Tree nuts	47	78	70	62	68	63	73	59
Oil crops	1,704	1,569	1,494	1,408	1,233	1161	1,115	1,043
Vegetable oils	420	429	428	598	499	486	507	546
Vegetables	3,379	3,201	3,109	3,378	3,263	3231	3,297	3,279
Fruits	7,250	7,626	8,117	8,863	7,461	7,032	7,083	6,608
Stimulants	90	92	85	97	107	105	119	131
Spices	293	290	291	326	320	331	345	324
Alcoholic beverages	2,294	2,301	2,666	2,813	2,824	2,483	2,472	2,603
Meat	1,727	1,823	1,907	2,030	1,874	1,789	1,864	1850
Offal	43	47	53	56	58	59	59	75
Animal fats	25	22	27	36	36	37	47	58
Milk (excluding butter)	1,664	1,677	1,628	1,420	1,568	1,495	1,747	1,891
Eggs	529	592	625	663	667	751	769	788
Fish and seafood	2,156	2,196	2,057	1,915	1,551	1,675	1,584	1,494

Source: FAOSTAT (2013).

Food is an importance source of macronutrients (protein, carbohydrates, and fats) and micronutrients (calcium, vitamin C, iron, and other minerals and vitamins) to reach energy requirements for physical activities and a healthy life. FAO (2012) uses the analysis of food availability (dietary energy and macronutrients) to evaluate the status of food security. The overall surplus of dietary energy available indicates that Thailand is food-secure (NSO/OAE, 2012). The availability of dietary energy can be applied with other indicators of food access and utilisation to determine food insecurity as measured by the prevalence of undernourishment

(FAO, 2012). Those undernourished declined from around 20m to 5m between 1990-92 and 2014-16 (FAO/IFAD/WFP, 2015). Figure 2.7 shows that the proportion of undernourishment diminished from 35% to 7% during the same period, and Thailand is close to eradicating hunger (less than 5%).

Figure 2.7 Proportion of Undernourished in Total Population in Thailand



Sources: FAO/IFAD/WFP (2015).

Note: * is an estimated value for the year 2016.

Table 2.5 illustrates the overall dietary energy and macronutrient supply as complied in the food balance sheet for 2005-2010. The level of dietary energy supply (DES) or availability increased from 2,900 kcal/person/day to 3,100 kcal/person/day. This increase corresponds with the increase in production of several food commodities, particularly cereals. Carbohydrates and protein increase by 14% and 8% while fats decrease by 8%. The increase in cereals, which are rich in carbohydrates, significantly influenced the increase of DES, and the reduction of fats is due to a fall in supply of the oil and fat commodities. Protein supply mainly comes from animal sources such as meat, fish and seafood, and eggs. Animal protein is expensive and this impacts on protein access particularly for the poor.

Table 2.5 Dietary Energy Availability and Macronutrients (per person per day), 2005-2010

Dietary energy and macronutrients	2005	2006	2007	2008	2009	2010
Dietary energy (kcal)	2,857	2,886	2,879	2,828	2,868	3,116
Carbohydrates (gram (g))	518	537	527	523	534	589
Protein (g)	64	63	63	62	64	69
Fats (g)	59	54	58	55	53	54

Source: NSO/OAE (2012).

2.6 Current Policies on Nutrition and Food Security in Thailand

The NESDB along with the Ministry of Agriculture and Cooperative (MOAC), Ministry of Public Health (MOPH), the National Food Committee (NFC) and the National Heath Act, developed the "Thailand Healthy Lifestyle Strategic Plan 2011–2020" (NESDB, 2011a; Tontisirin *et al*., 2013). This strategic plan emphasises local food production to achieve household food and nutrition security, with surpluses being sold (Tontisirin *et al*., 2013). The National Health Commission under the National Health Act (NHA) (2007) public policy focuses on major health problems. It aims to raise public awareness of being overweight and obese, to promote appropriate behaviours, and to strengthen the health monitoring and surveillance system (Tontisirin *et al*., 2013). Action plans are concentrated on six key issues: 1) to promote breast-feeding and healthy diets; 2) to control the food marketing and advertising for children; 3) to increase public awareness and communication about the risks of obesity; 4) to support health services and programmes that are associated with obesity; 5) to promote social and physical activities for prevention of obesity; and 6) to strengthen an overall system to address and monitor obesity and being overweight. In addition, the Bureau of Nutrition, MOPH (2010–2013), developed a national nutrition policy that mentions three nutritional challenges: 1) iodine deficiency prevention and monitoring; 2) optimum development of Thai children; and 3) obesity prevention. In Table 2.6, activities and action plans include public campaigns and promotions, guidelines for actions and development, monitoring and surveillance, nutrient supplementation and fortification. These campaigns are designed to fit with a new lifestyle and also promote the benefits of traditional Thai dishes (Tontisirin *et al*., 2013).

Table 2.6 The National Nutrition Plan, 2010–2013

Plans	Activities and implementation
Iodine deficiency disorder (IDD)	"- Cyclical monitoring of urinary in pregnant women, - Appropriate IDD surveillance system, - Increase household coverage of iodine salt, - Nutrition promotion in poverty zone, - Campaign on International Iodine Day, - Fortified fish sauce"
Optimum growth development of children	"- Breastfeeding policy and promotion, - Essential nutrient supplementation for pregnant women, - Dietary diversification campaign on problem nutrients: greater consumption of fruits and vegetables and iron rich diets, - Healthier food choices for children"
Obesity prevention	"- Healthy Thai Province: No Big Belly campaign, - Healthy Thai menu for Thais, - 2:1:1 Thai dishes (vegetables: rice: meat), - Diet and physical activity strategy (DPAS)"

Source: MOPH (2009) and Tontisirin *et al*. (2013)

The NFC (2012) also developed strategic plans for agriculture and food security based on a vision of ensuring the quality and safety of food supply for food security and human well-being. The strategic plan is divided into four themes, namely food security, food quality and safety, food education, and food management. Guidelines and action plans associated with these themes are shown in Table 2.7, which are also related to the strategic plans in the current 11th NESDP (2012-2016) of NESDB, Office of Prime Minister (NESDB, 2011b). In addition, the 11th NESDP places emphasis on the sustainable management of natural resources that can provide a strong base for food and energy production (NESDB, 2011b).

The main strategies of the 11th NESDP are: 1) to enhance the basis of natural resources for the agricultural sector by establishing a system for land management, supporting small-scale farmers to possess land for farming, and expropriating private land for agricultural land reform; 2) to increase agricultural productivity by improving fundamental services that support agricultural production, developing an appropriate knowledge and technology for agriculture, and supporting agricultural research and development; 3) to create value added for agricultural products by enhancing the quality of agricultural products to reach international standards, supporting local communities to add more value in food products, creating more value in livestock production, and providing incentives of food quality and safety for farmers; 4) to establish agricultural employment and income security by improving farmers' social welfare and encouraging farmers and skilled labour to work in the agricultural sector; 5) to develop food security and bioenergy at the household and community levels by promoting sustainable agriculture following the integrated farming philosophy, promoting the principle of zero waste in agricultural activities, and linking local production and consumption networks.

Table 2.7 Food Production and Security Strategies

Themes	Action plans and implementation
Food security	"- Accelerate land reform and agricultural area protection, - Manage water and land resource for agricultural and community forest, - Find the balance between food and energy plant, - Improve food production efficiency, - Create motivation in agricultural occupation and increase number of young farmers, - Promote food access in household and community level, - Develop and improve logistic systems for agricultural and food products, - Create collaborative between government agencies, private sectors and citizen in food security, - Research and develop technology and innovation in every steps of food production, - Create emergency plan for food security in emergency circumstance"
Food quality and safety	"- Standardised food safety and promote its implementation, - Improve quality and safety of primary food product, - Increase nutritional value, - Support and oversea food production in community level to prevent loss and increase value to the product, - Support and oversee food production in all industrial level, - Promote trading and marketing of standard product from community and industrial level, - Strengthen control and monitoring of national food quality and food safety"
Food education	"- Promote collaboration and integration of all involved agencies in food education, - Support research which can be applied to food-related issue, - Create knowledge management in food education and continuously distribute knowledge, - Promote appropriate food education to agriculturist and community, - Promote appropriate individual and community consuming behaviour"
Food management	"- Improve and strengthen structure of involved organisation, - Develop and improve laws related to food production, - Improve database and administration"

Source: NFC (2012) and NESDB (2011b).

MOAC (2012a) also provides a food security policy emphasising adequate and sustainable food supplies for the population at all times. Food production and stocks need to be sufficient for the stability and sustainability of food supply to meet domestic food demand. The MOAC's policy is aligned with the 11th NESDP, called the 11th agricultural development plan (2012 – 2016), which resolves to strengthen the agricultural structure to improve the quality of agricultural and food products to enhance food security. The plans are: 1) to increase efficiency in production, management and food security by balancing production between food and energy crops, promoting green production, and enhancing good quality and safe production and food safety standards; 2) to efficiently develop and balance agricultural resources for sustainability; 3) to promote the quality of life of farmers including job stabilisation, income and welfare security by rehabilitating severe damage caused by natural disasters, encouraging farmers to be self-reliant, encouraging a new generation to work in the agricultural sector, and supporting agricultural institutes and networks in policy development that can be implemented at the commodity level.

In addition, MOAC (2012b) also provides a strategic framework for food security (2013 – 2016) which is developed following the definition of food security defined by FAO (2002). The main strategies are: 1) to ensure the sustainability of domestic food demand; 2) to encourage all Thai people at all times to access good quality and nutritious food; 3) to develop the standards of food production for good quality and safe food, promote appropriate food utilisation, and reduce food waste; and 4) to support the sustainability of natural resource use for food production.

2.7 Summary

Thailand is an agriculture-based country. Its agricultural sector is not only an important source of livelihood and income for a large proportion of the population, but also an export revenue. The GDP of agricultural production is relatively small and the average income of agricultural labour is low which can lead to poor living conditions, and many suffer from malnutrition and food insecurity. The result is migration from the agricultural to non-agricultural sector. Overall, Thailand is food-secure and can provide sufficient domestic food. Cereals, predominantly rice, contribute significantly to domestic food supply. Over the past 40 years, Thailand achieved remarkable progress in reducing undernutrition because of the implementation of nutrition, food, and agricultural policies. Most of all, nutrition and micronutrient deficiency is no longer considered a national health problem, and only iron and iodine are still deficient among children and pregnant women in rural areas. However, agricultural labour may suffer from nutrition and food insecurity which contributes to lower work capability and productivity.

Chapter 3 Literature Review of Nutritional Status and Labour Productivity

3.1 Introduction

The relationship between nutritional status and economic outcomes is well-researched and can be observed in various measures such as increasing income or wages, work efficiency and productivity. Many studies are focused on nutrition-labour productivity links in the agricultural sectors of low- and middle-income countries. Previous literature reviews on the nutrition-labour productivity link, such as Strauss (1986), Deolalikar (1988), Behrman et al. (1997), Aziz (1995), Ayalew (2003) and Weinberner (2004), have employed agricultural household models (AMHs) as a theoretical framework which can be adjusted to allow nutrient intakes to effect labour productivity. These models are generally used to derive consumption, production, and labour supply decisions in a single framework when markets are imperfect because the imperfect markets lead to simultaneous decisions on consumption, production, and labour allocation. Various econometric approaches are applied to examine linkages between nutritional status and economic outcomes and the main aim is to derive output elasticities which can then be used to develop policies on nutrition and labour productivity as well as agriculture in Thailand.

This chapter reviews the literature on nutrition-labour productivity links which can identify research gaps and provide a research design. It is structured as follows: Section 3.2 examines AMHs; Section 3.3 examines nutrition-labour productivity linkages within AMHs; Section 3.4 reviews econometric approaches especially the sensitivity of estimates to alternative estimation approaches; Section 3.5 examines the literatures on the status of nutrition and labour productivity in Thailand; and Section 3.6 summarises.

3.2 Agricultural Household Models

Agriculture remains a main source of income generation, foreign exchange earnings, and employment for a majority in less developed countries (LDCs). Nearly one billion people in these countries are engaged in agriculture, or around one-third of all labour in the world (FAO, 2011). Agriculture also is a major focus of government policy and an important issue is to determine the effects of agricultural policies. Most agricultural households are semi-commercial, household-firms which behave as both sellers and consumers of their own goods (Singh *et al*., 1986a; De Janvry, 1991; Taylor and Adelman, 2003). They also supply some inputs from their own resources and procure some inputs for their production (Singh *et al*., 1986a, p. 6; Adhvaryu and Nyshadham, 2011). Thus, agricultural households behave neither as pure consumers nor pure firms and the formulation of government policy needs to be tailored to their particular characteristics. Specifically, changes in agricultural policy affect factors of production, consumption and labour supply and it is important to understand the behaviour of agricultural households when analysing government intervention.

AHMs are developed to understand family-farm household behaviour. These models are principally modelled at the micro-level in LDCs (Taylor and Adelmen, 2003). Originally, AHMs are designed as a tool for price policy analysis (Taylor and Adelmen, 2003), and they are applied to analyse several issues such as food demand and nutrition (Strauss, 1986), labour supply choices (Barnum and Squire, 1979; Dawson, 1984; Goodwin and Holt, 2002), the consumption-investment interaction (Phimister, 1995), migration (De Brauw *et al.*, 2002), and the impact of agricultural productivity crises (Jayachandran, 2006). A key feature of AHMs is to integrate producer, consumer, and labour supply decisions in a theoretically consistent manner (Taylor and Adelman, 2003). AHMs are often applied to household-firms or peasant agriculture in which markets are imperfect whereby the household's production decisions are influenced by consumption and the labour market (Taylor and Adelman, 2003; De Janvry and Sadoulet, 2006). The household partly produces for sale, partly consumes its outputs, and either provides or sells its own labour (Sadoulet et al., 1998; Findeis et al., 2003; Taylor and Adelman, 2003). When the household exclusively produces for its own consumption or consumes market-produced goods, it is regarded as a perfect market. AHMs can then be categorised and appropriate empirical techniques can be applied recursively. If there is market failure, separability between production and consumption decisions does not hold and the household's production and consumption decisions must be examined simultaneously (Singh et al., 1986, pp. 7 – 8).

The theory of peasant behaviour at the level of the individual family farm was first introduced by Chayanov (1925 cited in Millar, 1970) by combining the consumption and production decisions of the peasant family into a framework of household decision making. Within a cardinal utility framework, the family farm is assumed to maximise its utility by striking a labour-consumption balance, balancing the minimum of work required ('drudgery of work') with the consumption needs of the family (Ellis, 1988, p. 106; May, 1992; Rola-Rubzen and Hardaker, 1999). The level of this balance is influenced by the household size and the ratio of consumers to workers ('the c/w ratio') in the peasant household or the ratio of non-working to working members (Ellis, 1988, p. 106; May, 1992; Chen *et al.*, 1996). Chayanov's analysis of household behaviour does not include the labour market (Hunt, 1976; Ellis, 1988, p. 107; May, 1992). Building on Chayanov's framework, Nakajima (1957 cited in Findeis *et al.*, 2003) formalised the model by extending beyond the theory of a profit-maximising farm production unit. The model integrates farm production, household consumption and labour decisions into a joint framework of farm household utility maximisation where utility is ordinal. Nakajima's theory aims to understand the characteristics of the farm household as an economic unit, and it distinguishes between the decision-making behaviour of subsistence family farms and that of commercial family farms (Nakajima, 1986, pp. 1 – 2; May, 1992; Findeis, 2002). In addition, the theory is a framework for predicting the responses of farm households to variations in different aspects such as input prices, output prices, wage rate, income, technology, and family structure.

A related model to that of Chayanov which is known as the New Home Economics (NHE) model was proposed by Becker (1965) where the household is hypothesised to behave as a single unit of production and consumption, maximising utility subject to household-level constraints on production, money income and human time (Ellis, 1988, pp. 123 – 124; Huffman, 1991). The household utility is not only derived directly from market commodities, but also is obtained from output commodities produced by the household, and the production of each household-produced commodity requires an input of household time as well as purchased goods and services. The NHE model is mostly used to understand household behaviour where the households purely consumes units and gains income only through waged work (Huffman, 2010).

A further study by Barnum and Squire (1979) is based closely on NHE models. Their model presents a framework of household production, consumption, and labour supply behaviour for a semi-commercial farm with a competitive labour market. The farm household can hire in or hire out labour at a given market wage and is assumed to maximise utility derived from the consumption of home-produced goods, market-purchased goods, and total time available in the household subject to the production function, time and income constraint (Barnum and Squire, 1979; Ellis, 1988, pp. 128 – 129; Cohen *et al.*, 1996). Barnum and Squire also examine the impact of migration, output price changes, intervention, and technological change. They provide a framework for deriving comparative static propositions about the responses of the farm household to changes in domestic and market variables. Linked to the Barnum-Squire model, Singh *et al*. (1986a, p. 18) develop an AHM by assuming that the household maximises utility subject to constraints on the household's budget, time, and technology, and the model is recursive or separate (May, 1992), that is, production decisions are separated from consumption decisions although the consumption decisions are determined by the outcome of the production. However, recursivity does not hold if the household experiences market failures such as in the labour market (May, 1992; Taylor and Adelman, 2003) when production and consumption decisions are simultaneous. This framework has been widely used to study farm household behaviour in LDCs.

Following Singh *et al*. (1986), we present an AMH under the assumption that the household seeks to maximise utility from home-produced goods (C_a), market-purchased goods (C_m), and leisure (H):

$$\text{Max: } U = U(C_a, C_m, H) \tag{3.1}$$

Household utility is maximised subject to the cash income constraint, total time available to the household, and the production function or technology constraint. For the income constraint, the availability of cash income is:

$$p_m C_m = p_a(Q - C_a) - w(L - F) \tag{3.2}$$

where p_m and p_a are the prices of the market-purchased and home-produced products, Q is the household production so that $Q – C_a$ is its market excess, w is the market wage, L is total labour input, and F is the household labour input. If $(L – F) > 0$, the household hires labour from the market; whereas if $(L – F) < 0$, the farm supplies labour to the market. The household experiences a time constraint because it cannot allocate more time to leisure, on-farm production, or off-farm production than the total time available and:

$$H + F = T \tag{3.3}$$

where T is the total stock of household time. It also experiences a production constraint, including production technology, given by the production function:

$$Q = Q(L, LD) \tag{3.4}$$

where LD is the fixed household quantity of land.

The three constraints in (3.2) – (3.4) can be combined into one to simplify the problem. Substituting the production function in (3.4) and the time constraint for F in (3.3) into the cash income constraint in (3.2) yields:

$$p_m C_m + p_a C_a + wH = wT + p_a Q(L,LD) - wL \tag{3.5}$$

rearranging (3.5) gives:

$$p_m C_m + p_a C_a + wH = wT + \pi \tag{3.6}$$

where farm profit, π, is:

$$\pi = p_a Q(L,LD) - wL \tag{3.7}$$

In (3.6), the left-hand side represents total household expenditure on market-purchased commodities, purchasing of its own output, and purchasing its own time in the form of leisure, while the right-hand side is the household's income following the full-income concept of Becker where the value of the stock of time (wT) is allocated by the household. The extension for agricultural households includes a measure of farm profits with all labour valued at the market wage, which is a consequence of the assumption of price-taking behaviour in the labour market (Singh *et al*., 1986a, pp.17-19). These equations are the fundamental core for numerous studies of agricultural households.

3.3 Agricultural Household Models with Nutrition-Labour Productivity Links

AHMs are widely used to study the nutritional status of agricultural households especially in LDCs, and much research is concentrated on the relationship between nutrition and labour productivity. Liebenstein (1957), Stiglits (1976), Behrman *et al*. (1997), Horton (1999), and Weinberger (2004) point out that better nutrition enhances labour productivity and hence contributes to economic growth since better-nourished workers should be more productive and can earn higher wages. Similar to the notion of the nutritional efficiency wage hypothesis, a higher consumption of calories enables labour to work more productively, expressed in a greater marginal productivity as measured by increased income or wages received (Liebenstein, 1957; Strauss, 1986; Weinberger, 2004). This relationship can be denoted as:

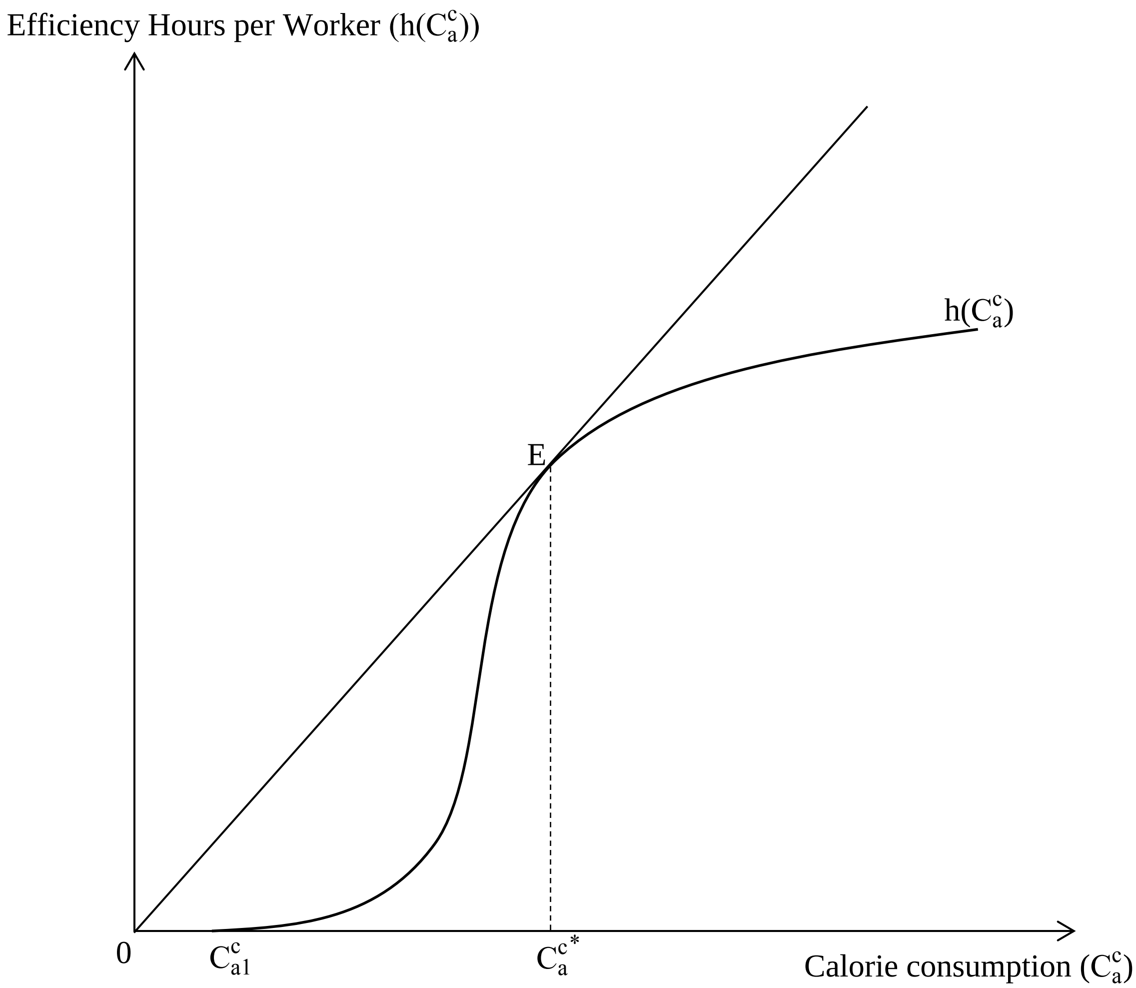
$$M = f(C) \tag{3.8}$$

where M stands for income and C stands for calorie consumption.

In addition, at low levels of income, labour productivity is positively associated with energy consumption (Liebenstein, 1957; Aziz, 1995). In Figure 3.1, the consumption-labour productivity link is explained in terms of the relationship between efficient hours for a worker and levels of calories consumption. The length of the working day is given as clock hours, while clock hours differ from efficient hours. Efficient hours are assumed to measure the productivity of the worker's effort, and the worker is hypothesised to spend all wages on food. More productive labour is expected to generate a higher number of efficient hours in a given number of clock hours when the worker consumes more calories. Thus, the labour productivity (in terms of the efficiency per hour worked) is presented as a function of consumption in calories, $h(C_a^c)$.

In Figure 3.1, $h(C_a^c)$ is assumed to begin at the origin point, 0. The level of daily consumption (C_a^c) is that required to cover the basic metabolic requirements for basic life functions. Calorie consumption which exceeds $0 - C_a^c$ provides energy for work activities. Efficient hours per worker rises over the range of calorie consumption up to C_a^{c*} where is the optimal point for effective effort, at point E; beyond C_a^{c*} diminishing returns set in with further increases in calorie consumption. Thus, employers should pay wages for employees to reach the consumption at the point C_a^{c*} for working in order to minimise the cost of effective labour.

Figure 3.1 Nutrition-based Efficiency Wage Hypothesis



Source: adapted from Strauss (1986, p. 303) and Aziz (1995, p. 8)

To measure labour productivity empirically, most studies employ a wage equation and household production function to estimate productivity within a farm household framework and the efficiency wage hypothesis (Singh *et al*., 1986; Deolalikar, 1988; Weinberger, 2004). Strauss (1986) extends the AHM to explore the impact of current nutritional status on labour productivity of farm households using cross-sectional data from a farm household survey in rural Sierra Leone. A Cobb-Douglas production function is modeled to estimate how nutrient intakes affect farm output by using non-linear two-stage least squares (NL2SLS) to control for simultaneity. Results show that an average calorie intake for effective labour in terms of an hour of work has a significantly positive relationship in the production function with an output elasticity of calories of 0.34 at the sample mean of average calorie intake; it is 0.49 at the average daily energy intake of 1,500 kcal, and is 0.12 at a daily energy intake of 4,500 kcal. However, a daily energy intake of 5,200 kcal has a negative impact on effective labour.

Adopting Strauss's (1986) framework, Deolalikar (1988) examines the relationship between nutritional status and labour productivity of farm households in rural south India. Using panel data, a Cobb-Douglas production function and a semi-log wage equation are applied to estimate the relationship by using random and fixed effects methods to control for a simultaneous problem. Results show that weight-for-height (WFH) is positively associated with wage and farm productivity but calorie intake has no influence on either wages or farm output. Similarly, Sahn and Alderman (1988) estimate the effect of household calorie intake on individual wages in Sri Lanka using cross-sectional data. The wage function is estimated by the two-stage least squares (2SLS) method (but without health proxies control) and results show significant gender differential impacts of nutrients on wages, and the estimated output elasticity for calories is 0.21 for men.

Haddad and Bouis (1991) study the impact of individual nutritional status on the agricultural wage received using panel data for rural households in the Philippines. The WFH, height, and individual energy intake data of workers are included in the estimated wage equation and they find that only the WFH has a significant effect on wages but results are not robust when controlling for endogeneity. When calories are added as the only one nutritional variable in the specification, the result is significantly positive. They also used ordinary least squares (OLS) and report the elasticity of wage with respect to calories is 0.09.

Aziz (1995) examines the link between nutritional and health status and labour productivity for men and women in India using data of the International Crops Research Institute (ICRI) undertaken from 1976-77 to 1977-78. A NL2SLS method is applied in the Cobb-Douglas production function to control the endogeneity in the model. Results show that an increase in calorie intake for female labour contributes to higher farm output, but the WFH is not significant. However, the calorie intake for male workers does not significantly contribute to farm output, while the WFH of male labour is positively associated with farm output. The calorie elasticity with respect to farm output for female labour is 0.45, and the WFH elasticity with respect to farm output for male labour is 1.16.

Thomas and Strauss (1997) explore the effect of body mass index (BMI), height, *per capita* calorie intake, and *per capita* protein intake on the wages of male and female workers using cross-sectional household survey data in urban Brazil. Instrumental variable (IV) techniques are employed for the wage equation regression and key findings are that height is a significant determinant of wages of both male and female market-workers, BMI is only a positive determinant of male wages among the less-educated, and *per capita* calorie intake and *per capita* protein intake have a significantly positive impact on the wages of males and females who work in the market sector, but not the self-employed. After controlling for BMI, height, and calories, *per capita* protein intake influences wages, and more so at higher intake levels.

Croppenstedt and Muller (2000) estimate the relationship between health and nutritional status and farm labour productivity in Ethiopia. They adopt a stochastic frontier production function, which can estimate both efficiency and productivity of farmers to estimate farm output, adding the WFH of the household head. They find that this indicator has significant effects on farm productivity. Also, they evaluate the robustness of the nutrition-productivity relationship by estimating wage equations for farm workers using Heckman's two-step method with height, WFH ratio, and BMI of the worker. Results indicate that health proxies have a positive impact on the wages of male workers and estimated elasticities are high: the male wage elasticities with respect to the height, BMI, and weight for height are 3.55, 3.02, and 3.04, respectively. Ayalew (2003) also uses data on rural Ethiopian households to examine the nutrition-labour productivity link by estimating a farm production function and a wage equation using panel data. Results show that calorie consumption has a considerable effect on the labour productivity of farm households in both farm production and wage estimates: the elasticities of the former and latter with respect to calorie intake are 1.47 and 0.02, respectively. However, the effect of nutrition on productivity and health are only observed in the wage equation by employing Heckman's two-step method and this effect is not robust. Thus, nutritional status has a minimal impact on productivity.

Weinberner (2004) analyses the effect of micronutrient intake on labour productivity of agricultural workers in India using 2SLS. A semi-log wage equation is adopted to measure the impact on productivity in terms of wages at the household level. Results show that iron and vitamin C intake have a significant effect on productivity, and increasing micronutrient intake can improve economic growth and development. Similarly, Jha *et al*. (2009) using household data for rural India for 1994 regress Poverty Nutrition Trap (PNT) calories of three categories of agricultural worker’s wage, namely harvesting, sowing and other for each gender. The wage data used is separately estimated based on the distribution of employment categories because the wage rate per day of each category is different. Tobit analysis and Heckman's procedure to correct for selectivity bias in estimating gender differentials are used, and findings reveal that PNT has a significant effect on agricultural labour productivity for three categories of wages, particularly for female workers.

A further line of inquiry is Ulimwengu *et al*. (2011) who estimate the linkage between micronutrient intakes and agricultural productivity in Uganda using structural equation modelling (SEM) and an IV Tobit approach. Results reveal that labour productivity significantly increases if micronutrient consumption is increased. Additionally, estimates of the elasticity of labour productivity with respect to nutrient intake range from 0.04 for vitamin B12 to 0.01 for iron.

Other slightly different studies, Calderon (2007) applies a two-step quantile regression (2SQR) approach to explore the relationship between health and labour productivity among male and female workers in Guatemala using data of a longitudinal study conducted in 1969-1977 and in 2000-2004. The health-labour productivity relationship is modelled using a semi-log wage equation to examine the effect of height and BMI at different quantiles of the conditional wage distribution. Results reveal that the relationship between height, BMI and wages is non-linear for both female and male labour. Decreasing returns to height and BMI appear at higher quantiles, while increasing returns appear at lower quantiles. This implies that height and BMI have an increasing payoff for both gender of poorer workers. Also, Kedir (2008) examines the impact of nutritional status measured as height and BMI on individual wages among men and women in Ethiopia using 2SQR. 1,500 Household panel data for 1994, 1995, 1997 and 2000 collected by the Department of Economics, Addis Ababa University. Results show that education, height and BMI have a positive and significant impact on individual wages for both gender. Also, returns to education suggest that an increase in years of education contributes to a rise in wages for very low-income people, especially women.

3.4 Econometric Approaches

The evaluation of estimates of the relationship between nutritional status and farm productivity requires that parameters are estimated accurately. To limit the impact of biased estimators, economists have used a variety of techniques, and it is important to understand the sensitivity of estimates to alternative methods. In the study of nutrition-labour productivity links, simultaneous-equation models are generally derived. For cross-sectional data, 2SLS, NL2SLS, and Heckman's two-step method are used; and for panel data, fixed effects and random effects models are used. IV Tobit using SEM is also used to examine the relative effect of both observed and unobserved variables, and 2SQR is used to estimate the effect of nutrient intake on labour productivity at different quantiles of the conditional distribution of earnings.

Table 3.1 summarises studies that link nutritional status to agricultural productivity. Most of these studies aim to estimate the elasticity of outputs with respect to nutritional and/or health proxies using econometric methods. When OLS is applied to examine the effect of nutritional status on wages, it seems likely that a simultaneity and unobserved heterogeneity bias occur because the measurement of nutritional and health status is multi-dimensional (Ware, 1987; Thomass and Strauss, 1997; Ulimwengu *et al*., 2011). In addition, Strauss (1986) notes that calorie consumption and health status, which are jointly determined with wages or productivity, are positively correlated with unobserved earnings or production factors, and this leads to endogenous bias in OLS estimators. Glick and Sahn (1998) also note that if the covariances between the residuals and nutritional indicators (such as calories or BMI) are non-zero, then OLS estimates of the effects of health or nutrition on wages are biased.

Table 3.1 Summary of studies that link nutritional status to agricultural productivity

Authors	Types of data	Method of estimation	Nutritional variables	Agricultural productivity variables
Strauss (1986)	Cross-sectional	NL2SLS	Energy intake	Production
Deolalikar (1988)	Panel	Random and Fixed	Energy intake/ weight-for-height	Production/Wage
Sahn and Alderman (1988)	Cross-sectional	2SLS, Two-step Heckman procedure	Calorie intake	Wage
Haddad and Bouis (1991)	Panel	2SLS, OLS, Random and Fixed	Calorie intake/ height/ weight-for-height	Wage
Aziz (1995)	ICRI household data for India, the year 1976-77 and 1977-78	NL2SLS	Calorie intake/ height/ weight-for-height	Production
Thomas and Strauss (1997)	Cross-sectional	IV	Height/ BMI/ *per capita* calorie intake/ *per capita* protein intake	Wage
Croppenstedt and Muller (2000)	Cross-sectional	Two-step Heckman procedure	Height/BMI/weight-for-height/calorie intake	Production/Wage
Ayalew (2003)	Cross-sectional and Panel data	IV, Two-step Heckman procedure, Random and Fixed	Calorie intake/Height	Production/Wage
Weinberner (2004)	Cross-sectional	2SLS	Energy intake/ micronutrient intake	Wage
Calderon (2007)	Panel	2SQR	Height/BMI	Wage
Kedir (2008)	Panel	2SQR	Height/BMI	Wage
Jah *et al.* (2009)	Household data for rural India, from January – June, 1994	Two-step Heckman procedure	Energy intake/ micronutrient intake	Wage
Ulimwengu *et al.* (2011)	Household survey data from Uganda, 2004-2005	IV Tobit	Energy intake/ micronutrient intake	Production

As a control for the simultaneity problem, Strauss (1986) employs 2SLS for the farm production equation using cross-sectional data. Yet, due to a non-linearity in the model, he adjusts the 2SLS procedure by adding the energy squared term to catch up the non-linearity, which is called NL2SLS. He calculates farm output elasticities with respect to nutrient intake ranging between 0.12 and 0.49. Correspondingly, Aziz (1995) use NL2SLS and the elasticity of nutrient intake on farm production is 0.45. Sahn and Alderman (1988) use 2SLS and the elasticity of nutrient intake on wages is 0.21. Weinberner (2004) also uses 2SLS and finds that the elasticity of iron and of the interaction of iron and vitamin C on wages is 0.34 and 0.25, respectively. Thomas and Strauss (1997) apply IV methods to control for inconsistent parameter estimation due to endogenous regressors to estimate a relationship between calorie and protein intakes on wages, and the elasticities of wages are 1.60 for calorie intake and 1.90 for protein intake.

On the other hand, Deolalikar (1988) argues that only using current energy intake as a measure of nutritional status might be a poor proxy for the amount of energy available for work. He also claims that if the data are a cross-section of individuals at different points in the energy cycle, it is difficult to appropriately control for unobserved time-persistent effects in testing the nutrition-labour productivity link since some procedures treat an individual or household as random variables which leads to bias in either direction depending on the relationship between calorie intake and omitted time persistent variables. Deolalikar uses panel data to estimate the wage equation and production function using random and fixed effect techniques and results show that only the WFH ratio affects wages and farm productivity, while calorie intake does not. This may result from a collinearity problem between calorie intake and anthropometric variables and the consequence of the joint effect of the energy intake and the WFH ratio on productivity. He also suggests that the human body can adjust to short- and medium-run effects of energy intake on labour productivity. Additionally, he found that the Hausman specification test leads to a rejection of the random effects model. Alternative econometric procedures applied to the relationship between nutritional status and agricultural productivity produce ambiguous estimates of elasticities.

Haddad and Bouis (1991) test for the sensitivity of four different techniques, namely OLS, 2SLS, within fixed effects (Within), and Hausman-Tylor (H-T) random-effects on the nutrition-wages link, and three instruments of individual nutritional status. They find that calorie intake and the WFH ratio have a significant effect in all four techniques, whereas height is only significant in the OLS and Hausman-Tylor methods. However, they do not report the results of 2SLS estimates because the estimators are highly unstable when they include both calorie intake and health proxies in the same equation. Further, results from fixed effects models when calorie intake and the weight-for-height ratio are included show that the coefficients of both variables are insignificant. In particular, when they include solely calorie intake as an explanatory variable, calorie intake has a positively significant impact on wages. They report the elasticity of calorie intake for adults on wages for OLS, Within, and H-T estimates of 0.09, 0.03, and 0.04, respectively.

All studies above only estimate the elasticity of caloric intake at the sample mean. The effect of nutrient intake on wages at different quantiles may provide interesting results, especially for the non-linear relationship between nutritional status and wages. Thus, Calderon (2007) and Kedir (2008) combine the 2SLS procedure with a quantile regression to explore the effect at different quantiles, then results are interpreted in term of returns to nutritional status.

Finally, Ulimwengu *et al.* (2011) assume that nutrient intake, agricultural income, and labour/land productivity are endogenous while socio-economic indicators such as education, gender, and production cost are exogenous. They apply SEM using the IV Tobit approach to examine and distinguish the effect of both observed variables and latent variables or unobserved variables. Findings are that the nutrient-intake elasticities estimated by the instrumental variable Tobit technique are similar to those of using 2SLS, ranging between 2.3 and 8.8 for the former and from 5.0 to 17.3 for the latter.

3.5 Literature on Labour Productivity and Nutritional Status in Thailand

3.5.1 Literature on Labour Productivity

Agriculture plays a pivotal role in the Thai economy and most workers are engaged in this sector. Agricultural labourers are the main labour force driving economic development. Accordingly, it is important to study the capability of labour to contribute directly to productivity and their nutritional status to improve labour productivity and raise the quality of life. We now consider the literature both on labour productivity in Thailand and on nutritional status involving food consumption patterns and health status.

Several studies have researched labour productivity in Thailand in both industrial and agricultural sectors. Kitprathan (1996) investigates factors influencing labour productivity in the manufacturing sector by employing cross-sectional data for 1998 and 2002 and multiple OLS regression analysis. He finds that the average value of capital per worker and the ratios of workers by level of education to the total number of workers are significant determinants of labour productivity growth. He also reports that increases in one baht of the average value of capital per worker and one percent of the ratios of workers with the vocational education and above increase average labour productivity by 0.19 and 8,507 Baht per year, respectively. On the other hand, a one percent increase of workers with secondary education decrease the labour productivity by 3,727 Baht per year.

Kanjanakaroon (2001) explores the determinants of both long- and short-run productivity growth. Findings indicate that changes in the growth of the export-labour ratio and the physical capital-labour ratio have a positive impact on labour productivity growth in both the short run and long run, while the growth of capital-labour ratio of transportation and that of communication have a significant effect on labour productivity only in the long run. He also reports that the change in the growth of the capital-labour ratio in agriculture has a significantly positive influence on labour productivity growth in both short and long runs, but that a change in the export-labour ratio has a significant effect only on long-run productivity.

Buala-or (2003) estimates the value of labour productivity in the agricultural, industrial, and service sectors for 1970-2003. She also investigates the role of public and private capital on labour productivity through the production function which is adjusted by human capital with catch-up technology and technological approaches. Results show that the growth rate of agricultural labour productivity is 2.10, while those of industrial and service sectors are 0.91 and 0.64, respectively. She also reports that only private capital has a positive impact on labour productivity in all sectors. The estimated elasticities of agricultural, industrial and service labour productivity with respect to private capital are 0.91, 1.24 and 1.28. In the same year, Chockpisansin (2003) examines factors influencing total factor productivity (TFP) growth during 1977-1999 by employing a growth accounting model adjusted by crude TFP to separate the effects of business fluctuation, the quality change of labour inputs, and the sectorial labour mobility. She finds that the growth rate of exports, imported capital, the share of labour in non-agricultural sectors, and the growth rate of share of educated labour at university level are the main factors that determine TFP growth.

Tuntijaruphat (2005) studies the relationship between the foreign direct investment (FDI) and labour productivity by using the data collected by National Statistical Office (NSO) of Thailand for 1997-2003 and OLS. Results show that FDI is a negatively significant determinant of the changing rate in labour productivity while capital intensity, labour quality, and firm size have a positive effect on labour productivity. They suggest that the government should reduce the restriction of technology transfer to derive more benefit from FDI in the manufacturing sector, and labour training should be provided in the private sector.

Santipollavut (2002) analyses the main factors determining labour productivity and also examines the relationship between quality of labour and worker productivity both at an aggregate and firm level using time series data for 1972-1996 and survey data for 1999-2000 from workers in sub-sector 31 of the Bangkok metropolitan and Vicinity areas. Path analysis methods are used to estimate the relationship by applying 2SLS. Results reveal that capital per labour and the level of education have a positively significant association with labour productivity, and that the quality of life is a significant determinant of labour productivity. From the survey data, the number of working years, the employment of physical assets related to production, and the level of life quality has a positive impact on labour productivity. To lend support to this result, Santipollavut *et al*. (2007) study factors that affect labourers using path analysis for 1987-2002. Results indicate that investment in physical capital, formal and informal education, and promotion of physical and mental health are significant determinants of improving labour productivity.

Nonthakot and Villano (2008) investigate the impact of labour migration on agricultural productivity in the Northern provinces of Thailand using a household survey of maize production data, and a stochastic production function is applied. Results show that remittances and the number of migrant workers enhance maize production and the productive capacity of maize farmers is determined by remittances, gender, the education of migrants, and the duration of migration. In the same year, Chuenchoksan and Nakornthab (2008) evaluate the performance of Thailand's economic growth between 1972 and 2007 by examining labour productivity using growth accounting methods. They find that the main driver of the economy is labour productivity growth consisting of capital deepening, growth in labour quality, and TFP growth. The role of capital deepening productivity strongly increased during 1987-1996. Likewise, TFP growth provides a sizable contribution to productivity growth. In addition, they also highlighted the impact of an aging population on labour quality.

Umkomen (2010) analyses factors that affect labour productivity of state enterprises using a panel of 52 state enterprises for 2000-2007. Results reveal that average labour cost, the value of current assets, and labour unions are positive and significant determinants of labour productivity whereas the number of labourers is a negative and significant determinant. Further, Arjchariyaartong (2011) examines technical efficiencies of agricultural productivity in 14

Asian countries including Thailand, using the cross-sectional FAO data for 1961-2004. A Cobb-Douglas production function is estimated with productivity being determined by land, labour, fertiliser, and machinery. Results reveal that labour is the most significant factor of production and the elasticity of output with respect to labour varies from 0.21 to 0.61.

Extending Santipollavut *et al.* (2007) and Nonthakot and Villano (2008), Chansarn (2013) examines the relationship between labour productivity and educational attainment in Thailand for 2001-2010 using OLS. He finds that educational attainment is a significant determinant of labour productivity growth because the findings reveal that employed persons are more productive as they receive more education. However, the educational system has failed to create human resources that are suitable for every sector.

Seankeaw and Jayanthakumaran (2013) study the link between trade liberalisation and manufacturing labour productivity and skilled employment using the manufacturing industrial surveys conducted by NSO in 1991, 1994, 1997, 2000, 2003, and 2007. A labour productivity growth model is applied to analyse the relationships. Results show that trade liberalisation and the growth in skilled employment increase manufacturing labour productivity while the overall growth in manufacturing employment has a negative effect on labour productivity.

3.5.2 Literature on Nutritional Status

We now review studies on nutritional status in Thailand. Food and nutrition are an essential basis to improve health status which is determined by several factors such as food consumption patterns, nutritional and health promotions and policies. Much research has been undertaken in this area to provide guidelines for policy makers to improve health and nutritional status. Trairatvorakul (1984) examines the impacts of a rice price change on the calorie intake of paddy famers using 1975/76 socio-economic survey data from NSO. The rice consumption function as a function of the rice price and farm household current income is derived to calculate these impacts. Results show that the influence of price on calorie intake of semi-subsistence farmers is similar to that of commercial farmers: the price elasticities of calorie intake for both semi-subsistence and commercial farmers are negative, being of -0.41 for semi-subsistence farmers who consume glutinous rice and -0.84 for those who consume non-glutinous rice, and -0.32 for commercial farmers who consume glutinous rice and -0.72 for those who consume non glutinous rice. This implies that when the rice price increases, calorie intake declines because farmers consume less rice, and the calorie intake of semi-commercial farmers decreases rather more than that of the commercial farmers.

With a focus on improving nutritional policy in Thailand, Smitasiri (2000) develops a framework to examine the relationship between nutrition and agricultural innovations. This "Decision Development Dimension" framework is a useful approach for implementing agricultural, nutritional and food policies. He argues that effective education and its promotion are essential factors contributing to the development of food and nutritional interventions as well as agricultural innovations.

Matsuda-Inoguchi *et al.* (2000) study the current nutrition status of working women in Thailand. Cross-sectional data are from 52 non-smoking and non-habitually drinking adult women in Bangkok using 24-hour food records, clinical examinations, and peripheral blood samples. The records are evaluated as a nutrition value by taking Thai food composition tables, and estimates for eight nutrient elements - calcium, copper, iron, magnesium, sodium, potassium, phosphorus, and zinc - by inductively coupled plasma mass spectrometry. Basic statistical analysis shows that lunch and dinner are equally important. The daily energy intake of participants on average is 1,630 kcal which is taken by consuming 224 grams (g) of carbohydrate with 60% from rice, 57g of lipid, and 55g of protein per day. Approximately 50% of participants are calculated as insufficient in calorie intake compared to the national Recommended Dietary Allowances (RDA). Protein intake is adequate in most cases, while more than a half of women consume lipid excessively.[3] Calcium, iron, magnesium, zinc and phosphorus intakes have a lower level than the RDA requirement in several participants.

Tonsiririn and Bhattacharee (2001) describe an overview of national actions to improve nutrition in Thailand. Three projects focus on nutritional status, namely the National Poverty Alleviation Plan, a Holistic Approach Integrating Nutrition, and Preventive and Promotional Guidance. They report that the development of a National Poverty Alleviation Plan enhanced the quality of life and eradicated under-nutrition in poverty stricken areas. A holistic approach integrating nutrition, food production, primary health care, and community based actions are promoted to help the rural poor through participation in the development plans. In terms of the preventive and promotional guidance for nutritional improvement, food-based dietary guidelines are used as information and communication tools to promote appropriate food intake. The projects conclude that a synthesis of national level policies contribute to the effective control of malnutrition.

[3] Lipids consist of fats, oils, hormones, certain vitamins, waxes, and most of the non-protein membrane of cells.

Kosulwat (2002) investigate the transition of health and nutrition status in Thailand in relation to social and economic changes, the changing patterns of demography, shifts in food consumption patterns, and nutritional problems. Using data from NSO and FAO for 1991-1999 and national health examination surveys for 1991 and 1996, results show that rapid changes in food intake and lifestyle patterns have a strong and significant influence on the shifting pattern of disease. Further, behaviours must be modified to promote suitable eating practices and physical activities.

Schmidt and Isvilanonda (2004) estimate Engel curves for vegetable consumption expenditure using survey data for 1998 from 23,000 Thai households and OLS. They find that an increase in additional food expenditure raises the share of vegetable consumption at the expense of cereal and rice. In addition, the variations of household vegetable expenditure are associated with incomes, regional and socio-demographic factors. Similarly, Bhadakom (2008) examines factors affecting the expenditure pattern of food prepared at home, prepared food taken home, and food eaten away from home using NSO survey data for 2004. An Engel curve equation within an almost ideal demand system (AIDS) is used to estimate consumption patterns. Results indicate that the share of total household expenditure spending for food away from home rises as household expenditure rises. All income elasticities of food away from home and that of both food prepared at home and prepared food taken home are positive. Additionally, the income elasticities of the former are greater than those of both the latter, implying that changing in income has more impacts on the consumption of food away from home than the consumption of food at home and prepared food taken home.

Pongchaiyakul *et al.* (2008) study calcium consumption among rural Thais in the Northeast region taking three-day food records and interviewer-administered food-frequency questionnaires for 73 food items. Results show that 67% of males and 87% of females have lower dietary calcium intake of less than half of the RDA and only 6% and 3% of men and women reach that level. The main food sources of calcium in the diet are glutinous rice followed by small animals with edible bones, fresh and fermented fish, dairy products, and vegetables. They also suggest that dairy products and calcium-rich foods should be promoted to increase consumption to prevent osteoporosis.

Taechangam *et al.* (2008) evaluate dietary status and observed changes in patterns of food intake by developing the Thai Healthy Eating Index (THEI). This index is calculated from the diets that comply with the recommendations of the Dietary Guideline and Thailand Nutrition

Flag. The THEI has 11 components: Components 1 to 5 measure the level of a person's diet following serving recommendations for the five major food groups of the Nutrition Flag; Components 6, 7 and 8 evaluate total fat, saturated fat, and added sugar consumption; total cholesterol and sodium intake are computed in Components 9 and 10; and Component 11 measures variety in a person's diet. All components have a score ranging from 0-10 so that the THEI has a total score of 110. The THEI scores are derived from three-day food record data collected from a selected 121 working adults aged 25–60 years. Results show that the diets of most people need to improve and some individuals consume a poor diet. They also recommended that the THEI is a practical index for describing overall diet quality and a basic means for providing nutritional education and promotion.

Following Schmidt and Isvilanonda (2004) and Bhadakom (2008), Suddeephong *et al.* (2010) examine the demand for fresh fruits and vegetables using cross-sectional data from 500 households in Bangkok and urban Chiang Mai province in 2007. An AIDS model is employed to estimate demand and results show that total household expenditure and the educational levels of household heads have a significant effect on the decision to purchase fresh produce from reputable retailers and minimally processed fresh fruits and vegetables. Additionally, the influence of safety and quality indications on purchasing decisions are significantly influenced by the educational levels of household heads, which indicates that higher educated buyers are aware of product safety and quality attributes when purchasing products.

Jitnarin *et al.* (2011) examine the linkages between dietary intake, weight, BMI and smoking status among Thai adults. Cross-sectional data are used from health and dietary questionnaires and from anthropometric measurements from 7,858 participants for 2004-2005. The study uses both analysis of variance (ANOVA) to test the difference of food intakes, macronutrient and micronutrient intakes differentiated by smoking status and gender, and factorial ANOVA to differentiate the distinction of BMI for smokers and non-smokers. Results show that energy and macronutrient intakes among male participants are statistically significantly different for smokers and the BMI of smokers in both genders is significantly lower than that of non-smokers.

Wigraiphat *et al.* (2012) examines factors affecting the households' expenditure on food away from home in the Bangkok area. 2,502 households from the cross-sectional data of NSO, 2009 are analysed by Tobit model. The results indicate that the average household expenditure on food away from home to the total household income is 0.12. The age of household head, total household income, household size, tenure of residence, household head's marital status, and occupation are the factors affecting the expenditure. Gender of household head, period of education of household head, type of residence, household debt and household head's hours of participation in the workforce have no influence on the expenditure. They also suggest that food businesses in the Bangkok area still have a good opportunity for growth because households' expenditure on food away from home is increasing.

3.6 Summary

AHMs have been developed to examine agricultural household behaviour, especially in LDCs. Agricultural households behave as a semi-commercial household or firm household which partially produce for sales and partly for their own consumptions. Labour is supplied by their families for farm-household production, and labour is hired from the market when there is insufficient family labour. As a consequence, a key feature of AMHs is to integrate the decisions of production, consumption and labour supply into a single framework.

AHMs are widely used to study the relationship between nutrient intake and labour productivity and the efficiency wages hypothesis is that better-nourished workers are more productive and earn higher wages. Thus, a production function and wage equation are employed to estimate farm productivity within a farm household framework. Households are assumed to maximise utility subject to agricultural production function, time endowment, and budget constraints. Most studies find that energy intakes and anthropometric proxies are a significant determinant of farm production and wages, and age, gender, and the level of education also have a positive impact on productivity. To obtain accurate estimates, econometric 2SLS approaches are employed to control for simultaneity in cross-sectional data. NL2SLS is used to tackle the non-linearity in recursive relationships between nutritional status and labour productivity; and OLS estimates are biased and inconsistent. In panel studies, fixed and random effects models are applied to calculate productivity consisting of calorie intakes and the WFH ratio, height and BMI to counter the problem of time-invariant effects. Also, 2SQR shows the consistent estimators of the nutrition-labour productivity link at different quantiles.

In Thailand, several studies analyse factors affecting labour productivity. The main determinants are capital intensity, educational level, number of workers, labour quality, trade liberalisation, as well as the physical and mental health of workers. In addition, labour is the main determinant of agricultural productivity. Linked to the physical aspects of labour and the quality of labour factors, nutritional status is widely investigated when evaluating health status.

Rapid changes in food intake and lifestyle patterns have an important effect on health transition, and nutrient intake is lower than the national recommended value although lipid is consumed increasingly in urban areas, particularly by women. In addition, the rural population faces malnutrition, and income, education, and region are significant influences on changing food intake patterns. While food consumption can lead directly to nutrient intake, these studies do not examine the effects of food consumption on work efficiency.

It is clear that there are gaps in the understanding of the relationship between nutrient intake and labour productivity, especially for agricultural workers in Thailand and further research is needed. This study adopts an AHM and uses a contemporary dataset with appropriate econometric techniques to better understand this relationship. Such knowledge is useful for policymakers to enhance productivity to meet food security goals.

Chapter 4 Theoretical Framework

4.1 Introduction

Farm households in less developed countries are typically characterised by a continuum between subsistence and commercial production. At one extreme is a "pure" subsistence farm household which utilises only the family's own labour for production and it consumes only what it produces without access to either labour or output markets. At the other extreme is a "pure" commercial farm household which makes decisions on producing commodities for sale using only hired labour to maximise profits (Nakajima, 1970, p. 165 (in Wharton (1970)); Nakajima, 1986, p. 9). Between these two extremes are two important farm household types. First, a subsistence farm household maximises utility by using its own labour on farm activities without access to the labour market and it either consumes its output or sells it in the market. Second, a commercial farm household makes decisions on producing and selling all output to maximise profits and at the same time maximises the utility of providing its own labour (Dawson, 1982; Nakajima, 1986, p. 9; Singh *et al.*, 1986, p. 17; De Janvry *et al.*, 1991). The commercial farm household can also sell its output and buy products from the market for its own consumption. The difference between selling and buying prices of a given farm product is the marketing margin for the trader.

A combination of the characteristics of subsistence and commercial farms provides a unique form for most farm households throughout the world and these are known as "semi-commercial households" which partly produce for their own consumption and partly for sale at the market price. In particular, the household may pay for a market-purchased product to meet its consumption needs, and also family labour can be employed on- and/or off-farm at the same wage rate (Ellis, 1988, pp. 102-103). These two characteristics make semi-commercial household decisions different from other types of firms. In particular, a farm household makes decisions with respect to both the quantity of family labour supplied and income to maximise its utility (Singh *et al.*, 1986, p. 6; Nakajima, 1986, p. 9; Ellis, 1988, p. 106). A component of income is derived entirely or partly from farm profits (and sometimes from off-farm work) (Singh *et al.*, 1986, p. 6).

There is a critical difference in the decision-making process between subsistence or semi-commercial farm households and commercial farm households. For a subsistence or semi-commercial farm household, production and consumption decisions are related since the former is determined by household preferences concerning labour and consumption of commodities (such as home-produced goods, market-purchased goods, and leisure). The commercial farm household on the other hand first attempts to maximise farm profits subject to a production function constraint, and the resulting income is then sacrificed to the consumption needs of the family to maximise utility (Singh *et al*., 1986, p. 17; De Janvry *et al*., 1991). This is a recursive, two-stage decision-making process because production decisions are made separately from consumption and labour-supply decisions (Singh *et al*., 1986, p. 17). By contrast, the recursive property of decision-making for subsistence or semi-commercial farm households is absent since decisions about production, consumption and labour supply are determined simultaneously (Hazell and Norton, 1986, p. 62; Singh *et al*., 1986, pp. 6-17; De Janvry *et al*., 1991).

As part of production and consumption decision-making, particularly if household income is low, higher wages or income allows for better nutritional intake of workers which can increase labour productivity, especially if a competitive labour market exists (Liebenstein, 1957, pp. 94-95; Stiglitz, 1976; Strauss, 1986; Deolalikar, 1988; Haddad and Bouis, 1991; Weinberger, 2004). This concept is known as "the nutritional effective wage hypothesis theory" which provides a link between production and consumption decisions of a farm household.

This chapter presents the decision-making behaviour of farm households which is then used as the basis for constructing an econometric model of the nutrition-labour productivity relationship for rice-farming households in Thailand. Section 4.2 then reviews the utility function of a farm household. Section 4.3 examines the production and income functions of the farm family. Section 4.4 examines the decision-making process of a subsistence farm family without the labour market, and some comparative statistics are derived. Section 4.5 considers the decision-making process of a commercial farm household. Section 4.6 examines the decision-making process for the semi-commercial household which consumes part of its output. Section 4.7 explains the labour efficiency function to show the nutrition-labour productivity link. Section 4.8 develops empirical equations used in the study. Section 4.9 summarises.

4.2 The Utility Function of the Farm Household

Assume a utility-maximising farm household which earns income through utilising its own family labour. The utility function is defined over income and the supply of family labour (Nakajima, 1986, p. 9) and is differentiable and strictly quasi-concave:

$$U=U(L_F, M) \tag{4.1}$$

where U is utility, L_F is family labour (hours) utilised in a year, and M is family income.[4] Assume that:

$$\overline{L}_F \geq L_F \geq 0, \quad M \geq M_0 > 0 \tag{4.2}$$

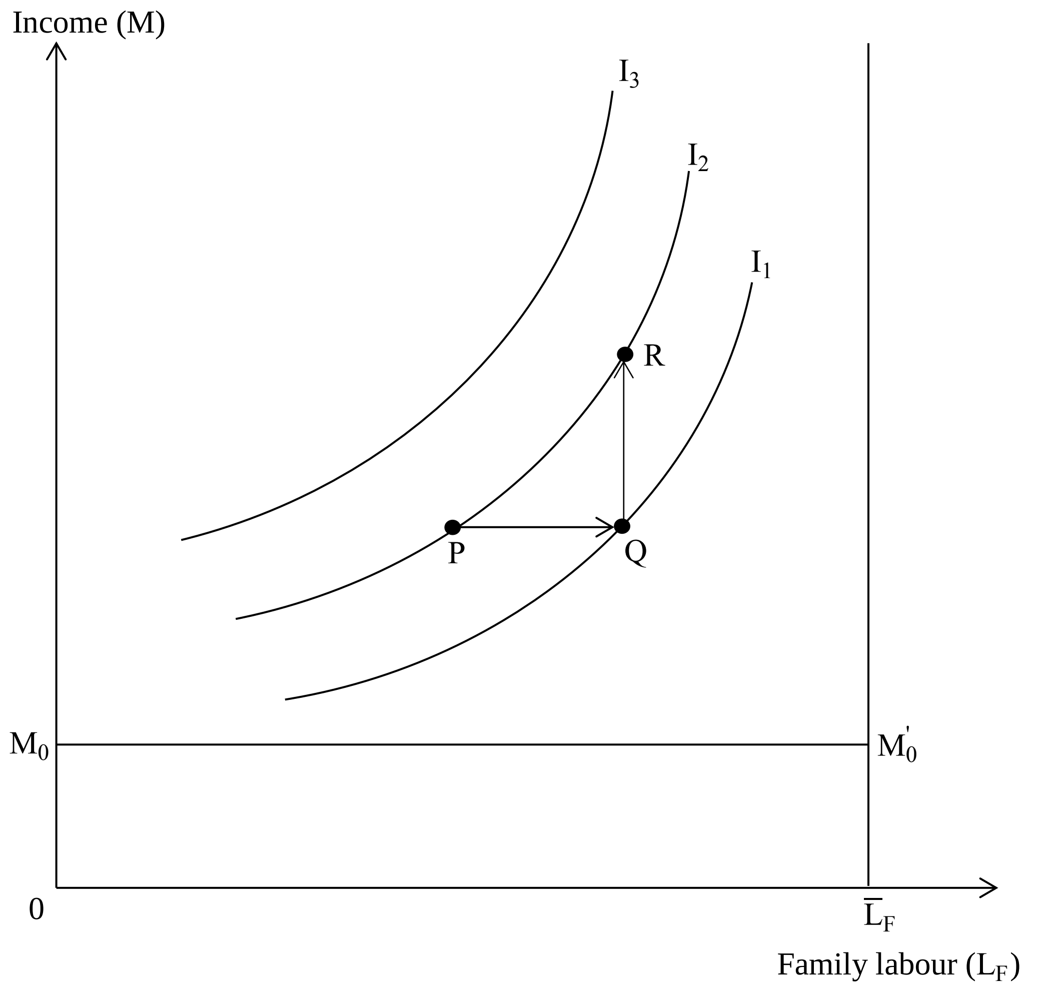
where $\overline{L}_F$ is the physiologically possible maximum labour hours for the whole family, and M_0 is its minimum subsistence standard of income which is the minimum income required for the farm household. Also assume that:

$$\left.\begin{array}{ll} U'_{L_F} < 0, & U''_{L_F} > 0 \\ U'_M > 0, & U''_M < 0 \end{array}\right\} \tag{4.3}$$

where U'_{L_F} is the (increasing) marginal (dis)utility of labour and U'_M is the (decreasing) marginal utility of income. The utility function in (4.1) can be illustrated by an indifference map which is shown in Figure 4.1. From the assumptions in (4.3), utility strictly decreases in labour but strictly increases in income. From the assumption that $U'_{L_F} < 0$, the marginal utility of labour is negative, so that $-U'_{L_F} > 0$, and this is called the "marginal disutility of labour". Further, labour can experience direct disutility through its physical and/or mental pains and face indirect utility due to decreasing leisure or free time. This is sometimes called “the marginal pain of labour” (Nakajima, 1986, p. 10).

[4] A household utility function aggregates the utility of individual family members as a single unit. In reality, a household utility function poses problems of interpersonal comparisons of utility since every household member is likely to have different preferences (Sen, 1966, p. 426; Rosenzweig, 1986; Alderman, 1995). Also, family members are hypothesised to make their labour input decisions from limited resources and these decisions are influenced by other members (Dawson, 1984). This implies that the household utility function is not only the utility of a household head, but also that of all family members, and this is known as “one pocket” and “one pain” (Nakajima, 1970, p. 167; Dawson, 1982; Dawson, 1984).

Figure 4.1 The Indifference Map of the Farm Family



Sources: Dawson (1982) and Nakajima (1986, p. 11)

From assumptions in (4.3), a set of indifference curves, I_1, I_2, I_3, which represent the utility of the farm household for different combinations of labour and income, are upward-slopping and strictly convex. Also, the utility level of I_3 is higher than that of I_2 and I_1, implying that the higher the indifference curve, the greater the level of utility. Consider the indifference curves in Figure 4.1. At a given level of utility, say I_2 and starting from a point P, a rise in L_F will decrease the total level of utility to point Q, and to maintain the initial level of utility, M must increase to point R. In other words, it is possible to remain on the same indifference curve if an increase in L_F (from P to Q) is compensated for by a corresponding increase in M (from Q to R).

Given an indifference curve with a given utility, totally differentiating (4.1) given (4.3) gives:

$$dU = \frac{\partial U(L_F)}{\partial L_F} dL_F + \frac{\partial U(M)}{\partial M} dM$$

or:

$$dU = U'_{L_F} \cdot dL_F + U'_M \cdot dM = 0 \tag{4.4}$$

Rearranging (4.4) gives the slope of the indifference curve:

$$\frac{dM}{dL_F} = \frac{-U'_{L_F}}{U'_M} \tag{4.5}$$

Thus, the slope of the indifference curve is the marginal rate of substitution of family labour for income ($MRS_{L_F, M}$) which measures the amount of M required to compensate for a small increase in L_F so as to maintain a constant level of utility. It also represents the value of a marginal unit of family labour utilised by the family itself and is sometimes called "the marginal valuation of family labour" (Nakajima, 1986, p. 12; Ellis, 1988, p. 104). This slope is positive, $\frac{-U'_{L_F}}{U'_M} > 0$, and the indifference curve is upward-slopping, and becomes steeper when moving horizontally to the right or vertically upwards.

4.3 The Production and Income Functions of the Farm Family

For simplicity, assume that the farm household produces a single end output from amounts of labour, land and another input, say fertiliser throughout the production period (usually a crop season). Production decisions are once-and-for-all decisions which are made at the beginning of the production period. All input prices are given, and the output is sold at the given market price. The farm household is assumed to operate in conditions of subjective certainty. Thus, at the end of the production period, total revenue is known and definite.

The production function describes the maximum level of output that is obtained from any given combination of inputs and is given by:

$$Q = f(L, LD, FE) \tag{4.6}$$

where Q is output, L is total labour which is the sum of family labour (L_F) and hired labour (L_H) or $L = L_F + L_H$, LD is land, and FE is fertiliser. We employ the assumption of production function that it is continuous, twice differentiable and strictly quasi-concave. Also, suppose that the marginal products of all inputs is positive and diminishing, that is:

$$\left.\begin{array}{ll} f'_{L} > 0, & f''_{L} < 0; \\ f'_{LD} > 0, & f''_{LD} < 0; \\ f'_{FE} > 0, & f''_{FE} < 0 \end{array}\right\} \tag{4.7}$$

To maximise output, the farm household first makes decisions with respect to the levels of inputs: what output to produce, how much to produce, and how to produce this output. This problem is to maximise total revenue for these given inputs and the total farm revenue (TR) is a function of inputs given the market price of the output (P) and is expressed as:

$$TR = P \cdot f(L, LD, FE) \tag{4.8}$$

Regarding the farm having given levels of its own labour and land. Farm decisions are concerned with how much fertiliser to utilise. Assuming that there are no labour costs, the variable cost is solely of fertiliser, that is, $P_{FE}FE$ where P_{FE} is the fertiliser price. The fixed cost (F) is the amount paid for the fixed input land. Assume that any off-farm income (M_0) accrues to the farm family at the end of the production period. Now, we can define net autonomous income (A) as the difference between off-farm income and the fixed costs, that is:

$$A = M_0 - FC \tag{4.9}$$

Define $\overline{TR}$ as total revenue minus other input costs plus net autonomous income, that is:

$$\overline{TR}(L, LD, P_{FE}, A) = P \cdot f(L, LD, FE) - P_{FE}FE + A \tag{4.10}$$

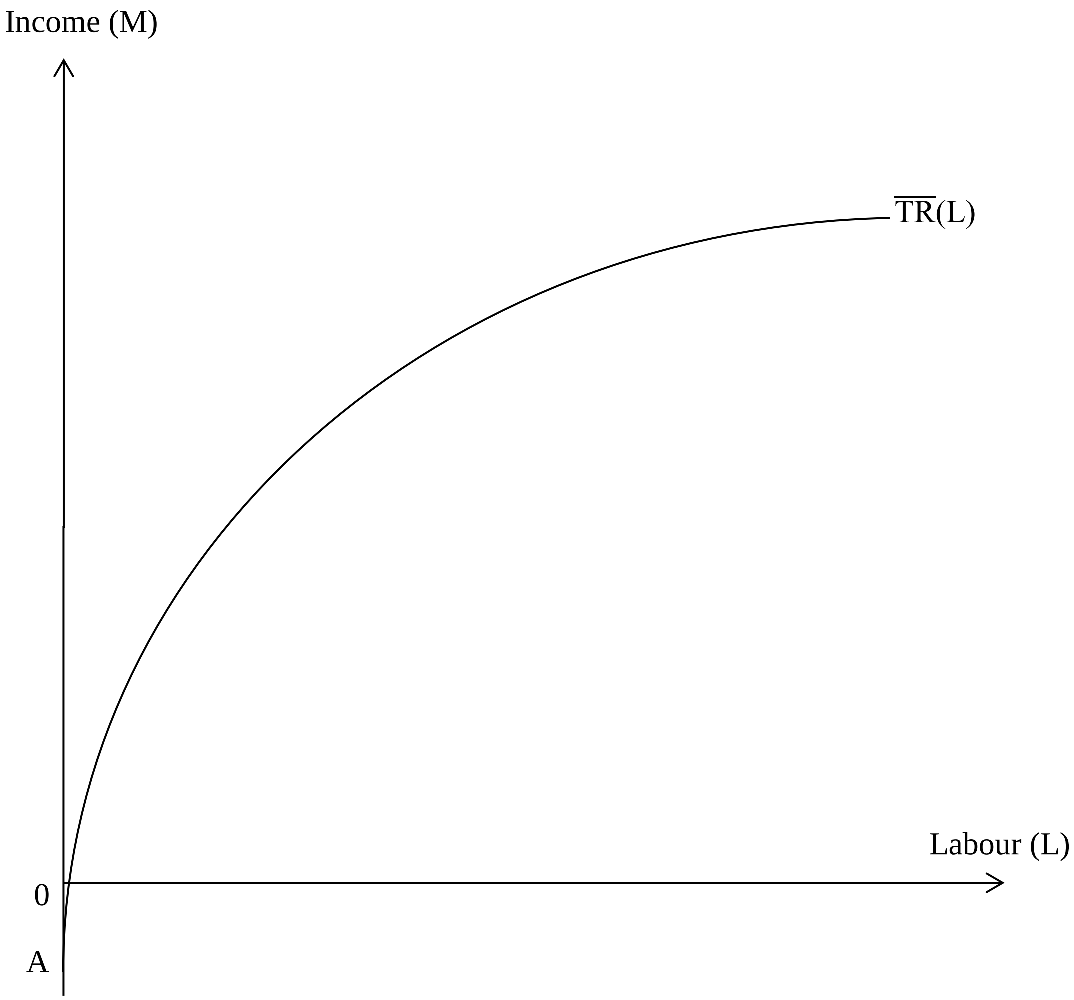
Thus the maximum value for $\overline{TR}$ or gross farm income is a function of labour, land, fertiliser price and net autonomous income. The strict concavity of the total revenue function is a sufficient condition for the corresponding second-order condition for maximisation of $\overline{TR}$ to hold. In addition, the strict concavity of the total revenue function implies that the $\overline{TR}$-function is strictly concave in terms of labour as well as land and fertiliser. The $\overline{TR}$-function is shown in

Figure 4.2. $\overline{TR}(L)$ shows the maximum value for $\overline{TR}$ for every level of labour, given the amount of land, net autonomous income, and the fertiliser price. The distance 0A, which is negative in this case[5], denotes the level of net autonomous income. From the assumptions above, total revenue must always coincide with net farm income (Nakajima, 1970, p. 168). This can be summarised as:

$$M = \overline{TR}(L, LD, P_{FE}, A) \tag{4.11}$$

From (4.7), the marginal value product of labour is non-negative and decreasing, so $\overline{TR}^{'}(L) > 0$ and $\overline{TR}^{''}(L) < 0$, as shown in Figure 4.2.

Figure 4.2 The $\overline{\textbf{TR}}$-function of the Farm Family



Source: Dawson (1982)

[5]There is no restriction on the autonomous income from having zero or any negative value.

4.4 The Decision-making Process of the Subsistence Farm Family

A subsistence farm household maximises utility by using its own labour on farm activities without access to the labour market and it also consumes its output that can also be sold in the market. Only labour, land and fertiliser are the factors of production, and land is fixed. The absence of a labour market implies that labour is neither hired in nor hired out. This means that the amount of family labour must be equal to the amount of labour input on its own farm.

In (4.1), the utility function of the farm family is defined over family labour and income, that is, $U = U(L_F, M)$. The farm family is assumed to maximise its utility subject to the farm family's revenue constraint. We now have the following equation for household income (M) adjusted from (4.11) as:

$$M = P \cdot f(L, LD, FE) - P_{FE}FE + A \tag{4.12}$$

where $L = L_F$

Maximising (4.1) subject to (4.12), gives:

$$P \cdot f'_{L_F} = \frac{-U'_{L_F}}{U'_M} \tag{4.13}$$

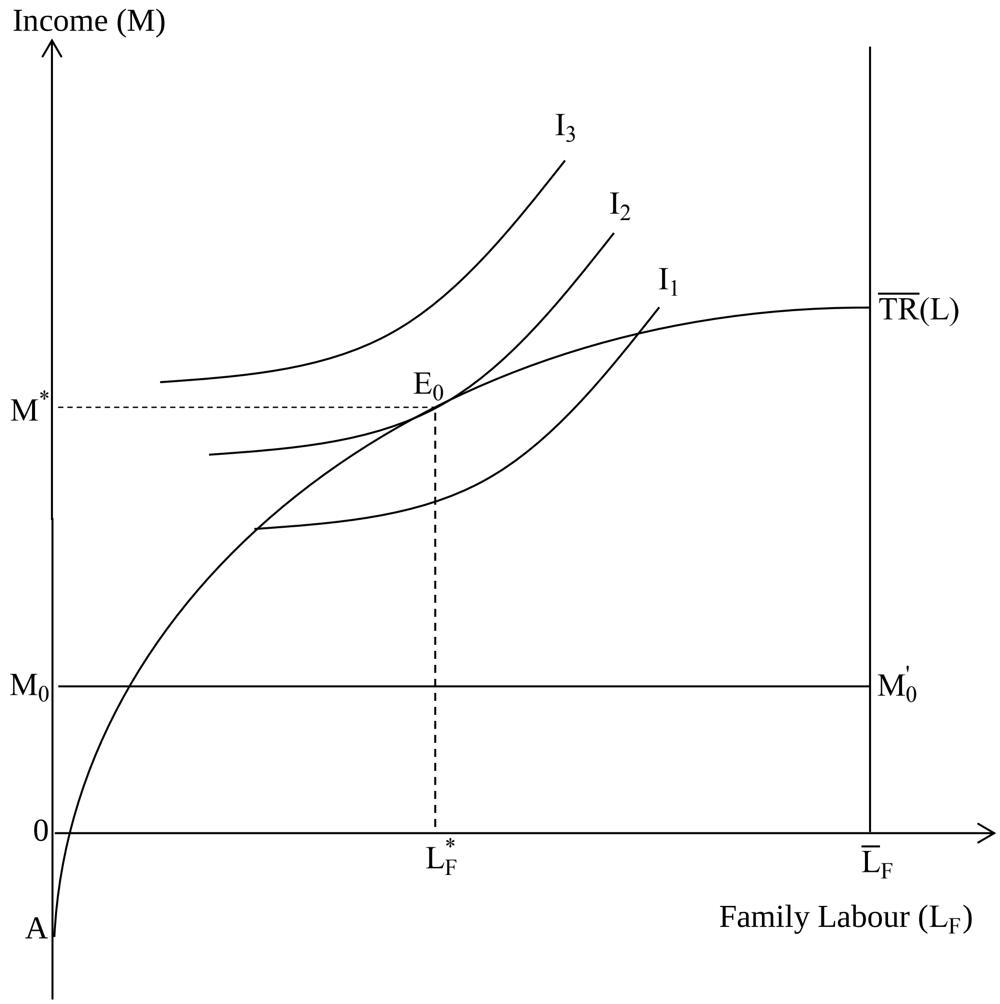
and:

$$P \cdot f'_{FE} = P_{FE} \tag{4.14}$$

In (4.13), the marginal value product of labour equals the marginal valuation of family labour or the marginal rate of substitution of family labour for income ($MRS_{L_F, M}$). In (4.14), FE is used until its price equals its marginal value product (and if $P \cdot f'_{FE} > P_{FE}$, FE will not be used). The utility-maximising equilibrium in Figure 4.3 is E_0 where the indifference curve, I_2 is tangential to the income curve; L_F^* is the equilibrium level of family labour and M^* is the equilibrium level of income.

Without a labour market, the peasant household is assumed to spend all of its initial income on consumption expenditure, so that the family's income is equals to consumption (Currie, 1981, p. 53). Moreover, the equilibrium marginal value product of labour tends to vary from farm family to farm family because of different number of workers and dependents and the levels of available non-labour resources (Mellor, 1963; p. 517; Nakajima, 1970, p. 169). Then, some comparative statics are considered.

Figure 4.3 Farm Household with No Labour Market



Source: Adapted from Nakajima (1986, p.25)

4.4.1 Effects of Autonomous Income Change

Consider the effects of a change in autonomous income. Suppose that labour, land and the fertiliser price are given. Following Nakajima (1988, pp. 39–42), regarding the equilibrium condition of (4.1) subject to (4.12), the necessary conditions for maximising utility are:

$$P \cdot f'_{L_F} - \frac{-U'_{L_F}}{U'_M} = 0 \tag{4.15}$$

$$\frac{d}{dL_F}\left(\frac{dU}{dL_F}\right) = \frac{d}{dL_F}\left[U'_M\left(P \cdot f'_{L_F} - \frac{-U'_{L_F}}{U'_M}\right)\right] < 0 \tag{4.16}$$

Now, we rewrite (4.13) which is the marginal valuation of family labour function as:

$$P \cdot f'_{L_F} = \frac{-U'_{L_F}}{U'_M} \equiv f(L_F, M) \tag{4.17}$$

Also, additional assumptions are provided as:

$$\frac{\partial\left(\frac{-U'_{L_F}}{U'_M}\right)}{\partial L_F} > 0, \quad \text{and} \quad \frac{\partial\left(\frac{-U'_{L_F}}{U'_M}\right)}{\partial M} > 0 \tag{4.18}$$

Recall that the simultaneous equations (4.12) and (4.17) provide the equilibrium values of L_F and M as a function of A. Differentiating (4.12) and (4.17) partially with respect to A and solving, we get:

$$\frac{\partial L_F}{\partial A} = \frac{-1}{\Delta} \cdot \frac{\partial\left(\frac{-U'_{L_F}}{U'_M}\right)}{\partial M} < 0 \tag{4.19}$$

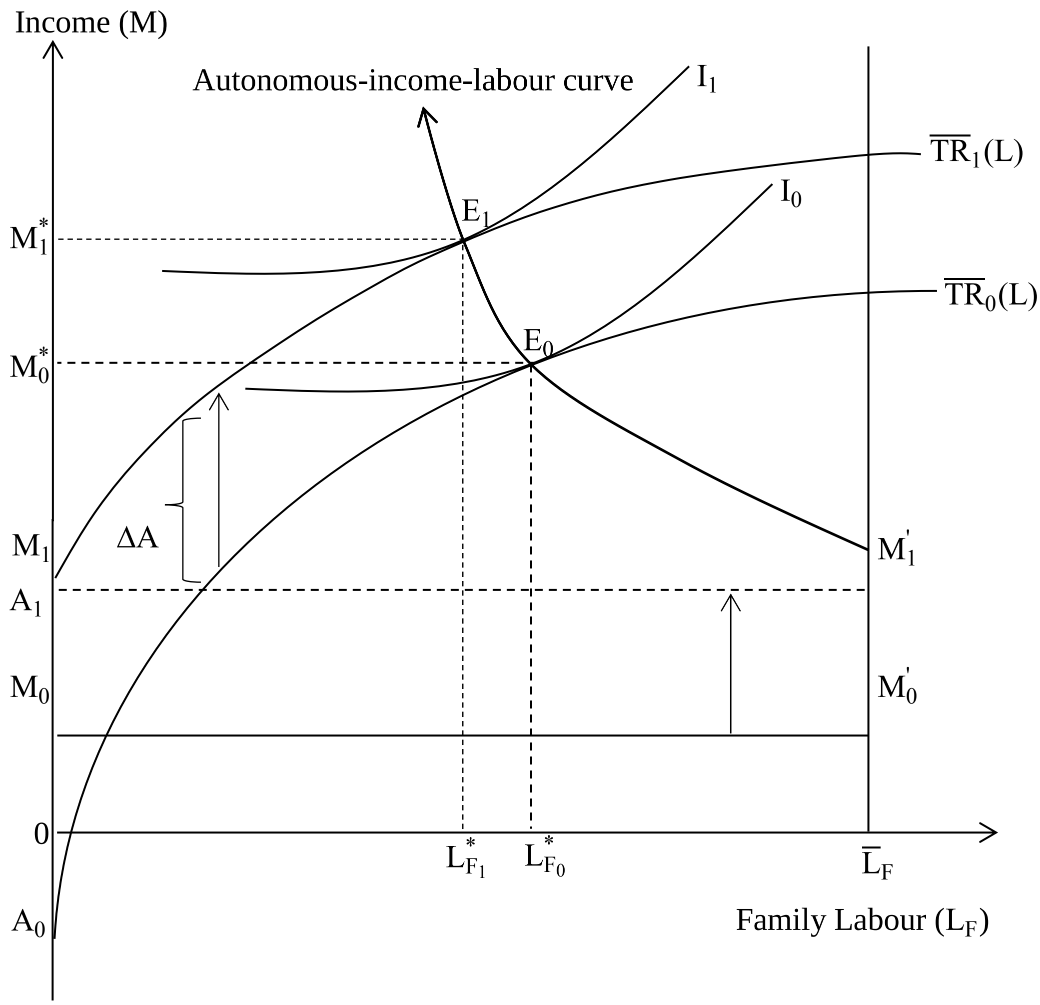
and:

$$\frac{\partial M}{\partial A} = \frac{1}{\Delta}\left(\frac{\partial\left(\frac{-U'_{L_F}}{U'_M}\right)}{\partial A} - P \cdot f''_{L_F} \right) > 0 \qquad (4.20)$$

where $\Delta = \frac{-U'_{L_F}}{U'_M} \cdot \frac{\partial\left(\frac{-U'_{L_F}}{U'_M}\right)}{\partial M} + \frac{\partial\left(\frac{-U'_{L_F}}{U'_M}\right)}{\partial A} - P \cdot f''_{L_F} > 0$.[6]

From the assumptions (4.18), a rise in autonomous income will lead to a rise in income and a decrease in family labour. These effects are shown in Figure 4.4.

Figure 4.4 The Effects of a Change in Autonomous Income



Source: Nakajima (1970, p. 171)

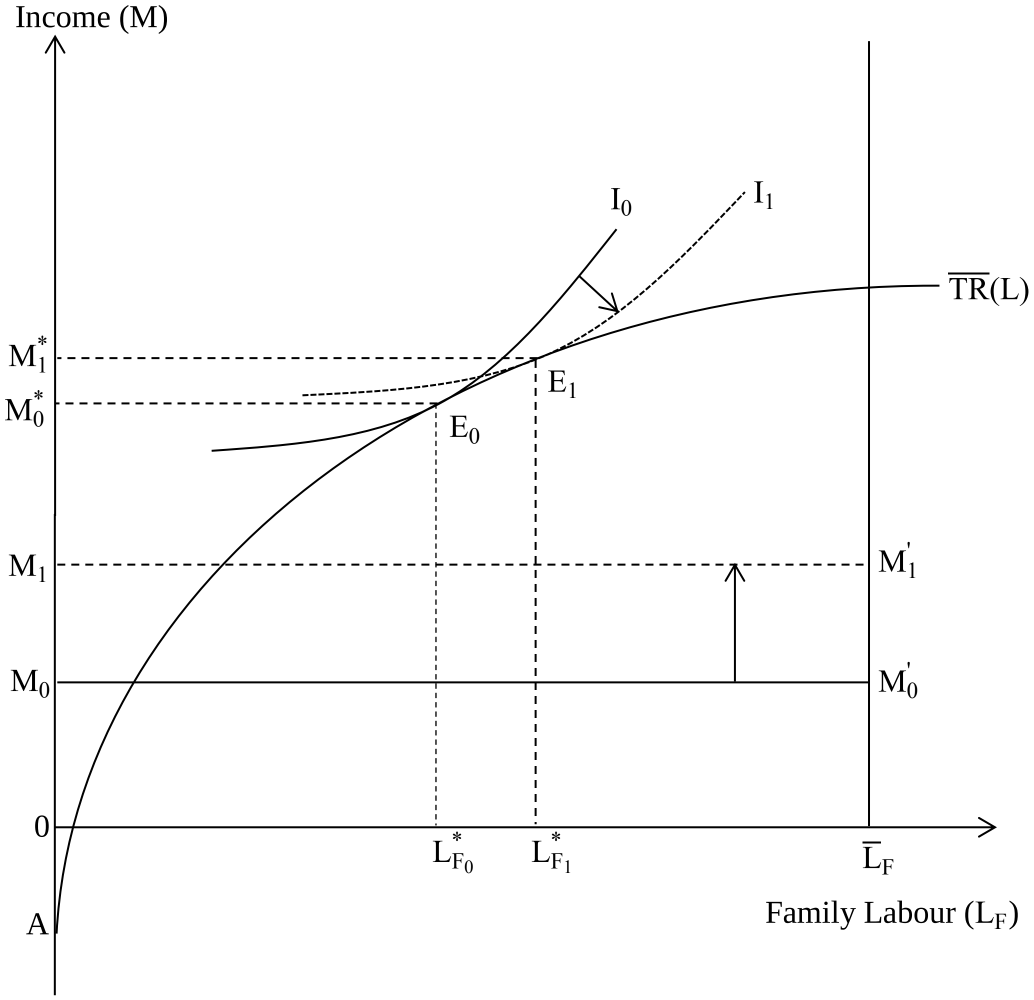
[6] See Nakajima (1988, pp. 37 – 39), stability condition for subjective equilibrium of the farm household in basic model.

When autonomous income rises from A_0 to A_1, the family income curve shifts from $\overline{TR}_0(L)$ to $\overline{TR}_1(L)$. The initial equilibrium point is E_0 and the new equilibrium point is E_1. The optimal level of income increases from M_0^* to M_1^*, but family labour decreases from $L_{F_0}^*$ to $L_{F_1}^*$. The curve connecting equilibria (E_0, E_1) is called the autonomous-income-labour curve. This effect of a change in autonomous income is an income effect.

4.4.2 Effects of Family Size Change

Nakajima (1986, pp. 58 - 62) considers the effects of changes in the numbers of family workers and dependents. Let us start with the effects of changing the number of dependents. In Figure 4.5, a rise in the number of dependents raises the minimum standard income from M_0 to M_1; however, it does not affect the maximum labour line ($\overline{L}_F$). An increase in the number of dependents is also likely to reduce the slope of the indifference curve, which is equivalent to the marginal valuation of family labour ($\frac{-U'_{L_F}}{U'_M}$) at every point above the line M_0M_0' because of rising U'_M. Thus, the indifference map changes as preferences change and the relevant indifference curve moves from I_0 to I_1. The equilibrium point moves from E_0 to E_1 where the indifference curve I_1 is tangential to the curve $\overline{TR}(L)$ where the marginal valuation of labour equals the marginal product of labour. The equilibrium amount of family labour upturns from $L_{F_0}^*$ to $L_{F_1}^*$, and income rises from M_0^* to M_1^*. However, we cannot assert that whether the utility of the farm family increases or not because its utility function (and indifference map) changes.

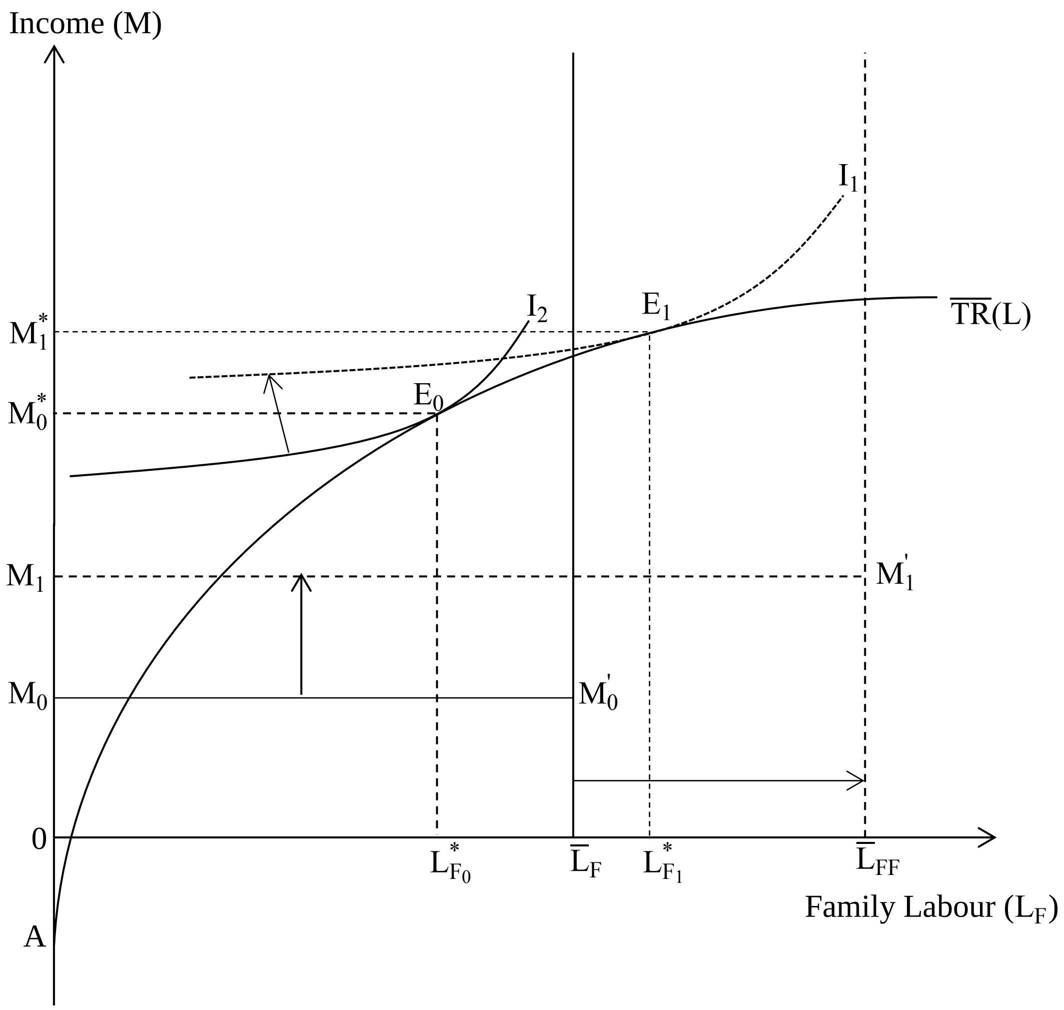
Figure 4.5 The Effect of a Change in the Number of Dependents



Source: Nakajima (1986, p. 59)

Now consider the impact of a change in the number of workers. In Figure 4.6, this not only raises the subsistence minimum income from M_0 to M_1 but also moves the maximum labour to the right from $\overline{L}_F$ to $\overline{L}_{FF}$. As in the case of an increase in the number of dependents, the slope of each indifference curve falls at every point in the area above M_1M_1' because U_M' increases and $-U_{L_F}' > 0$ from (4.3). Thus, the indifference curve shifts from I_0 to I_1 in the area between $\overline{L}_F$ to $\overline{L}_{FF}$; again the indifference map changes because preferences change. Yet, I_1 can lie to the left or the right of the line $\overline{L}_F$ due to the amount of labour per total worker. The equilibrium moves from E_0 to E_1 along the curve $\overline{TR}(L)$, so that the optimal level of labour rises from $L_{F_0}^*$ to $L_{F_1}^*$, and the optimal income rises from M_0^* to M_1^*. Normally these effects are more than the effects of a change in the number of dependents. Thus, the impact of the rise in the number of workers is to increase the amount of family labour used, increase income, and increase output, but the marginal product of labour diminishes.

Figure 4.6 The Effects of a Change in the Number of Workers



Source: Adapted from Nakajima (1986, p. 61)

In addition, Nakajima (1988, pp. 60 – 62) also derives these effects mathematically. Rewriting (4.17) as:

$$\left(\frac{-U'_{L_F}}{U'_M}\right) = f(L_F, M; d_1, d_2) > 0 \qquad (4.21)$$

where d_1 is the number of dependents and d_2 is that of workers of the farm family. Equation (4.17) is therefore called the marginal valuation of family labour function. Assume that

$$\frac{\partial\left(\frac{-U'_{L_F}}{U'_M}\right)}{\partial L_F} > 0;\ \frac{\partial\left(\frac{-U'_{L_F}}{U'_M}\right)}{\partial M} > 0 \tag{4.22}$$

and;

$$\frac{\partial\left(\frac{-U'_{L_F}}{U'_M}\right)}{\partial d_1} < 0;\ \frac{\partial\left(\frac{-U'_{L_F}}{U'_M}\right)}{\partial d_2} < 0 \tag{4.23}$$

Equation (4.12) and (4.17) now imply that each of the equilibrium values of L_F and M is a function *inter alia* of d_1 and d_2. Then, differentiating these simultaneous equations partially with respect to d_1 and solving, gives:

$$\frac{\partial A}{\partial d_1} = \frac{-1}{\Delta}\ \frac{\partial\left(\frac{-U'_{L_F}}{U'_M}\right)}{\partial d_1} (> 0) \tag{4.24}$$

$$\frac{\partial M}{\partial d_1} = \frac{-1}{\Delta}\ \frac{\partial\left(\frac{-U'_{L_F}}{U'_M}\right)}{\partial d_1} (> 0) \tag{4.25}$$

that is, a rise in the number of dependents leads to decrease in the marginal valuation of family labour $\left(\frac{-U'_{L_F}}{U'_M}\right)$, and as a result the optimal amounts of family labour input and income increase. Likewise, for the case of d_2, we get:

$$\frac{\partial A}{\partial d_2} > 0 \text{ and } \frac{\partial M}{\partial d_2} > 0 \tag{4.26}$$

In (4.26), a rise in the number of workers leads to an increase in the level of family labour and household income.

4.4.3 Effects of Farm Size Change

Consider the effects of a change in land. In the income function of (4.12), assume that LD is variable and is owned and operated by the farm family, and for simplicity to focus on the relationship between labour and land, suppose that FE is fixed, that is:

$$M = P \cdot f(L_F, LD \mid FE) + A \tag{4.27}$$

Following the assumptions in (4.7), assume also:

$$\left.\begin{array}{l} f''_{L_F LD} > 0; \\ f''_{L_F} f''_{LD} - (f''_{L_F LD})^2 > 0 \end{array}\right\} \tag{4.28}$$

Maximising utility in (4.1) subject to (4.27), and differentiating the resultant first-order conditions with respect to LD and solving gives[7]:

$$\frac{\partial L_F}{\partial LD} = \underbrace{P \cdot f'_{L_F}\left(\frac{\partial L_F}{\partial A}\right)}_{IE(-)} + \underbrace{\frac{1}{\Delta} P \cdot f''_{L_F LD}}_{SE(+)} \; (\lesseqgtr 0) \tag{4.29}$$

and;

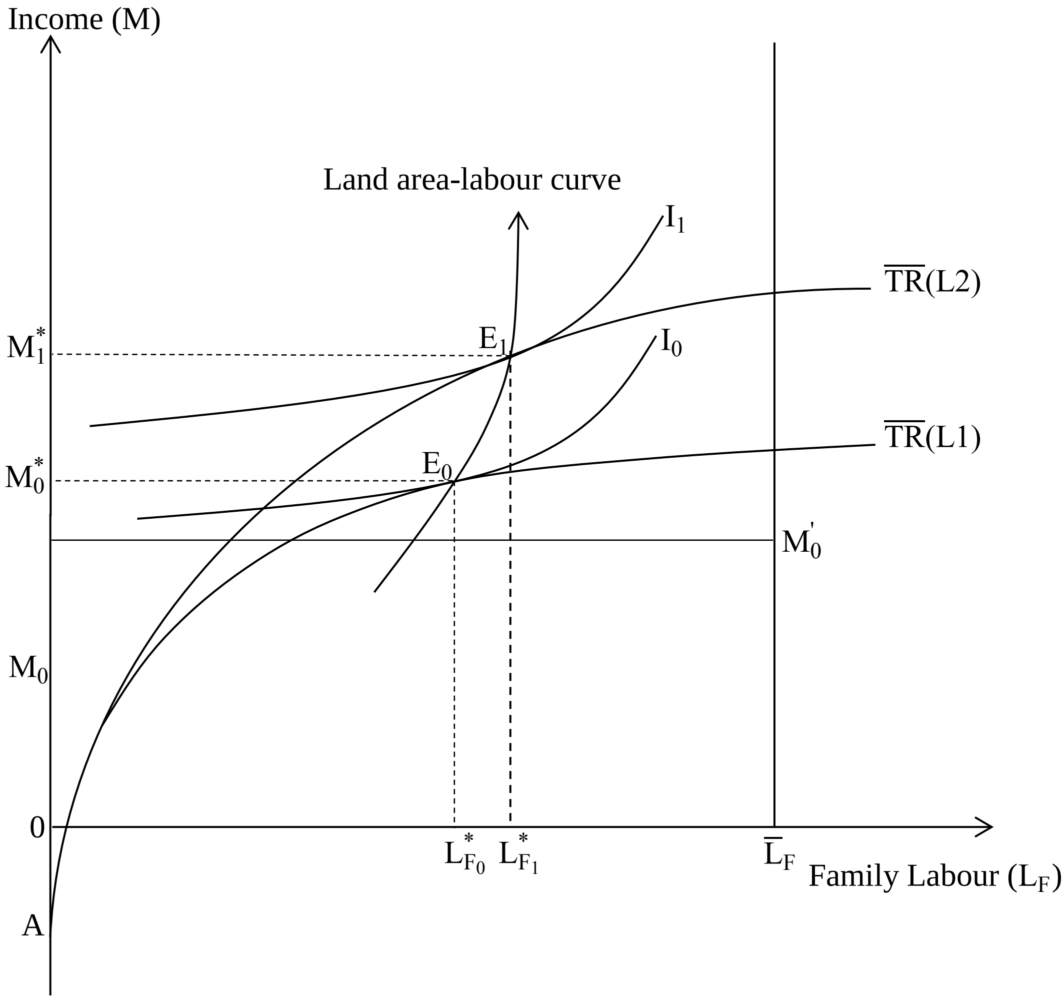
$$\frac{\partial M}{\partial LD} = \underbrace{P \cdot f'_{LD}\left(\frac{\partial M}{\partial A}\right)}_{IE(+)} + \underbrace{\frac{1}{\Delta} P \cdot f''_{L_F LD} \cdot \left(\frac{-U'_{L_F}}{U'_M}\right)}_{SE(+)} \; (>0) \tag{4.30}$$

In (4.29), the first term (negative) on the right-hand side is an income effect, and the second term (positive) is a substitution effect. Thus, the total effect is indeterminate. The case when $\frac{\partial L_F}{\partial N} > 0$ is shown in Figure 4.7. As land size increases, $\overline{TR}(L1)$ shifts upward to $\overline{TR}(L2)$ and the equilibrium moves from E_0 to E_1. As a result, the family labour increases from $L^*_{F_0}$ to $L^*_{F_1}$. Equation (4.30) shows the effect of a change in land on income. Here, both income and substitution effects are reinforced and the total effect is positive and a rise in land areas

[7] Nakajima (1988, p. 56) generates the expressions (4.29) and (4.30) into an income effect (IE) and a substitution effect (SE).

contributes to a rise in the income from M_0^* to M_1^* in Figure 4.7 The line connecting points E_0 to E_1 is "the land-area-labour curve".

Figure 4.7 The Effect of a Change in Land Area



Source: Adapted from Nakajima (1986, p. 57)

4.4.4 Effects of Fertiliser Price Change

Consider the effect of a change in the fertiliser price. Let us assume that the output price, labour and (fixed) land are given, but the fertiliser price varies. Thus, the income function is:

$$M = P \cdot f(L_F, FE \mid LD) + A \tag{4.31}$$

Now assume that each of the equilibrium levels of L_F and M in the simultaneous equations (4.13) and (4.31) is a function *inter alia* of the fertiliser price (P_{FE}). Also, Assume that:

$$f''_{L_F FE} > 0;$$

$$f''_{L_F} f''_{FE} - (f''_{L_F FE})^2 > 0 \tag{4.32}$$

Differentiating (4.13) and (4.31) partially with respect to P_{Fe} and solving and simplifying, we get:

$$\frac{\partial L_F}{\partial P_{FE}} = \underbrace{- FE\left(\frac{\partial L_F}{\partial A}\right)}_{IE(+)} \underbrace{- \frac{1}{\Delta} P \cdot f''_{L_F FE}}_{SE(-)} (\lesseqgtr 0) \tag{4.33}$$

and;

$$\frac{\partial M}{\partial P_{FE}} = \underbrace{- FE\left(\frac{\partial M}{\partial A}\right)}_{IE(+)} \underbrace{+ \frac{1}{\Delta} P \cdot f''_{L_F FE} \cdot Z}_{SE(+)} (> 0) \tag{4.34}$$

Equation (4.33) can be divided into an income and a substitution effect. The income effect is positive which indicates that an increase in the fertiliser price leads to a rise in family labour, and the substitution effect is negative which implies that the fertiliser price increase result in a decline in family labour. Thus, the total effect is indeterminate. The impact of a change in fertiliser price on income is shown in (4.34) which is also derived into income effect and substitution effect. These effects have a positive sign, so the total effect is positive and an increase in the fertiliser price will increase household income.

4.5 The Decision-making Process of the Commercial Farm Household

Let us now assume the existence of a labour market so that the family may sell part of its labour for use off the farm or it may hire labour. However, most farm households in Thailand are rice farmers with low-incomes and few hire labour (Kiatpathomchai, 2008, pp. 7 – 13; Kiatpathomchai *et al*., 2009, pp. 2 – 7; Cawannote, 2011, p. 15). Accordingly, we focus only on the commercial farm household that does not hire labour.

Assume that the common wage rate (W) is given. When the family labour works off-farm, then $(L - L_F) < 0$ or $L_F > L^*$ which implies that the cost of hired labour is zero. Total family income includes off-farm income earned by the family at the given wage rate ($W \cdot (L - L_F)$). Thus, the family's income function is:

$$M = \overline{TR}(L, LD, P_{FE}, A) - P_{FE}FE - W \cdot (L - L_F) \tag{4.35}$$

where L is the total labour input.

The problem for the farm household is to maximise net income by choosing optimal levels of family labour and fertiliser. Let us take the first-order derivative of (4.35) with respect to L_F and Fe, and the necessary conditions for maximising net income are:

$$\frac{dM}{dL_F} = \overline{TR}'(L) - W = 0 \tag{4.36}$$

or

$$P \cdot f'_{L_F} = W \tag{4.37}$$

and;

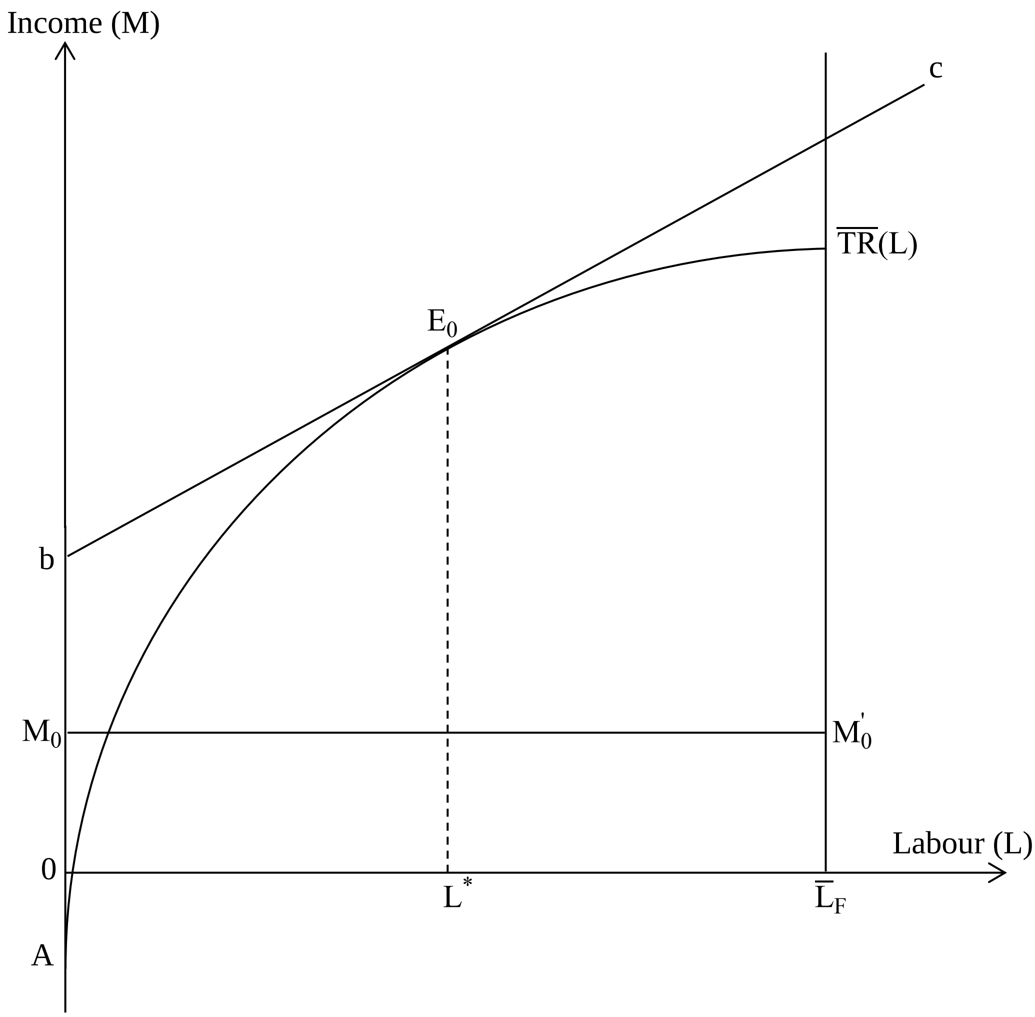
$$\frac{dM}{dFE} = \overline{TR}'(FE) - P_{FE} = 0 \tag{4.38}$$

or

$$P \cdot f'_{FE} = P_{FE} \tag{4.14}$$

Thus in (4.36), for positive levels of labour, the marginal value product of labour equals the wage rate, that is, $\overline{TR}'(L) = W$. This equilibrium is shown in Figure 4.8. The $\overline{TR}(L)$ curve is the household income curve where $\overline{TR}'(L)$ is its slope, and the line bc is the wage rate line whose slope is the wage rate. Equilibrium is at point E_0 when the slope of bc touches the $\overline{TR}(L)$-curve and L^* is the optimal on-farm labour.

Figure 4.8 The $\overline{TR}(L)$ Function of the Farm Family with a Labour Market



Source: Adapted from Dawson (1982)

Maximising family net income implies maximising the utility function in (4.1) subject to (4.35) and the necessary conditions are:

$$P \cdot f'_{FE} = P_{FE} \qquad (4.14)$$

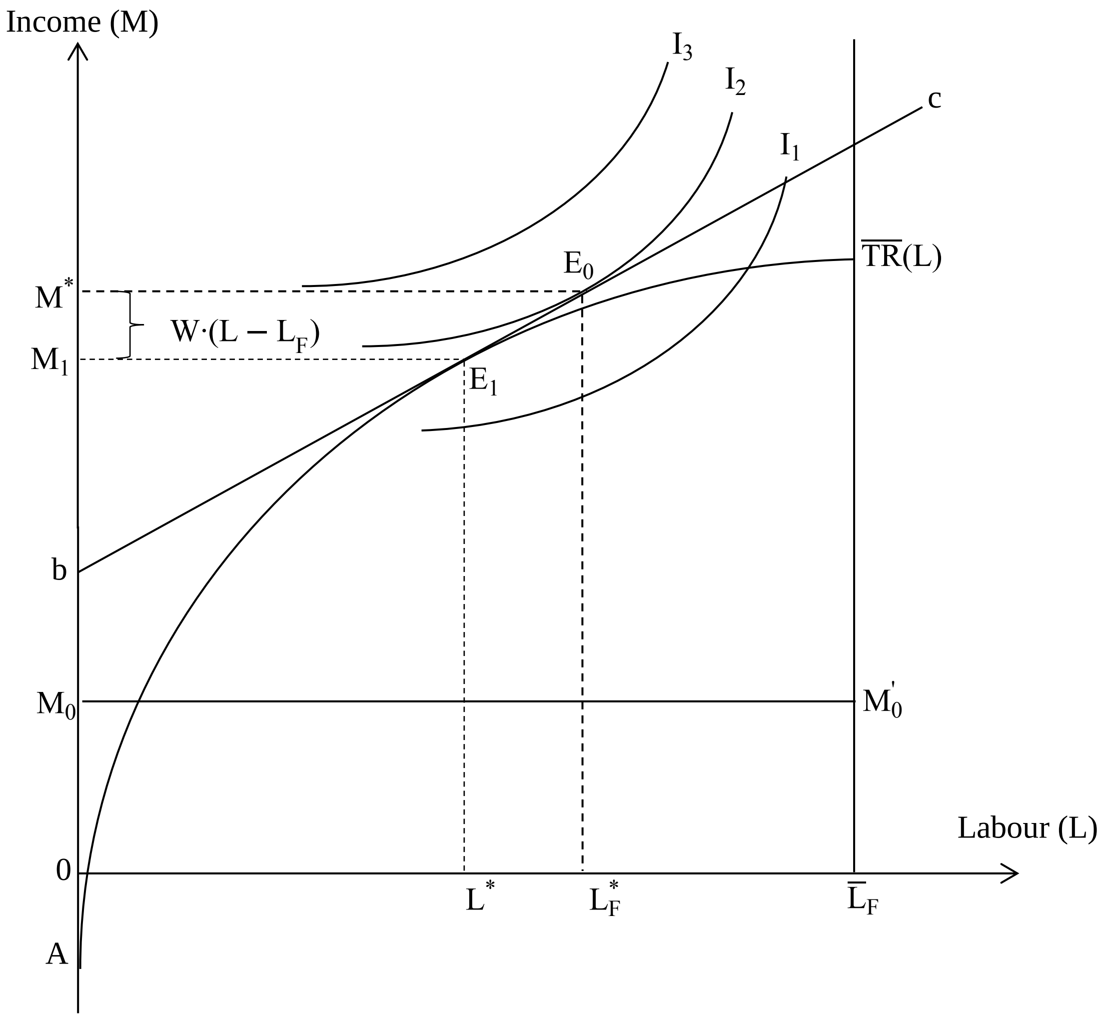
$$P \cdot f'_{L} = W \qquad (4.39)$$

$$\frac{-U'_{L_F}}{U'_M} = W \qquad (4.40)$$

We can see that (4.14), (4.39) and (4.40) are not simultaneous equations. L is only determined by (4.39), and L_F and M are determined by (4.14) and (4.34). Additionally, the two labour conditions (4.39) and (4.40) illustrate the two stages of decision-making: first, the household makes decisions based on profit maximisation; and second, the amount of family labour is based on utility maximisation.

The commercial farm household which works off-farm is shown in Figure 4.9. The $\overline{TR}(L)$-curve represents the household income constraint. The equilibrium, where the family maximises utility by utilising its own labour, is at point E_0 where the indifference curve I_2 is tangential to $\overline{TR}(L)$, that is, where the marginal valuation of labour equals the wage rate. Also at point E_1, the wage rate is equivalent to the marginal product of labour. L_F^* is the equilibrium amount of family labour, and L^* is the family labour use on-farm. $L_F^* - L^*$ is the amount of family labour supplied off-farm; off-farm income is presented as M_1M^*; and total income is AM^*.

Figure 4.9 The Equilibrium Condition of the Farm Family when $(L - L_F) < 0$ or $L_F > L^*$



Source: Adjusted from Dawson (1982)

Again, consider the comparative statics, the effects of changes in the autonomous income, composition of farm family, land size and fertiliser prices on this model are not different from the subsistence farm family model. An increase in the autonomous income, land area, the number of dependents, and that of workers leads to an increase in family labour as well as income. However, an increase in fertiliser prices leads to a decrease in the amount of family labour, but it increases the family's income.

4.6 The Decision-making Process of the Semi-commercial Farm Family

This section presents the decision-making process of the farm family where part of its output is consumed (home consumption) and part is sold on the market (commercial sale) (Nakajima, 1986, p. 125). The farm family utilises its own labour to maximise utility, but the utility maximisation is also related to consumption. Also, the household can buy some market-purchased products at the market price which may differ from its output price to be sold to maximise the household utility, and for simplicity only assume that the purchasing price is greater than the selling price. Again, assume perfectly competitive output and labour markets.

The farm household seeks to maximise its utility through its consumption needs by utilising family labour (Rosenzweig, 1986, p. 21; Ellis, 1988, p. 106). Household income is required to meet consumption in which the family's income comprises of two components, namely money income (C_m), which refers to an amount of market-purchased goods, and income in kind in terms of money (C_a), which refers to an amount of home-produced goods which are consumed. Thus, the utility function is defined over income in kind, money income, and family labour, that is:

$$U=U\left(C_a, C_m, L_F\right) \tag{4.41}$$

Assume that:

$$\left.\begin{array}{l} -U'_{L_F} > 0, \quad U'_{C_a} > 0, \; U'_{C_m} > 0 \\ -U''_{L_F} < 0, \quad U''_{C_a} < 0, \; U''_{C_m} < 0 \end{array}\right\} \tag{4.42}$$

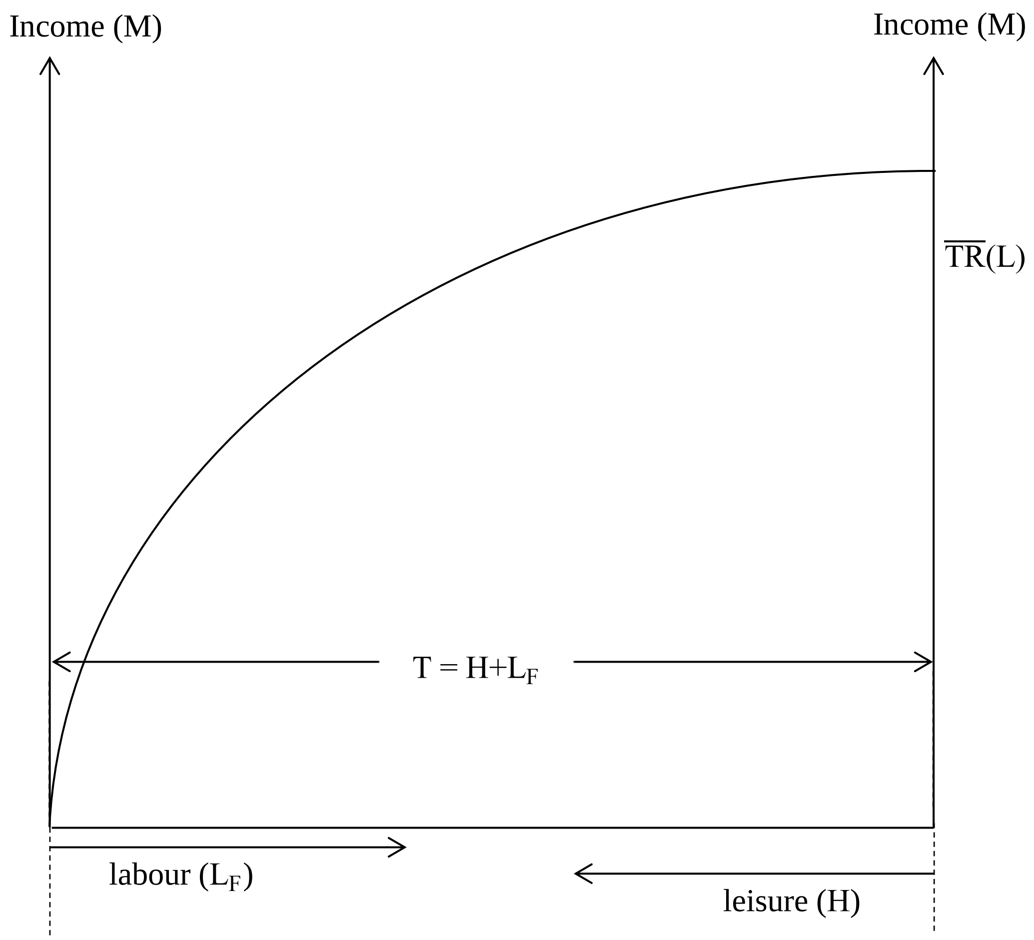
where there are diminishing marginal utilities of home-consumption and market-purchased consumption, that is U'_{C_a} and $U''_{C_a} < 0$, and U'_{C_m} and $U''_{C_m} < 0$.

The farm family provides "the drudgery of farm work" (or disutility of work) to meet household needs (Ellis, 1988, p. 106; May, 1992, p. 20), and leisure is preferred to work. Thus, the relationship between leisure and working hours of family labour can be linked to total household time available as:

$$T = H + L_F \tag{4.43}$$

where T is the total stock of household time and H is leisure. Thus, the optimal levels of labour and leisure can be traded off as shown in Figure 4.10 on the horizontal axis.

Figure 4.10 The Relationship between the Level of Labour and that of Leisure



Sources: Adapted from Ellis (1988, p. 107)

Consequently, the utility function of (4.41) can be rewritten following the AHM of Singh *et al*. (1986) which is hypothesised that the farm household maximises its own utility from the consumption of home-produced goods (C_a), market-purchased goods (C_m), and leisure (H):

$$U = U(C_a, C_m, H) \tag{4.44}$$

and:

$$\left.\begin{aligned} U'_{C_a} > 0, \quad U'_{C_m} > 0,\ U'_H > 0 \\ U''_{C_a} < 0, \quad U''_{C_m} < 0,\ U''_H < 0 \end{aligned}\right\} \tag{4.45}$$

where U'_H is diminishing marginal utility of leisure where $U''_H < 0$.

Household utility is maximised subject to three main constraints comprising of cash income, production function and total time available (T). For the income constraint, the availability of cash income is:

$$P_mC_m = P_a(Q - C_a) - W(L - L_F) \qquad (4.46)^8$$

where P_m is the price of the market-purchased product, P_a is the price of home-produced products that are marketed, and Q is household production. The marketed surplus is determined by $Q - C_a$.

The household also faces both a time constraint, as the total time available limits allocating additional time to the sum of leisure, on-farm production and off-farm work, and a production function constraint in (4.6). Joining the three constraints to make the problem simpler in (4.6), (4.43) and (4.46) can be achieved by replacing the production function in (4.6) for Q and the time constraint (4.43) for L_F into the cash income constraint in (4.46) to yield:

$$P_mC_m + P_aC_a + W \cdot H + P_{FE}FE = W \cdot T + P_a.Q(L, LD, FE) - W \cdot L \qquad (4.47)$$

In (4.47), the left-hand part denotes total household expenditure on market-purchased commodities, the purchasing of both its own output, and own time in the form of leisure. The first-term on the right side is household income and complies with Becker's (1965) concept of full income where the amount of available time owned by the household is $W \cdot T$ and farm profits are $P_a.Q(L, LD, FE) - W \cdot L$ where all labour is valued at the market wage (Singh *et al*., 1986, pp.17-19).

In (4.47), the household chooses the optimal levels of consumption for the three commodities and total labour input in farm production. The first-order conditions for maximising each of these variables can be derived. That for labour is:

[8] When $(L - L_F) < 0$, the farm household supplies labour to the market in which it can earn wage income from off-farm employment as for a commercial farm household. Conversely, when there is no labour market, the farm family only uses its own labour on its farm production, $(L - L_F) = 0$, so that $W(L - L_F) = 0$, implying that there is neither a cost of hired labour nor income earned from off-farm employment, as for a subsistence farm household.

$$P_a \frac{\partial Q}{\partial L} = W \tag{4.48}$$

which implies that the marginal value product of labour is equal to the market wage rate which is the same condition as (4.37). Similarly, the other condition for FE is the same as (4.14). Only L, which is endogenous, is contained in (4.48). The other endogenous variables, C_a, C_m and H, are not present and hence do not affect the household's choice of L. Consequently, L can be solved as a function of P_a and W, the technological variables of the production function, that is fertiliser, and the fixed quantity of land. Thus:

$$L^* = L^*(W, \; P_a, FE, LD) \tag{4.49}$$

and production decisions are made independently of consumption and labour supply (or leisure) decisions.

Substituting (4.49) into (4.47) and simplifying, we obtain:

$$P_m C_m + P_a C_a + W \cdot H + P_{FE} FE = Y^* \tag{4.50}$$

where $Y^* = W \cdot T + P_a Q\left(L^*, LD, FE\right) - W \cdot L^*$ which represents the full income associated with profit-maximising behaviour. Now, maximising the utility function in (4.44) subject to the full income constraint in (4.50), where an interior solution is assumed for family labour, gives the first-order necessary conditions:

$$\frac{\partial U}{\partial C_m} = \lambda P_m \tag{4.51}$$

$$\frac{\partial U}{\partial C_a} = \lambda P_a \tag{4.52}$$

$$\frac{\partial U}{\partial H} = \lambda W \tag{4.53}$$

where λ is a Lagrangian multiplier. These conditions are the standard conditions of consumer-demand theory. The solution to (4.50), (4.51), (4.52), and (4.53) provides standard demand curves for C_m, C_a, and H, that is:

$$C_m = C_m(P_m, P_a, W, Y^*) \tag{4.54}$$

$$C_a = C_a(P_m, P_a, W, Y^*) \tag{4.55}$$

$$H = H(P_m, P_a, W, Y^*) \tag{4.56}$$

Observe that income is determined by farm production activities. Thus, if factors affecting production change, then Y^* and consumption behaviour change, and consumption and production are related.

4.7 The Labour Efficiency Function

Recall the efficiency wage hypothesis in Chapter 3 where the standard model of nutrition-based efficiency wage provides the assumption by which higher wage rates allow for higher consumption by workers which fuels their effort, especially in low-income households (Liebenstein, 1957; Bliss and Stern, 1978a; Stiglitz, 1981; Struass, 1986; Aziz, 1995, pp.6-7; Swamy, 1997; Dalgaard and Strulik, 2011; Powell and Murphy, 2014). As consumption increases, workers are hypothesised to provide more effective labour, and therefore efficiency per hour worked is influenced by consumption (Stiglitz, 1981, pp. 2-5; Aziz, 1995, p. 13). In particular, Liebenstein (1957, p. 95) and Bliss and Stern (1978b) convert consumption into calorie intake to examine productivity. The expectation is that, within a pre-determined period, a worker who consumes more calories will produce a greater number of hours of efficient labour and hence is more productive. Accordingly, the efficiency per hour worked function ($h(\cdot)$) is dependent on caloric consumption at the personal level, that is:

$$h(\cdot) = h(C_a^c) \tag{4.57}$$

Equation (4.57) is often assumed to be a quadratic function of current and past nutritional indicators where a section of the corresponding curve at low calorie intakes increases at an increasing rate, and this is followed by a section rising at a diminishing rate. Thus, the efficiency per hour worked function ($h(\cdot)$) is S-shaped as shown in Figure 3.1.

In addition, Strauss (1986, p. 302) argues that the individual level of caloric consumption is determined by house food consumption, which is based on intra-household distribution and biological food-calorie conversion rates, and the calories that are consumed throughout the current year are hypothesised to influence annual effective labour. Here, the effects of long-term deficiencies and/or stock effects are ignored and we assume that current and past consumption are correlated with joint effects. Thus, the level of caloric consumption is measured through current intakes. Further, in identifying effective labour in this model, we apply the notion of effeciency wage hypothesis by making effective labour (L_e) the efficiency per hour worked function relating to current caloric consumption and labour hours:

$$L_e = h(C_a^c)L \tag{4.58}$$

The notion of efficient labour hours based on the efficiency wage hypothesis provides an explanation of nutrition-productivity relationship that is beneficial for both employees and employers.

4.8 The Empirical Models of Nutrition-Labour Productivity Link

We now apply this framework of the AHM in Section 4.7 to develop a relationship which links consumption, including calorie and nutrient intake, and production. Recall that the household chooses optimal levels of food consumption, non-food consumption, and leisure to maximise utility. Following Singh *et al*. (1986) and the nutrition-based efficiency wage hypothesis, we assume that total income equals household expenditures where the latter consists of the value of non-food consumption. Income sources comprise of the value of family labour supplied off-farm and that of household output which is sold. Also, labour is treated as effective labour which is defined as the product of the efficiency per hour worked function and family labour, that is:

$$L_e = h(C_a^c)L_F \tag{4.59}$$

Substituting (4.59) into (4.47), the full income constraint with effective labour is:[9]

[9] The substitution of effective labour does not affect the optimisation problem in the loss of concavity in the production set because as C_a^c in (4.59) increases, productivity returns rise more rapidly initially and then decrease after a particular range of C_a^c, indicating that the production set is still concave (Stiglitz, 1976).

$$P_mC_m + P_aC_a + W \cdot H + P_{FE}FE = WT + P_aQ(L_e, LD, FE) - W \cdot L_e \tag{4.60}$$

In competitive markets, suppose that the nutrition-productivity relationship exists, the information about the interaction of nutrition-labour productivity link, such as nutrient, food price, market wage rate and so on, is known by both employees and employers. Thus, the efficiency wage or wage per effective hour, not clock hour, is determined by family labour. So W in (4.60) is measured as wage per effective hour, and:

$$P_mC_m + P_aC_a + W \cdot h(C_a^c)H + P_{Fe}FE = W \cdot h(C_a^c)T + P_aQ(L_e, LD, FE) - W \cdot h(C_a^c) \cdot L_F \qquad (4.61)^{10}$$

The problem for the farm household is then to maximise utility in (4.44) subject to (4.61):

$$\text{Max: } U = U(C_a, C_m, H) \tag{4.62}$$

$$\text{Subject to: } P_mC_m + P_aC_a + W \cdot h(C_a^c)H + P_{FE}FE = W \cdot h(C_a^c)T + P_aQ(L_e, LD, FE) - W \cdot h(C_a^c)L_F$$

The corresponding Lagrangian expression is:

$$\mathcal{L}\text{: } U + \lambda[W \cdot h(C_a^c)T + P_aQ(L_e, LD, FE) - W \cdot h(C_a^c)L_F - P_mC_m - P_aC_a - W \cdot h(C_a^c)H - P_{FE}FE] \tag{4.63}$$

The necessary first-order condition with respect to food consumption is:

$$\frac{\partial \mathcal{L}}{\partial C_a} = \frac{\partial U}{\partial C_a} + \lambda \left[\frac{W \partial h(C_a^c)T}{\partial C_a} + \frac{P_a \partial Q(L_e, LD, FE)}{\partial C_a} - \frac{W \partial h(C_a^c)L_F}{\partial C_a} - P_a - \frac{W \partial h(C_a^c)H}{\partial C_a} \right] = 0$$

$$= \frac{\partial U}{\partial C_a} - \lambda P_a \left[1 - \left(\frac{\partial Q}{\partial L_e}\right)\left(\frac{\partial L_e}{\partial C_a}\right) - \frac{W}{P_a}\left(\frac{\partial h(C_a^c)T}{\partial C_a}\right) + \frac{W}{P_a}\left(\frac{\partial h(C_a^c)L_F}{\partial C_a}\right) + \frac{W}{P_a}\left(\frac{\partial h(C_a^c)H}{\partial C_a}\right) \right] = 0$$

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10 Following Grossman (1972), Strauss (1986, p. 303) and Ayalew (2003), the total stock of household time available (T) in (4.61) can be formulated as total household time minus time lost caused by sickness, say the stock of non-sick or healthy time available which is associated in part with nutrient intake. However, this is not admitted here due to a lack of data, and we assume that total household time is healthy time which can be dedicated to leisure, off-farm employment and home production.

$$= \frac{\partial U}{\partial C_a} - \lambda P_a \left[1 - L_F \left(\frac{\partial Q}{\partial L_e}\right)\left(\frac{\partial h(C_a^c)}{\partial C_a}\right) - \frac{W}{P_a}(T - L_F - H)\left(\frac{\partial h(C_a^c)}{\partial C_a}\right)\right] = 0$$

or:

$$\frac{\partial U}{\partial C_a} = \lambda P_a \left[1 - L_F \left(\frac{\partial Q}{\partial L_e}\right)\left(\frac{\partial h(C_a^c)}{\partial C_a}\right) - \frac{W}{P_a}(T - L_F - H)\left(\frac{\partial h(C_a^c)}{\partial C_a}\right)\right] \qquad (4.64)$$

That with respect to non-food consumption is:

$$\frac{\partial \mathcal{L}}{\partial C_m} = \frac{\partial U}{\partial C_m} - \lambda \cdot P_m = 0$$

or:

$$\frac{\partial U}{\partial C_m} = \lambda \cdot P_m \qquad (4.65)$$

That with respect to leisure is:

$$\frac{\partial \mathcal{L}}{\partial H} = \frac{\partial U}{\partial H} - \lambda P_a [W \cdot h(C_a^c)] = 0$$

or:

$$\frac{\partial U}{\partial H} = \lambda [W \cdot h(C_a^c)] \qquad (4.66)$$

That with respect to family labour is:

$$\frac{\partial \mathcal{L}}{\partial L_F} = -\lambda \left[W - P_a \left(\frac{\partial Q}{\partial L_e}\right)\left(\frac{\partial L_e}{\partial L_F}\right)\right] = 0$$

$$= -\lambda \left[W - P_a \left(\frac{\partial Q}{\partial L_e}\right)\left(\frac{h(C_a^c)\partial L_F}{\partial L_F}\right)\right] = 0$$

$$= -\lambda\left[W - P_f\left(\frac{\partial Q}{\partial L_e}\right)h(C_a^c)\right] = 0 \tag{4.67}$$

Dividing (4.67) by $h(C_a^c)$ and rearranging gives:

$$\frac{W}{h(C_a^c)} = P_f\left(\frac{\partial Q}{\partial L_e}\right) \tag{4.68}$$

In (4.68), the wage per efficiency labour hour ($\frac{W}{h(C_a^c)}$) equals the marginal value product of effective labour ($P_f\left(\frac{\partial Q}{\partial L_e}\right)$), implying that production is related to consumption through efficient labour, and production and consumption are determined simultaneously. Likewise, (4.64) indicates that consumption choices are linked to production; and in (4.65), the market-purchased goods are supplied to households until its price equals its marginal valuation. Further, in (4.66), the marginal valuation of leisure depends on the wage rate and the efficiency per hour worked through the amount of home-produced goods.

This study applies the Cobb-Douglas production function and a semi-log wage equation to examine the consumption-production relationship. Consumption including calories or nutrients is added as an endogeneity variable to these functions. Moreover, the empirical models should provide an explanation for the non-linear nature of the effect of human capital variables such as the impact of calories or nutrient on the efficiency of labour (Aziz, 1995). These models are described in the following section.

4.8.1 The Wage Equation

The relationship between nutritional status and labour productivity as measured by wages is the wage equation. It is motivated by the life cycle and human capital approaches of earnings (Ayalew, 2003). A functional form for the wage equation used widely in the earnings literature is the semi-log form (where only the dependent variable is in logs). This is adjusted by adding nutritional intake as an explanatory variable based on the notion of the effective wage hypothesis (Deolalikar, 1988; Sahn and Alderman, 1988; Haddad and Bouis, 1991; Croppenstedt and Muller, 2000; Ayalew, 2003; Weinberger, 2004). The wage equation to be estimated here follows Deolalikar (1988), Haddad and Bouis (1991), Croppenstedt and Muller

(2000), Weinberger (2004) and Ahsan and Idrees (2014) where nutrition status focuses solely on the nutritional intake of the household, that is:

$$\ln W_i = \beta_0 + \beta_1 \mathbf{C}^c_{a_i} + \beta_2 \mathbf{VI}_i + \beta_3 \mathbf{VT}_i + u_i \tag{4.69}$$

where i indexes the household, $\mathbf{C}^c_a$ is a vector of nutritional intake, **VI** is a vector of time-invariant control variables at the household level such as sex, education levels of household head, **VT** is a vector of time-variant control variables such as age of household head, and u is an error term with the usual properties. The comparative statics in Section 4.4.2 show that household composition (dependency ratio) and farm size affect labour input and we include these variables in the VI-vector. Thus, the wage equation is:

$$\ln W_i = \beta_0 + \beta_1 \mathbf{C}^c_{a_i} + \beta_2 EDU_i + \beta_3 GEND_i + \beta_4 DR_i + \beta_5 AGE_i + \beta_6 LD_i + \beta_7 AREA_i + u_i \tag{4.70}$$

where EDU is the educational level of household head, GEND is gender of household head, DR is dependency ratio (household composition), AGE is age of household head, LD is farm land, AREA is administrative areas, and β_k=1,…,7, are coefficients to be estimated. The wage-nutrition relationship is summarised by the elasticity of wage with respect to nutritional input (E_w), that is:

$$E_w = \frac{dW_i}{dC^c_{a_i}} \times \frac{\mathbf{C}^c_{a_i}}{W_i} = \beta_1(\mathbf{C}^c_{a_i}) \qquad (4.71)^{11}$$

4.8.2 The Production Function

The Cobb-Douglas production function is widely applied to model agricultural production, and a number of studies apply it to study the impact of caloric intake and health on labour productivity by adding nutritional inputs (Strauss, 1986, p. 307; Deolalikar, 1988, p. 409; Aziz, 1995, p. 18; Croppenstedt and Muller, 2000, p. 482; Ayalew, 2003, p. 20; Traore, 2007, p. 4). The comparative statics in Sections 4.4.3 and 4.4.4 imply that changes in land area and fertiliser

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[11] From (4.82), $W_i = e^{(\beta_0 + \beta_1 C^c_{a_i} + \beta_2 EDU_i + \beta_3 GEND_i + \beta_4 DR_i + \beta_5 AGE_i + \beta_6 LD_i + \beta_7 AREA_i + u_i)}$. Using the chain rule for the derivative of e with the functional exponent, $\frac{dW_{ih}}{d\mathbf{C}^c_{a_i}} = e^{(\beta_0 + \beta_1 C^c_{a_i} + \beta_2 EDU_i + \beta_3 GEND_i + \beta_4 DR_i + \beta_5 AGE_i + \beta_6 LD_i + \beta_7 AREA_i + u_i)} \cdot \beta_1 \equiv \beta_1 W_i$. Then substituting $\frac{dW_i}{d\mathbf{C}^c_{a_i}}$ into (4.83) yields $E_w = \beta_1(\mathbf{C}^c_{a_i})$.

price influence labour input, and we adopt the seminal model of Strauss (1986) and Deolalikar (1988) by using effective family labour, fixed land size and fertiliser expenditure as inputs in the farm production function:

$$\ln Q_i = \alpha_0 + \alpha_1 \ln L_{e_i} + \alpha_2 \ln LD_i + \alpha_3 \ln FE_i + u_i \qquad i = 1,\ldots,n \qquad (4.72)$$ [12]

where α_0, α_1,α_2, and α_3 are coefficients to be estimated, i indexes the farm household, and u is an independently identically distributed error term with the usual properties. In addition, effective labour hours is estimated here only for adult family labour:

$$L_{e_i} = h\left(C^c_{a_i}\right) L_{F_i} \qquad (4.73)$$

where i is the household.

More specifically, Strauss (1984, p. 14) identifies the efficiency per hours worked in two specifications, one possessing one parameter, and other possessing two. The one-parameter function is log-reciprocal function:

$$\log h(C^c_a) = a_0 - \frac{a_1}{C^c_a} \qquad (4.74)$$

where a_0 and a_1 are estimated coefficients.

This function implies a sigmoid shape for $h(C^c_a)$, starting from the origin and converging asymptotically to a maximum at e^{α_0}. The two-parameter function is a quadratic:

$$h(C^c_a) = b_0 + b_1 C^c_a + b_2 (C^c_a)^2 \qquad (4.75)$$

where b_0, b_1 and b_2 are estimated coefficients.

which is flexible and allows for an array of negative productivity effects at high levels of food consumption (Strauss, 1986, p. 308). However, it does not allow for both convex and concave

[12] Alternatively, more flexible functional forms such as transcendental logarithmic (translog) function could be used (Croppenstedt and Muller, 2000; Ulimwengu, 2009).

sections but observed values seem likely to be located on the concave section of the curve since that is the more relevant economic region.[13] The coefficients for all the $h(C_a^c)$ in (4.74) and (4.75) are normalised, so that $h(C_a^c)$=1 at the same mean value of daily calories intake ($\overline{C_a}$). For (4.74), the function of $h(C_a^c)$ is normalised and expressed as:

$$\log h(C_a^c) = -\,a^*\left(\frac{\overline{C_a}}{C_a^c} - 1\right) \tag{4.76}$$

and for (4.75), the function of $h(C_a^c)$ is normalised as:

$$h(C_a^c) = 1 + b_1^*\left(\frac{C_a^c}{\overline{\overline{C_a}}} - 1\right) + b_2^*\left[\left(\frac{C_a^c}{\overline{\overline{C_a}}}\right)^2 - 1\right] \tag{4.77}$$

For these normalised functions, there is an additional benefit that if the calorie coefficients, a^*, b_1^* and b_2^*, are zero, then $h(C_a^c)$=1, so the equation (4.69) can be regarded as one of special cases hypothesised here. In addition, other functional forms for $h(C_a^c)$ can be used including a cubic function, log-log functions, or an exponential function (Strauss, 1986; Deolalikar, 1988; Aziz, 1995).

The characteristic of an exponential function can also fit the S-curve and describe the efficient labour process since the efficiency process is regarded as an intermediate transition between lower initial levels of efficiency and an upper stable rate (Aziz, 1995). Further, Aziz (1995) and Traore (2007) also employ the natural exponential function for $h(C_a^c)$ which is expressed as:

$$h\left(C_{a_i}^c\right) = e^{h(C_{a_i}^c)} \tag{4.78}$$

Following Aziz (1995), consistent with the exponential, (4.78) is formulised as:

$$h\left(C_{a_{ij}}^c\right) = e^{\alpha_0^* - \frac{\alpha_1^*}{h(C_{ai1}^c)} - \frac{\alpha_2^*}{h(C_{ai2}^c)} - ,\ldots, \frac{\alpha_n^*}{h(C_{ain}^c)}} \tag{4.79}$$

---

[13] If $\frac{dh(C_a^c)}{dC_a^c}$ increases at a faster rate than the marginal product of effective family labour decreases, then it is possible for second-order condition to be violated (Struass, 1984).

where j is the number of nutritional variables: i = 1, …, n. Thus, the effective labour in (4.73) can be written as:

$$L_{e_i} = e^{\alpha_0^* - \frac{\boldsymbol{\alpha}_{ij}^*}{h\left(\mathbf{C}_{a_{ij}}^c\right)}} \cdot L_{F_i} \tag{4.80}$$

Substituting (4.80) into (4.72) gives:

$$\ln Q_i = \alpha_0 + \alpha_1 \left(\alpha_0^* - \frac{\boldsymbol{\alpha}_{ij}^*}{h\left(\mathbf{C}_{a_{ij}}^c\right)} + \ln L_{F_i} \right) + \alpha_2 \ln LD_i + \alpha_3 \ln FE_i + \mu_i \tag{4.81}$$

Rearranging (4.81) gives:

$$\ln Q_i = a_0^* - \mathbf{B}_{ij} \frac{1}{h\left(\mathbf{C}_{a_{ij}}^c\right)} + \alpha_1 \ln L_{F_i} + \alpha_2 \ln LD_i + \alpha_3 \ln FE_i + \mu_i \tag{4.82}$$

where $a_0^* = \alpha_0 + \alpha_1 \alpha_0^*$ and $\mathbf{B}_{ij} = \alpha_1 \boldsymbol{\alpha}_{ij}^*$.

This relationship between output and nutritional input can also be expressed in terms of the elasticity of production (E_p) which measures the response of output to a change in the use of an input, where:

$$E_p = \frac{dQ_i}{d\mathbf{C}_{a_{ij}}^c} \times \frac{\mathbf{C}_{a_{ij}}^c}{Q_i} = -\mathbf{B}_{ij} \frac{1}{h\left(\mathbf{C}_{a_{ij}}^c\right)} \qquad (4.83)^{14}$$

[14] In (4.79), Q can be rewritten as: $Q_i = e^{a_0^* - \mathbf{B}_{ij} \frac{1}{h\left(\mathbf{C}_{a_{ij}}^c\right)} + \alpha_1 \ln L_{F_i} + \alpha_2 \ln LD_i + \alpha_3 \ln FE_i + \mu_i}$. Let $u\left(C_{a_{ij}}^c\right) = a_0^* - \mathbf{B}_{ij} \frac{1}{h\left(\mathbf{C}_{a_{ij}}^c\right)} + \alpha_1 \ln L_{F_i} + \alpha_2 \ln LD_i + \alpha_3 \ln FE_i + \mu_i$, so $Q_i = e^{u(C_{a_{ij}}^c)}$. Using the chain rule for the derivative of the functional exponent (e), then $\frac{dQ_i}{dC_{a_{ij}}^c} = \frac{\partial e^{u(C_{a_{ij}}^c)}}{\partial u\left(C_{a_{ij}}^c\right)} \cdot \frac{\partial u\left(\frac{1}{h\left(\mathbf{C}_{a_{ij}}^c\right)}\right)}{\partial C_{a_{ij}}^c} = e^{u(C_{a_{ij}}^c)} \cdot \alpha_1 \cdot h'\left(C_{a_{ij}}^c\right) = -Q_i \cdot \mathbf{B}_{ij} \frac{1}{h\left(\mathbf{C}_{a_{ij}}^c\right)^2}$. Substituting $\frac{dQ_i}{dC_{a_{ij}}^c}$ into (4.80) gives $E_p = -\mathbf{B}_{ij} \frac{1}{h\left(\mathbf{C}_{a_{ij}}^c\right)}$.

If $E_p>1$, output responds more than proportionately to increases in the use of the input; if $0<E_p<1$, output increases less than the increase in the input; if $E_p<0$, output decreases as the input increases, and if $E_p=1$, the proportionate increases are equal.

In addition, the interpretation of the estimated coefficients can be expressed as the marginal product which basically shows the change in output with one unit change in input, $\left(\frac{\partial Q}{\partial \mathbf{C}_a^c}\right)$. The marginal product with respect to the nutritional variables can be mathematically written as:

$$\frac{\partial Q_i}{\partial C_{a_{ij}}^c} = -Q_i \cdot \mathbf{B}_{ij} \frac{1}{h\left(\mathbf{C}_{a_{ij}}^c\right)^2} \qquad (4.84)$$

4.9 Summary

The theoretical framework applied in this study is built on the AHMs for explaining and understanding the decision-making behaviour of a farm family under different conditions. The household decision-making that underlies the subsistence farm family is concerned about its own production provided by its own supply of labour without a labour market. Otherwise, the decision of the commercial farm family is to maximise farm profit by using its own labour, and family labour can be worked on-farm and/or off-farm. The combination of both these characteristics, called a semi-commercial household, then provides the basis for examining household behaviour where decisions about production, consumption and labour allocation decisions are jointly determined.

The most applicable model for Thailand is the semi-commercial household model and semi-commercial household models with access to a labour market. In addition, from the efficiency wage hypothesis, labour is treated as effective labour which is associated with caloric consumption, and nutritional consumption directly affects labour productivity. The objective of this chapter is to explain the nutrition-labour productivity link. The production function and wage equation are derived to illustrate the relationship between nutritional intake and labour productivity by measuring the farm output and wages respectively. To test the nutritional-productivity effect, the data used and econometric methodology are presented in the next chapter.

Chapter 5 Econometric Methodology

5.1 Introduction

This chapter discusses the econometric approaches that are used to estimate nutrition-labour productivity links of rice-farming households in Thailand. Labour productivity is typically measured in the literature in terms of wages received and/or farm productivity, and a semi-log wage equation and Cobb-Douglas production function are widely used (Strauss, 1986; Deolalikar, 1988; Sahn and Alderman, 1988; Haddad and Bouis, 1991; Aziz, 1995; Thomas and Strauss, 1997; Croppenstedt and Muller, 2000; Ayalew, 2003; Weinberger, 2004; Traore, 2007; Jha et al., 2009; Uliwengu et al., 2011). Here household income is used instead of wage received due to the data limitations.[15]

In the efficiency wage hypothesis, household income and farm production are determined in part by consumption and *vice versa*, which results in the problem of reverse or bidirectional causality (Strauss, 1986; Sahn and Alderman, 1988; Aziz, 1995; Thomas and Strauss, 1997; Weinberger, 2004). This is the problem of endogeneity whereby the ordinary least squares (OLS) estimator is inconsistent (Sahn and Alderman, 1988; Thomas and Strauss, 1997; Croppenstedt and Muller, 2000; Weinberger, 2004; Baum, 2006, pp. 185 – 186; Greene, 2012, pp. 259 – 264). To obtain a consistent estimator in nutrition-labour productivity models, two-stage least squares (2SLS) and two-step quantile regression (2SQR) can be applied to the wage equation in which an endogenous regressor is controlled for, while non-linear least squares (NL2SLS) can be applied to the production function due to the presence of internal instruments in which the predicted value of the endogenous regressor is substituted inside the non-linear function (Amemiya, 1983; Bowden and Turkington, 1984, p. 163 – 166; Aziz, 1995; Baum, 2006, p. 188, Trore, 2007).

This chapter discusses both methods and is organised as follows. Section 5.2 introduces the causes of endogeneity, particularly the reverse-causality problem which commonly occurs in nutrition-labour productivity links. Section 5.3 presents the 2SLS method. Section 5.4 discuss 2SQR and Section 5.5 discusses NL2SLS. Section 5.6 specifies empirical models for estimating the two relationships between nutrition and labour productivity, namely a semi-log wage

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[15] The econometric methods used in this study are based on the data availability which is described more in detail in Chapter 6.

equation using 2SLS and 2SQR and a Cobb-Douglas production function using NL2SLS. Section 5.7 summarises.

5.2 Endogeneity

The assumption that regressors and the error term are uncorrelated implies that OLS is consistent, while failure to hold leads OLS to be inconsistent (Baum, 2006, p. 185; Cameron and Trivedi, 2010, p. 177; Greene, 2012, p. 259). Consider the linear regression with dependent variable y_{1i} which is dependent on regressors y_{2i} and x_i, i = 1, 2,…, k:

$$y_{1i} = \beta_0 + \beta_1 y_{2i} + \beta_2 x_i + \ldots + \beta_k x_k + u_{1i} \tag{5.1}$$

where u_{1i} is an error term. When u_{1i} is uncorrelated with x_i or there is a zero-covariance condition between x_i and u_{1i} that is, $\mathrm{Cov}[x_i, u_{1i}] = 0$, and x_i is exogenous. If u_{1i} is correlated with y_{2i} or $\mathrm{Cov}[y_{2i}, u_{1i}] \neq 0$, y_{2i} is endogenous and the OLS estimator is inconsistent (Wooldridge, 2002, pp. 49 – 50; Baum, 2006, p. 185). When the intercept β_0 is included in the zero-covariance assumption, $E[u_{1i}] = 0$, this is the assumption of zero-conditional-mean (Wooldridge, 2002, pp. 49 – 50; Baum, 2006, p. 185). Thus in linear regressions, we use the following zero-conditional-mean assumption which is sufficient for zero-covariance:

$$E[u_{1i}|y_{2i}, x_1, \ldots x_k] = 0 \tag{5.2}$$

There are three circumstances where (5.2) is violated. First, omitted-variable bias appears when we cannot include an independent variable that is correlated with both dependent and one or more independent variables in models because of data unavailability (Wooldridge, 2002, p. 50; Greene, 2012, pp. 260 – 261). Second, measurement error (errors in variables) arises when we want to measure the partial effect of a variable, say y^*_{2i}, but observe an imperfect measure of it, say y_{2i} (Wooldridge, 2002, p. 51; Greene, 2012, p. 261). Thus, when we substitute y_{2i} for y^*_{2i}, we need to include measurement error in u_{1i}. The third is simultaneity (or reverse causality) which is the simultaneous determination of y_{1i} and y_{2i} (Wooldridge, 2002, p. 50; Baum, 2006, p. 185; Greene, 2012, p. 260).

Using (5.1) to model the efficiency wage hypothesis, denote y_{1i} as labour productivity and y_{2i} as nutrition. Since y_{1i} depends on endogenous y_{2i} and the other exogenous regressors x_i, in turn

y_{2i} is also determined by y_{1i} and the other regressors (Strauss, 1986; Thomas and Strauss, 1997).[16] This is a structural-equation or simultaneous-equation model. The error term, u_{1i}, is assumed to be uncorrelated with y_{2i} but is correlated with y_{1i}. This correlation leads to the OLS estimator of β_1 to be inconsistent. In simultaneous-equation models (unlike single-equation models), the parameters in a single equation should not be estimated without taking into account information provided by other equations in the system. Rewrite (5.1) as:

$$y_{2i} = \delta_0+\delta_1 y_{1i} + \delta_2 x_2+\ldots+ \delta_{k-1} x_{k-1} + u_{2i} \tag{5.3}$$

where u_{2i} is an error term. If y_{2i} in (5.1) is distributed independently of u_{1i} and y_{1i} is distributed independently of u_{2i}, then OLS provides inconsistent estimates (Gujarati and Porter, 2009, pp. 673 – 675). There are two common solutions to this problem. First, instrumental variables (IV) control for the effects of confounding of observed and unobserved variables and measurement error (Wooldridge, 2002, pp. 83 – 90; Cameron and Trivedi, 2010, pp. 177 – 179; Greene, 2012, p. 262). However, the IV estimator is inconsistent when more than one instrument variable is available for the endogenous regressor which leads to the problem of overidentification (Cameron and Travedi, 2005, pp. 180 – 182; Baum, 2006, p.185). By contrast, 2SLS is a consistent estimator in the case of multiple instrument variables in which the instrumental variables are pooled into an optimal instrument which can then be applied in the simple IV estimator (Baum, 2006, p. 188). Further, 2SLS can be used in a system of equations where the structural model specifies additional equations to explain the correlation between regressors and the error term to enable estimation of the full set of parameters (Greene, 2012, p. 262).[17]

5.3 Two-Stage Least Squares (2SLS)

To use IV, we need an observable, instrumental variable (z) which is not in (5.1) and which is uncorrelated with u_1, that is $Cov[z, u_{1i}] = 0$ (Wooldridge, 2002, pp. 83 – 85). We can apply IV when the number of z equals the number of endogenous regressors, which is exactly- identified

[16] The nutrition-labour productivity link has an endogeneity problem which is caused by simultaneity measurement error and omitted-variable bias. Here, only simultaneity is assumed to be a problem.

[17] Zellner and Theil (1962) show that if the disturbance terms in the equation system are associated with each other, then three-stage least squares (3SLS) is more efficient. 3SLS is identical to 2SLS when there is no correlation among the error terms (Zellner and Theil, 1962; Baum *et al*, 2003). Here, we assume that the error terms among our equations in the system are uncorrelated and only 2SLS is used.

(Baum, 2006, pp. 185 – 189). If the number of instruments is more than that of endogenous variables, then the endogenous variables are over-identified and 2SLS is needed.
Consider 2SLS with the endogenous variable y_{2i} and more than one potential instrument, say z_h, where h = 1, 2, …, m. Recall (5.1) where y_{2i} is correlated with u_{1i}. Suppose $Cov[z_h, u_{1i}] = 0$, so that each z_h is exogenous, and the vector of exogenous variables is $\mathbf{z} = (1, x_1, \ldots, x_{k-1}, z_1, \ldots, z_m)$ as 1×L vector (L = K + M) which are correlated with y_{2i} given by the linear projection of y_{2i} on **z**. In this case, y_{2i} is overidentified (Wooldridge, 2002, p.92; Baum, 2006, pp. 190 – 191; Gujarati and Porter, 2009, p. 692). The reduced-form equation of y_{2i} with all instruments is:

$$y_{2i} = \delta_0 + \delta_1 x_1 + \ldots + \delta_{k-1} x_{k-1} + \theta_1 z_1 + \ldots + \theta_m z_m + \varepsilon_i \tag{5.4}$$

where $E[\varepsilon_i] = 0$ and ε_i is uncorrelated with each variable on the right-hand side. Following Wooldridge (2002, p. 90), there are no exact linear dependencies among the exogenous variables so we can estimate (5.4) consistently by OLS. We can therefore generate the instrument as the predicted values of y_{2i} ($\hat{y}_{2i}$) where $\hat{y}_{2i}$ is an optimal linear combination of z_h with all exogenous variables that are uncorrelated with u_1 in (5.1). We use $\hat{y}_{2i}$ in the place of y_{2i}, and we treat $\hat{y}_{2i}$as a variable in **x** and project **x** itself ($\hat{\mathbf{x}}_i$).

Using $\hat{\mathbf{x}}_i$ as the instrument for $\mathbf{x}_i$, the IV estimator is:

$$\hat{\boldsymbol{\beta}}_{IV} = \left(\sum_{i=1}^{N} \hat{\mathbf{x}}_i' \mathbf{x}_i\right)^{-1} \left(\sum_{i=1}^{N} \mathbf{x}_i' y_i\right) = (\hat{\mathbf{X}}'\mathbf{X})^{-1} \hat{\mathbf{X}}'\mathbf{Y} \tag{5.5}$$

where unity is the first element of $\mathbf{x}_i$.

Baum (2006, p. 188) observes that the 2SLS and IV estimators are the same if the number of instruments are needed to estimate the equation and fill-in the **Z**-matrix which is of dimension N×L, L ≥ K, of instruments. To clarify, the first-stage estimations define the instruments as:

$$\hat{\mathbf{X}} = \mathbf{Z}(\mathbf{Z}'\mathbf{Z})^{-1}\mathbf{Z}'\mathbf{X} = \mathbf{P}_Z\mathbf{X} \tag{5.6}$$

where the projection matrix $\mathbf{P}_Z = \mathbf{Z}(\mathbf{Z}'\mathbf{Z})^{-1}\mathbf{Z}'$, which is idempotent and symmetric. Consequently, $\widehat{\mathbf{X}}'\mathbf{X} = \mathbf{X}'\mathbf{P}_Z\mathbf{X} = (\mathbf{P}_Z\mathbf{X})'\mathbf{P}_Z\mathbf{X} = \widehat{\mathbf{X}}'\widehat{\mathbf{X}}$. Substituting this into (5.5) gives the IV estimator that uses instruments $\hat{\mathbf{x}}_i$. This is the second-stage regression is:

$$\hat{\boldsymbol{\beta}}_{2SLS} = (\widehat{\mathbf{X}}'\widehat{\mathbf{X}})^{-1}\widehat{\mathbf{X}}'\mathbf{Y} = (\mathbf{X}'\mathbf{Z}(\mathbf{Z}'\mathbf{Z})^{-1}\mathbf{Z}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{Z}(\mathbf{Z}'\mathbf{Z})^{-1}\mathbf{Z}'\mathbf{Y} \tag{5.7}$$

where the 2SLS estimator can be estimated in one computation using data on **X**, **Z**, and **y**. When L = K, there is only one instrument for y_2 and the 2SLS and IV estimators are identical.

To summarise 2SLS: in the first-stage, we obtain the fitted variables $\hat{y}_2$ from the regression (5.4) with y_2 on $1, x_1, \ldots, x_{K-1}, z_1, \ldots, z_m$; while in the second-stage, the fitted variables $\hat{y}_2$ are substituted into (5.1) and the OLS regression y_1 on $1, x_1, \ldots, x_{K-1}, \hat{y}_2$ is performed to produce $\hat{\boldsymbol{\beta}}_{2SLS}$. The point of using 2SLS is to obtain the consistent estimation of $\hat{\beta}_{2SLS}$ in a model that has a response variable y and regressors **X**, some of which are correlated with error terms. Prediction involves the original regressors **X**, but not the instruments $\widehat{\mathbf{X}}$. The two stages should not perform sequentially since the predicted values $(\widehat{\mathbf{X}})$ from first-stage regressions is generated by running endogenous regressors on the instrument set and then the second-stage OLS estimation using those fitted variables produces incorrect residuals, $\hat{\mathbf{u}}_i = \mathbf{y}_i - \widehat{\mathbf{X}}\hat{\boldsymbol{\beta}}_{2SLS}$ rather than the correct residuals, $\hat{\mathbf{u}}_i = \mathbf{y}_i - \mathbf{X}\hat{\boldsymbol{\beta}}_{2SLS}$ (Wooldridge, 2002, p. 91; Baum, 2006, p. 189). Statistics computed from incorrect residuals are inconsistent because $\widehat{\mathbf{X}}$ is not the true explanatory variables (Wooldridge, 2002, p. 91; Davidson and MacKinnon, 2004, p. 324).

The error terms in 2SLS are assumed to be iid but when this homoscedasticity assumption is not satisfied, the estimators are consistent but inefficient (Baum, 2006, p. 194; Cameron and Trivedi, 2009, p. 180). The generalised method of moments (GMM) can be linked to a linear system of equations and can be applied to construct efficient 2SLS estimators in the presence of heteroscedasticity (Wooldridge, 2002, pp. 186 – 188; Baum, 2006, p. 194). GMM estimation is also a two-step procedure and can be expressed as:

$$\hat{\boldsymbol{\beta}}_{GMM} = (\widehat{\mathbf{X}}'\mathbf{ZWZ}'\widehat{\mathbf{X}})^{-1}\widehat{\mathbf{X}}'\mathbf{ZWZ}'\mathbf{Y} \tag{5.8}$$

where **W** is any full-rank symmetric-weighting matrix. In general, the weights in **W** depend on both data and unknown parameters. For exactly-identified models, all choices of **W** produce the same estimator (Cameron and Trivedi, 2005, p. 181; Baum, 2006, p. 195). This estimator minimises the objective function:

$$Q_N(\beta) = \left(\frac{1}{N}(\mathbf{y} - \mathbf{X}\boldsymbol{\beta})'\mathbf{Z}\right)\mathbf{W}\left(\frac{1}{N}\mathbf{Z}'(\mathbf{y} - \mathbf{X}\boldsymbol{\beta})\right) \tag{5.9}$$

which is a matrix-weighted quadratic form in $\mathbf{Z}'(\mathbf{y} - \mathbf{X}\boldsymbol{\beta})$. To obtain the 2SLS estimator, $\mathbf{W} = (\mathbf{Z}'\mathbf{Z})^{-1}$. The optimal GMM estimator uses $\mathbf{W} = \hat{\mathbf{S}}^{-1}$ which can be written as:

$$\hat{\boldsymbol{\beta}}_{OGMM} = (\hat{\mathbf{X}}'\mathbf{Z}\hat{\mathbf{S}}^{-1}\mathbf{Z}'\hat{\mathbf{X}})^{-1}\hat{\mathbf{X}}'\mathbf{Z}\hat{\mathbf{S}}^{-1}\mathbf{Z}'\mathbf{Y} \tag{5.10}$$

where $\hat{\mathbf{S}}$ is an estimate of $\mathrm{Var}(\frac{1}{\sqrt{N}}\mathbf{Z}'u)$. If $\mathbf{u}_i$ is independent and heteroscedastic, then $\hat{\mathbf{S}} = \frac{1}{N}\sum_{i=1}^{n} \hat{u}_i^2 \mathbf{z}_i \mathbf{z}_i'$, where $\hat{\mathbf{u}}_i = \mathbf{y}_i - \mathbf{X}\hat{\boldsymbol{\beta}}_{2SLS}$. Cameron and Trivedi (2005, p. 181) note that $\hat{\boldsymbol{\beta}}_{OGMM}$ reduces to $\hat{\boldsymbol{\beta}}_{IV}$ when the model is exactly-identified.

In the IV context, it is often difficult to find an appropriate instrument and many studies commonly apply the first-stage F-statistic (Staiger and Stock, 1997; Baum, 2006, p. 207). If F>10, the instrument is sufficiently strong (Stock *et al*, 2002; Cameron and Trivedi, 2005, p. 105; Stock and Yogo, 2005; Young, 2009; Greene, 2012, pp. 290). When we have sufficient valid instruments, the parameters in the equation must be identified so that the 2SLS estimator leads to unique estimates (Baum, 2006, p. 190). 2SLS is applied to the wage equation that is discussed in more detail in Section 5.6.1.

5.4 Two-Step Quantile Regression (2SQR)

In the economic and health literature, the analysis of the nutrition-labour productivity relationship is commonly performed as a mean regression, whether instrumented or not. The methods only estimate the impacts of nutritional variables on labour productivity, say wages or income, at mean values which are restrictive because these methods may omit the impacts at different quantiles of the conditional distribution of earnings (Calderon, 2008; Kedir, 2008; Kumar *et al.*, 2014). For this reason, a quantile regression (QR) approach is therefore applied in this study which combines with the IV method, which is called two-step quantile regression

(2SQR) or IV quantile regression (IVQR) method. This may provide some interesting results of the relationship at different quantiles.

Now we briefly review the theoretical background of QR analysis. Following Cameron and Trivedi (2010, pp. 211 – 222), quantiles and percentiles are synonymous which are the value of a set of ranked data. Let u_i be the model prediction error, then OLS minimises $\sum_i u_i^2$, median regression minimises $\sum_i |u_i|$, and QR minimises a sum that gives the asymmetric penalties $(1 - q)|u_i|$ for over-prediction and $q|u_i|$ for under-prediction, where q is q^{th} quantile. The studies of model conditional moments, especially the conditional mean function are mainly focused on the conditional prediction of y (the wage received) given **x** (explanatory variables including the nutritional variables). Let $\hat{y}(\mathbf{x})$ be the prediction function and $u(\mathbf{x}) \equiv y - \hat{y}(\mathbf{x})$ be the prediction error. Then we have:

$$L\{u(\mathbf{x})\} = L\{y - \hat{y}(\mathbf{x})\} \tag{5.11}$$

(5.11) is called the loss association with u_i. The optimal loss-minimising predictor depends on the function $L(\cdot)$. If $L(u) = u^2$, then the function of the conditional mean, $E(y|\mathbf{x}) = \mathbf{x}'\boldsymbol{\beta}$ in the linear case, is the optimal predictor. If L(e) is absolute error loss, the optimal predictor is the conditional median, $med(y|\mathbf{x})$. If the function of the conditional median is linear, so $med(y|\mathbf{x}) = \mathbf{x}'\boldsymbol{\beta}$, then the optimal predictor is $\hat{y} = \mathbf{x}'\hat{\boldsymbol{\beta}}$, where $\hat{\boldsymbol{\beta}}$ is the least absolute-deviations estimator that minimises $\sum_i |y_i - \mathbf{x}_i'\boldsymbol{\beta}|$. In addition, Cameron and Trivedi (2010, pp. 212) also point out that the functions of both the squared-error and absolute-error loss are symmetric, which implies that the same asymmetric penalty can be applied for prediction error of a given magnitude regardless of the direction of the prediction error. The asymmetry parameter q is specified in the interval (0, 1) with symmetry when q = 0.5 and increasing asymmetry as q approaches 0 or 1. Then the optimal predictor is the q^{th} conditional quantile which can be written as $Q_q(y|\mathbf{x})$. Also, standard conditional QR analysis assumes that the conditional QR $Q_q(y|\mathbf{x})$ is linear in **x**.

Koenker and Bassett (1978) and Koenker and Hallock (2001) also define a QR as the solution to the problem of minimising a weight sum of absolute residuals. To optimise the linear problem, the q^{th} QR estimator $\hat{\boldsymbol{\beta}}_q$ minimises over $\boldsymbol{\beta}_q$, the objective function as:

$$Q(\beta_q) = \sum_{i:y_i \geq x_i'\beta}^{n} q\left|y_i - \mathbf{x}_i'\boldsymbol{\beta}_q\right| + \sum_{i:y_i \geq x_i'\beta}^{n} (1-q)\left|y_i - \mathbf{x}_i'\boldsymbol{\beta}_q\right| \tag{5.12}$$

where $0 < q < 1$, and we use $\boldsymbol{\beta}_q$ rather than $\boldsymbol{\beta}$ to make clear that different choices of q estimate different values of $\boldsymbol{\beta}$. If $q = 0.9$, for instance, then much more weight is placed on prediction for observations with $y \geq \mathbf{x}'\boldsymbol{\beta}$ than for observations with $y < \mathbf{x}'\boldsymbol{\beta}$. Commonly, $q = 0.5$ gives the least absolute-deviations estimator that maximises $\sum_i |y_i - \mathbf{x}_i'\boldsymbol{\beta}_{0.5}|$ which is often used in regressions.

Furthermore, we assume that the full sample of n observations is used in the estimation of each quantile and there is no loss in estimating as many quantiles as desired. Subsequently, QR is more general than a simple mean regression, and is more powerful when the coefficients of $Q(\beta_q)$ are significantly different across quantiles, implying that the marginal effect of a particular variable, return to nutrition in this paper, is not homogenous across q quantiles.

QR can be applied to estimate (5.1) but the estimates of the returns to nutrition may result in an inconsistent estimator as we use OLS because of the endogeneity bias (Thomas and Strauss, 1997; Behrman *et al*., 2005). This problem can be solved by adopting the IV approach in the QR framework (Ribeiro, 2001; Calderon, 2007; Kumar *et al*., 2014). This mixed method, called two-step quantile regression (2SQR) or instrumental variable quantile regression (IVQR), can yield a set of quantile estimators while simultaneously correct the endogenous bias. This method is first proposed by Amemiya (1982), followed by Powell (1983). Then, Chen (1988) and Portnoy (1991) extend the results of Amemiya's and Powell's studies for the consistency and asymptotic normality of the QR estimator with IV methods in a two-stage procedure.

Similar to 2SLS, consider the structural model (5.1) and (5.4), we collect a set of z instruments in the matrix $\mathbf{Z}$. QR is combined with the classical IV approach to consistently estimate heterogeneity across quantiles of the conditional y distribution. Ribeiro (2001) and Calderon (2007) explain that the 2SQR estimate proceeds in two steps: a first stage reduced form equation of the endogenous explanatory variables is estimated on the exogenous variables of the system using OLS, and then the fitted values are used in the quantile regression estimation of the structural equation of interest. Calderon (2007) also mentions that 2SQR is able to distinguish the non-linear relationship between nutrition and productivity, diminishing or increasing return to nutrition, at different quantiles of the conditional earning distribution. This procedure is also applied to the wage equation which is explained more in detail in Section 5.6.1.

5.5 Non-linear Two-Stage Least Squares (NL2SLS)

The 2SLS method is commonly applied in IV models that are linear in both variables and parameters. There are some interaction models which are non-linear in parameters and/or variables such as Cobb-Douglas production function, and taking logarithms of the variables can transform the non-linear form into a linear form for estimation purposes (Strauss, 1986; Aziz, 1995; Gujarati and Porter, 2009, pp. 159 – 165; Greene, 2012, pp. 221 – 222). 2SLS can be adapted to obtain consistent estimates. However, the endogenous variables in 2SLS are first regressed on exogenous and instrumental variables using OLS, and the fitted or predicted values of the endogenous variables are then substituted into the main regression to obtain estimates of parameters using OLS. If the parameters of the endogenous variables in the main regression are non-linear, then the linear instruments are unable to select patterns of non-linearity and 2SLS is no longer applicable (Amemiya, 1983; Bowden and Turkington, 1984, p. 163 – 166; Aziz, 1995; Wooldridge, 2002, p. 230).

Consider the general non-linear regression model:

$$\mathbf{y}_{1i} = \mathbf{q}_t(\mathbf{y}_{2i}, \mathbf{X}_i, \boldsymbol{\theta}_t) + \mathbf{u}_i, \qquad i = 1, \ldots, n \text{ and } t = 1, \ldots, T \tag{5.13}$$

where $\mathbf{y}_1$ denotes labour productivity, $q(\cdot)$ is a specified function, $\mathbf{y}_2$ is a vector of nutritional variables, $\mathbf{X}_i$ is a vector of other exogenous variables, $\boldsymbol{\theta}$ is a K-vector of unknown parameters, and $\mathbf{u}_i$ is scalar iid random variables with $E[\mathbf{u}_i] = 0$ and $Var[\mathbf{u}_i] = \sigma^2$. This implies that $E\left[\mathbf{u}_i \middle| \mathbf{q}_t(\mathbf{y}_{2i}, \mathbf{X}_i, \boldsymbol{\theta}_t)\right] = 0$ which allows a much wider range of functional forms than the linear model can accommodate (Goldfeld and Quandt, 1972; Amemiya, 1983; Greene, 2012, p. 221 – 225). Applying a non-linear least squares to (5.12) gives a consistent estimator, $\boldsymbol{\theta}$. However when $E\left[u_i \middle| \mathbf{y}_{2i}, \mathbf{X}_i\right] \neq 0$, $\boldsymbol{\theta}$ is inconsistent (Cameron and Trivedi, 2005, pp. 192 – 193) and we need to employ non-linear IV, namely non-linear two-stage least squares (NL2SLS).

The term NL2SLS usually means a set of instruments consisting of exogenous variables and low-order polynomials of all exogenous variables in the system (Amemiya, 1974; Bowden and Turkington, 1984, p. 163 – 166). Following Amemiya (1974) and Amemiya (1983, pp. 362 – 379), suppose that the explanatory variables $\mathbf{X}$ be predetermined and there are as many instruments $\mathbf{Z}$ as the number of parameters $\boldsymbol{\theta}$ in any equation. A consistent NL2SLS estimator is obtained by minimising:

$$Q(\theta) = (\mathbf{y}_{1i} - \mathbf{q}_t(\mathbf{y}_{2i}, \mathbf{X}_i, \boldsymbol{\theta}_t))'\mathbf{Z}(\mathbf{Z}'\mathbf{Z})^{-1}\mathbf{Z}'(\mathbf{y}_{1i} - \mathbf{q}_t(\mathbf{y}_{2i}, \mathbf{X}_i, \boldsymbol{\theta}_t)) \tag{5.14}$$

where $\mathbf{Z}$ is the N × L matrix of instruments with rank at least equal to K that satisfies the condition $E[\mathbf{u}_i|\mathbf{Z}_i] = 0$. Note that this is the same conditional moment condition as in the linear case, except that $\mathbf{u}_i = (\mathbf{y}_{1i}, \mathbf{y}_{2i}, \mathbf{X}_i, \boldsymbol{\theta}_t)$ rather than $\mathbf{u}_i = \mathbf{y}_i - \mathbf{q}_t(\mathbf{y}_{2i}, \mathbf{X}_i, \boldsymbol{\theta}_t)$.

Wooldridge (2002, pp. 426 – 427) and Cameron and Trivedi (2005, pp. 193 – 197) observe that this method is an extension of the GMM method for linear models. Unlike linear models, there is no explicit formula for non-linear estimators but the asymptotic distribution can be found as a special case of the GMM estimator, which is called a non-linear GMM estimator. Since $E[\mathbf{u}_i|\mathbf{Z}_i] = 0$, then $E(\mathbf{Z}_i\mathbf{u}_i) = 0$. In matrix notation, let $\mathbf{u}$ be the N × 1 error vector with i^{th} entry u_i given in (5.12) and $\mathbf{Z}$ is the N × L matrix of instruments with i^{th} row $\mathbf{z}_i'$, then $\frac{1}{N}\sum_i^N \mathbf{z}_i u_i = \mathbf{Z}'\mathbf{u}$. The GMM estimator of the non-linear IV model, $\hat{\theta}$, minimises the quadratic form in the corresponding sample moment condition:

$$Q_N(\theta) = (\frac{1}{N}\mathbf{u}'\mathbf{Z})\hat{\boldsymbol{\omega}}_{\mathbf{N}}(\frac{1}{N}\mathbf{Z}'\mathbf{u}) \tag{5.15}$$

where $\hat{\boldsymbol{\omega}}_{\mathbf{N}}$ is a L × L weighting matrix. Unlike the linear GMM, the first-order conditions do not contribute to a solution of closed-form for the non-linear GMM estimator (Cameron and Trivedi (2005, p. 194). In (5.13), $\hat{\theta}$ is consistent given $E[\mathbf{u}_i|\mathbf{Z}_i] = 0$ and asymptotically normally distributed with estimated asymptotic variance as:

$$\text{Var}(\theta) = N[\hat{\mathbf{D}}'\mathbf{Z}\hat{\boldsymbol{\omega}}_{\mathbf{N}}\mathbf{Z}'\hat{\mathbf{D}}]^{-1}[\hat{\mathbf{D}}'\mathbf{Z}\hat{\boldsymbol{\omega}}_{\mathbf{N}}\hat{\mathbf{S}}\hat{\boldsymbol{\omega}}_{\mathbf{N}}\mathbf{Z}'\hat{\mathbf{D}}][\hat{\mathbf{D}}'\mathbf{Z}\hat{\boldsymbol{\omega}}_{\mathbf{N}}\mathbf{Z}'\hat{\mathbf{D}}]^{-1} \tag{5.16}$$

where $\hat{\mathbf{S}}$ which is similar to the linear case of (5.11) but now $\hat{u}_i = (\mathbf{y}_{1i}, \mathbf{y}_{2i}, \mathbf{X}_i, \hat{\boldsymbol{\theta}})$ or $\hat{u}_i = \mathbf{y}_i - \mathbf{q}(\mathbf{y}_{2i}, \mathbf{X}_i, \hat{\boldsymbol{\theta}})$ for independent heteroskedastic errors, and $\hat{\mathbf{D}}$ is a N × K matrix of derivatives of the error term:

$$\hat{\mathbf{D}} = \frac{\partial \mathbf{u}}{\partial \boldsymbol{\theta}'}\bigg|_{\hat{\boldsymbol{\theta}}} \tag{5.17}$$

With i^{th} non-additive errors, $\widehat{\mathbf{D}}$ has i^{th} row $\frac{\partial\,(\mathbf{y}_{1i}, \mathbf{y}_{2i}, \mathbf{X}_i, \theta)}{\partial\theta'}\Big|_{\hat{\boldsymbol{\theta}}}$; and with additive errors, $\widehat{\mathbf{D}}$ has i^{th} row $\frac{\partial\,\mathbf{y}_i -(\mathbf{y}_{2i}, \mathbf{X}_i, \theta)}{\partial\theta'}\Big|_{\hat{\boldsymbol{\theta}}}$. The asymptotic variance of the GMM estimator in the non-linear model is thus identical to that in the linear model but replacing the regressor matrix, **X**, by derivative $\frac{\partial\mathbf{u}}{\partial\boldsymbol{\theta}'}\Big|_{\hat{\boldsymbol{\theta}}}$. By analogy with the linear IV, Cameron and Trivedi (2005, p. 194) and Stewart (2011) suggest that the rank condition for identification is that $\operatorname{plim} \frac{1}{N}\mathbf{Z}'\frac{\partial\mathbf{u}}{\partial\boldsymbol{\theta}'}\Big|_{\boldsymbol{\theta}}$ is of rank K and the weaker order condition is that $L \geq K$.

In (5.15), the NL2SLS estimator of Amemiya (1974) is a special case of the GMM estimator when instrument sets are $\widehat{\boldsymbol{\omega}}_{\mathbf{N}} = (\frac{1}{\mathbf{N}}\mathbf{Z}'\mathbf{Z})^{-1}$ (Wooldridge, 2002, pp. 426 – 427; Cameron and Trivedi, 2005, p. 196; Stewart, 2011), and replacing it in (5.6) gives the NL2SLS estimator that minimises:

$$Q_N(\theta) = \frac{1}{N}\mathbf{u}'\mathbf{Z}\,(\mathbf{Z}'\mathbf{Z})^{-1}\mathbf{Z}'\mathbf{u} \tag{5.18}$$

In addition, nonlinearity can occur in the case that the model for the dependent variable is linear but the reduced form is non-linear. This can be explained in systems of non-linear estimations following Goldfeld and Quandt (1972) and Wooldridge (2002, pp. 428 – 431). Rewrite (5.13) as non-linear structural equations:

$$\begin{aligned} &q_1(\mathbf{y}_{1i}, \mathbf{y}_{2i}, \mathbf{x}_i, \boldsymbol{\theta}_1) = u_{i1} \\ &\vdots \\ &q_T(\mathbf{y}_{1i}, \mathbf{y}_{2i}, \mathbf{x}_i, \boldsymbol{\theta}_T) = u_{iT} \end{aligned} \tag{5.19}$$

where $\boldsymbol{\theta}_t$ is a $P_t \times 1$ vector of parameters and $t = 1, \ldots, T$. Taking the simultaneous relationship between nutrition, y_2 and labour productivity, y_1 as an example:

$$y_1 = \boldsymbol{\alpha}_1\mathbf{x}_1 + \varphi_1 y_2^{\varphi_2} + u_1 \tag{5.20}$$

$$y_2 = \boldsymbol{\alpha}_2\mathbf{x}_2 + \varphi_3 y_1 + u_2 \tag{5.21}$$

This model is non-linear in parameters as well as in the endogenous variables. Although we assume that $E[u_1|\mathbf{x}] = 0$ and $E[u_2|\mathbf{x}] = 0$, the parameters in the system can be estimated by GMM by defining $q_1(\mathbf{y}_1, \mathbf{y}_2, \mathbf{x}, \boldsymbol{\theta}_1) = y_1 - \boldsymbol{\alpha}_1\mathbf{x}_1 - \varphi_1 y_2^{\varphi_2}$ and $q_2(\mathbf{y}_1, \mathbf{y}_2, \mathbf{x}, \boldsymbol{\theta}_2) = y_2 - \boldsymbol{\alpha}_2\mathbf{x}_2 - \varphi_3 y_1$. Thus, if we have more than one equation in the system, the errors in (5.19) need to satisfy the assumption that $E[u_{it}|\mathbf{x}_{it}] = \mathbf{0}$ for some sub-vector $\mathbf{x}_{it}$ of $\mathbf{x}_i$. This allows elements of $\mathbf{x}_i$ to be associated with some error terms. Under the assumption $E[u_{it}|\mathbf{x}_{it}] = \mathbf{0}$, let $\mathbf{z}_{it} \equiv \mathbf{f}_t(\mathbf{x}_{it})$ be a $1 \times L_t$ vector of possibly non-linear functions of $\mathbf{x}_i$. If there are no restrictions on the parameters $\boldsymbol{\theta}_t$ across equations, $\boldsymbol{\theta}_t$ is identified if $L_t \geq P_t$. Also, if we assume that $E(\mathbf{z}_{it}^{'}\mathbf{u}_{it}) = 0$ for all $t = 1, \ldots, T$, a set of orthogonality conditions are specified by defining the $T \times L$ matrix $\mathbf{Z}_i$ as the block diagonal matrix with $\mathbf{z}_{it}$ in the t^{th} block:

$$\mathbf{Z_i} = \begin{vmatrix} \mathbf{z}_{i1} & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & \mathbf{z}_{i2} & \cdots & \mathbf{0} \\ \vdots & \vdots & \vdots & \vdots \\ \mathbf{0} & \mathbf{0} & \cdots & \mathbf{z}_{iT} \end{vmatrix} \tag{5.22}$$

where $L \equiv L_1 + L_2 + \ldots + L_T$. Letting $\mathbf{q}(\mathbf{y}_{1i}, \mathbf{y}_{2i}, \mathbf{x}_i, \boldsymbol{\theta}) \equiv [q_{i1}(\boldsymbol{\theta}_1), \ldots, q_{iT}(\boldsymbol{\theta}_T)]^{'}$ and $\mathbf{u}_{it} = \mathbf{q}(\mathbf{y}_{1i}, \mathbf{y}_{2i}, \mathbf{x}_i, \boldsymbol{\theta}_t)$, by iterated expectations $E(\mathbf{Z}_i^{'}, \mathbf{q}(\mathbf{y}_{1i}, \mathbf{y}_{2i}, \mathbf{x}_i, \boldsymbol{\theta})) = 0$ holds under the assumption $E(\mathbf{z}_{it}^{'}\mathbf{u}_{it}) = 0$. As there are no restrictions on $\boldsymbol{\theta}_t$ across equations and $\mathbf{Z}_i$ is chosen as in (5.22), the system 2SLS estimator reduces to the NL2SLS estimator equation by equation which is similar to the Amemiya's estimator. Thus for each t, the NL2SLS estimator solves:

$$\min_{\theta_t} \left(\sum_{i=1}^{N} \mathbf{z}_{it}^{'} q_{it}(\theta_t) \right)^{'} \left(\frac{1}{N} \sum_{i=1}^{N} \mathbf{z}_{it}^{'} \mathbf{z}_{it} \right)^{-1} \left(\sum_{i=1}^{N} \mathbf{z}_{it}^{'} q_{it}(\theta_t) \right) \tag{5.23}$$

Given only the orthogonality conditions $E(\mathbf{z}_{it}^{'}\mathbf{u}_{it}) = 0$, the NL2SLS estimator is an efficient estimator of $\boldsymbol{\theta}_t$ if:

$$E(u_{it}^2 \mathbf{z}_{it}^{'} \mathbf{z}_{it}) = \sigma_t^2 E(\mathbf{z}_{it}^{'} \mathbf{z}_{it}) \tag{5.24}$$

where $\sigma_t^2 \equiv E(u_{it}^2)$ which is sufficient for (5.23) to hold, that is $E[u_{it}^2|\mathbf{x}_{it}] = \sigma_t^2$. Let $\hat{\theta}_t$ be the NL2SLS estimator, then the consistent estimator of σ_t^2 is:

$$\hat{\sigma}_t^2 = \frac{1}{N}\left(\sum_{i=1}^{N} \hat{u}_{it}^2\right) \tag{5.25}$$

where $\hat{u}_{it} \equiv q_t(\mathbf{y}_{1i}, \mathbf{y}_{2i}, \mathbf{x}_i, \hat{\theta}_t)$ are the NL2SLS residuals. Under the conditions that $E(\mathbf{z}_{it}^{'}\mathbf{u}_{it}) = 0$ and (5.24), the asymptotic variance of $\hat{\theta}_t$ is:

$$\hat{\sigma}_t^2 \left\{ \left(\sum_{i=1}^{N} \mathbf{z}_{it}^{'} \nabla_t q_{it}(\hat{\theta}_t)\right)^{'} \left(\sum_{i=1}^{N} \mathbf{z}_{it}^{'} \mathbf{z}_{it}\right)^{-1} \left(\sum_{i=1}^{N} \mathbf{z}_{it}^{'} \nabla_t q_{it}(\hat{\theta}_t)\right) \right\}^{-1} \tag{5.26}$$

where $\nabla_t q_{it}(\hat{\theta}_t)$ is the $1 \times P_t$ gradient.

Wooldridge (2002, p. 430) also notes that if only the assumption $E(\mathbf{z}_{it}^{'}\mathbf{u}_{it}) = 0$ holds but (5.24) does not, the NL2SLS estimator is still $\sqrt{N}$-consistent, but it is not the efficient estimator that uses the orthogonality condition $E(\mathbf{z}_{it}^{'}\mathbf{u}_{it}) = 0$ if $L_t > P_t$. Then (5.26) is no longer valid and a more efficient estimator is obtained by minimising:

$$\min_{\theta_t} \left(\sum_{i=1}^{N} \mathbf{z}_{it}^{'} q_{it}(\theta_t)\right)^{'} \left(\frac{1}{N}\sum_{i=1}^{N} \hat{u}_{it}^2 \mathbf{z}_{it}^{'} \mathbf{z}_{it}\right)^{-1} \left(\sum_{i=1}^{N} \mathbf{z}_{it}^{'} q_{it}(\theta_t)\right) \tag{5.27}$$

with asymptotic variance:

$$\left\{ \left(\sum_{i=1}^{N} \mathbf{z}_{it}^{'} \nabla_t q_{it}(\hat{\theta}_t)\right)^{'} \left(\sum_{i=1}^{N} \hat{u}_{it}^2 \mathbf{z}_{it}^{'} \mathbf{z}_{it}\right)^{-1} \left(\sum_{i=1}^{N} \mathbf{z}_{it}^{'} \nabla_t q_{it}(\hat{\theta}_t)\right) \right\}^{-1} \tag{5.28}$$

If (5.24) is still holds, this estimator (5.28) is asymptotically equivalent to the NL2SLS estimator.[18] NL2SLS is applied to the production function that is discussed in more detail in Section 5.6.2.

[18] Wooldridge (2002, pp. 430 – 431) and Cameron and Trivedi (2005, pp. 196) show that if cross equation restrictions are imposed on θ_t in (5.64), the non-linear three stage least squares (NL3SLS) estimator is more efficient than the 2SLS estimator. However, if this estimator does not exploit correlation in the errors u_{ig} and u_{it} in different equations, NL3SLS reduces to 2SLS.

5.6 The Specification Models of the Nutrition-Labour Productivity Links

We model the relationship between nutrition and labour productivity using a semi-log wage function and a Cobb-Douglas production function following many empirical studies including Strauss (1986), Deolalikar (1988), Sahn and Alderman (1988), Haddad and Bouis (1991), Aziz (1995), Croppenstedt and Muller (2000), Ayalew (2003), Weinberger (2004), Traore (2007), Jha *et al*. (2009) and Uliwengu (2011). Consider the estimation of each specification model.

5.6.1 Semi-log Wage Equation with 2SLS and 2SQR[19]

A semi-log wage equation is widely applied to test the link that better nutrition improves labour productivity (Deolalikar, 1988; Sahn and Alderman, 1988; Haddad and Bouis, 1991; Croppenstedt and Muller, 2000; Ayalew, 2003; Weinberger, 2004). Recall (4.70):

$$\ln W_i = \beta_0 + \beta_1 \mathbf{C}^c_{a_i} + \beta_2 EDU_i + \beta_3 GEND_i + \beta_4 DR_i + \beta_5 LD_i + \beta_6 AREA_i + u_i \qquad (5.29)$$

where

- W is household income (Baht per month),[20]
- $\mathbf{C}^c_a$ is a vector of nutritional variables,
- EDU is the educational level of the household head which = 1 for completing primary level and below and = 0 otherwise, = 2 for completing secondary level and below and = 0 otherwise, and = 3 for completing bachelor's degree (graduated) and above and = 0 otherwise,
- GEND is the gender of household head which = 0 for female and = 1 for male,
- DR is the dependency ratio[21] where $DR = \frac{\text{number of dependents}}{\text{total number of family members}}$,
- LD is cultivated land,
- AREA is the administrative areas which = 0 for non-municipal areas and = 1 for municipal areas,
- ln is the natural logarithm, and
- i is the household for i=1,…,N.

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[19] Many studies apply the two-step Heckman procedure due to the problem of limited-dependent variables. Only 2SLS is discussed here because the dependent variable - household income - is available for all observations.

[20] Due to data limitations, monthly income is used instead of the wage received per hour.

[21] As we hypothesise that the households with higher dependents should earn more money than those who have lower dependents, so assume that DR = 1 if there are no children living in the household, and DR → 0 as the ratio of children to all family members increases.

Nutritional variables in (5.29) are calculated as per adult equivalent to avoid the difference of nutrition requirements among members which include daily calorie intake (kcal/day), calorie intake squared, protein (gram(g)/day), calcium (milligram (mg)/day), iron (mg/day), phosphorus (mg/day), vitamin A (mg/day), vitamin C (mg/day), thiamin (vitamin B1) (microgram (μg)/day), riboflavin (vitamin B2) (μg/day), and niacin (vitamin B3) (μg/day).[22] In (5.29), W and $\mathbf{C}_a^c$ are simultaneously determined and we apply 2SLS (Haddad and Bouis, 1991; Weinberger, 2004). To estimate the structural and reduced forms, 2SLS performs as first regresses each of the endogenous variables on all of the exogenous and instrumental variables in the system using OLS to obtain the estimated values of the endogenous variables. Variables that are assumed to be exogenous to households are EDU, GEND, DR, AGE, LD, and AREA. The reduced forms for $\mathbf{C}_a^c$, which is the first step is to be estimated:

$$\widehat{\mathbf{C}_{a_i}^c} = \hat{\delta}_0 + \hat{\delta}_1 EDU_i + \hat{\delta}_2 GEND_i + \hat{\delta}_3 DR_i + \hat{\delta}_4 AGE_i + \hat{\delta}_5 LAND_i + \hat{\delta}_6 AREA_i + \hat{\delta}_7 HSIZE_i + \hat{\delta}_8 MTH_i + \hat{\delta}_9 REGN_i + \hat{\delta}_{10} KID_i \tag{5.30}$$

where

- HSIZE is the household size which = 1 when there is one member and = 0 otherwise, = 2 when there are two members and = 0 otherwise, = 3 when there is three members and = 0 otherwise, = 4 when there is four members and = 0 otherwise, = 5 when there are five members and = 0 otherwise, and = 6 when the family members are 6 or more and = 0 otherwise,
- MTH is an operating month of data collection,
- RGN is region,
- KID is the number of family members younger than 15 years which = 0 if family members are over than four members and = 0 otherwise, = 1 for one family member and = 0 otherwise, = 2 for two family members and = 0 otherwise, = 3 for three family members, and = 4 for four family members and = 0 otherwise,
- ^ (hat) denotes predicted values.

We use (5.30) to predict all nutrient-intake variables separately, that is, we estimate (5.30) for each of the 10 nutrient-intake variables. In the second step, all estimated values are used as regressors in (5.29) and OLS is used to estimate:

[22] We do not add the interaction between nutritional variables because of multicollinearity problem.

$$\ln W_i = \beta_0 + \beta_1 \widehat{Kcal}_i + \beta_2 \widehat{Kcal_i^2} + \beta_3 \widehat{VA}_i + \beta_4 \widehat{VC}_i + \beta_5 \widehat{Cal}_i + \beta_6 \widehat{Ir}_i + \beta_7 \widehat{Phos}_i + \beta_8 \widehat{B1}_i + \beta_9 \widehat{B2}_i + \beta_{10} \widehat{B3}_i + \beta_{11} \widehat{Pro}_i + \beta_{12} EDU_i + \beta_{13} GEND_i + \beta_{14} DR_i + \beta_{15} AGE_i + \beta_{16} LD_i + \beta_{17} AREA_i + u_i \tag{5.31}$$

where

- Kcal is the energy intake per adult equivalent,
- $Kcal^2$ is the energy intake squared,
- VA is the vitamin-A intake per adult equivalent,
- VC is the vitamin-C intake per adult equivalent,
- Cal is the calcium intake per adult equivalent,
- Ir is the iron intake per adult equivalent,
- Phos is the phosphorus intake per adult equivalent,
- B1 is the vitamin B1 intake per adult equivalent,
- B2 is the vitamin B2 intake per adult equivalent,
- B3 is the vitamin B3 intake per adult equivalent'
- Pro is the protein intake per adult equivalent.

In the IV context, some instruments are invalid because they may be influenced through u_h. To confirm valid instruments, their exogeneity is tested using Hausman's (1978) test and Durbin-Wu-Hausman's (DWH) test (Wu, 1973). These tests compare the coefficients of the endogenous variables. Under the null that $\mathbf{C}_a^c$ is exogenous, the two estimators of $\hat{\boldsymbol{\beta}}_{LS}$ and $\hat{\boldsymbol{\beta}}_{IV}$ are consistent, while under the alternative, only $\hat{\boldsymbol{\beta}}_{IV}$ is consistent. Hausman's H-statistic $H\sim \chi^2_{K^*}$ where $K^* = K - K_0$ in which K_0 is the number of explanatory variables that are not under consideration with respect to endogeneity. Cameron and Trivedi (2005, p. 189) note that this test is appropriate when the errors are independent and homoscedastic. The alternative DWH-test uses the heteroskedasticity-robust statistic which is implemented as an F test (Wu, 1973; Davidson, 2000; Wooldridge, 2002, p. 121; Cameron and Tirvedi, 2005, p. 189), and the test statistic is $F_{K^*,N-K-K^*}$ which is applied to test (5.31) by adding the error term from the first-stage regressions of all variables in $\mathbf{C}_a^c$. Also, we apply the first-stage F-statistic to identify a weakness of instruments (Staiger and Stock, 1997; Baum, 2006, p. 207). If F>10, the instruments are sufficiently strong (Stock *et al*, 2002; Cameron and Trivedi, 2005, p. 105; Stock and Yogo, 2005; Young, 2009; Greene, 2012, pp. 289 – 291).When we have sufficient valid instruments, the parameters in the equation are identified so that 2SLS produces unique estimates (Baum, 2006, p. 190).

Testing for overidentifying restrictions is also applied using a Lagrangain Multiplier (LM) test. In particular, the test of Sargan (1958) and Basmann (1960) is commonly used to check whether the instrumental variables are exogenous (Davidson and Mackinnon, 1993, pp. 235 – 236; Baum *et al*., 2003; Cameron and Trivedi, 2005, p. 191; Basal, 2008; Greene, 2012, p. 279). Under the null that all instruments are not correlated with u, LM ~ χ^2_r where r is the number of overidentification restrictions, that is, the number of the excess instrumental variables. If the null is rejected, at least one instrumental variable is not correlated with the error term, and we need a new instrument set.

For cross-sectional data, we estimate (5.29) and (5.30) using the robust errors to address problems of heteroscedasticity (Wooldridge, 2002, p. 128; Baum *et al*., 2003). Heteroscedasticity can be tested by the LM-test. Under the null of homoscedasticity, LM ~ χ^2_Q where Q is the number of regressors in the auxiliary regression. Failure to reject does not help in indicating the variables that cause heteroscedasticity (Gujarati and Porter, 2009, p. 389; Greene, 2012, p. 316). An alternative test is the Breusch-Pagan test (Breusch-Pagan, 1979). It is an LM-statistic which involves regressing $\hat{u}_h^2$ on a set of variable in the auxiliary regression (Wooldridge, 2002, pp. 185 – 186) and is more powerful that White's test, but it is sensitive to the assumption of normality (Baum, 2006, p. 145; Gujalati and Porter, 2009, p. 389; Greene, 2012, p. 317). Waldman (1983) and Greene (2012, p. 317) explain that if the variables in the auxiliary regression are the same as those in the White test, then two tests are algebraically the same. In the IV context, another test of heteroscedasticity is the Pagan-Hall test (Pagan and Hall, 1983) which is specifically implemented in 2SLS models and is similar to the Breush-Pagan and White tests (Baum, 2006, p. 206). Under the null that the error term is homoscedastic and independent of instruments **Z**, the Pagan-Hall statistic is distributed as χ^2_p, where p is the degrees of freedom irrespective of the presence of heteroscedasticity elsewhere in the system.

Moreover, (5.29) can be estimated by 2SQR to examine the nutrition-labour productivity link at different quantiles of the conditional distribution of household income. The point of using 2SQR is that there may be asymmetries in the nutrient intakes response to household income changes over the population. In the 2SQR estimator, (5.30) is regressed using OLS at the first stage, then (5.31) is run using the QR estimation. The validity and quality of instrumental used of the estimation are checked using as the same tests in 2SLS.

To estimate (5.31) for 2SLS and 2SQR, we use data from the Socio-Economic Survey (SES) of National Statistical Office (NSO), Thailand, undertaken between January and December 2011 with a total sample of 2,781 rice-farming households. The SES does not distinguish between on-farm and off-farm households, and from our theoretical framework, (5.31) is estimated for both on- and off-farm labour. STATA (13^{th}-version) is used throughout for the wage estimation.

5.6.2 Cobb-Douglas Production Function with NL2SLS

A significant impact of nutrition on wages may not be conclusive evidence in favour of the nutrition-productivity link, especially in an imperfect labour market where farm labour is not paid its marginal product (Weiss, 1980; Deolalikar, 1988). Strauss (1986) and Deolalikar (1988) suggest that the nutrition-productivity effect also requires the estimation of the farm production function to estimate the marginal product of labour. We use the Cobb-Douglas production function and although restrictive, it is widely used in the literature (Strauss, 1986; Deolalikar, 1988; Aziz, 1995; Ayalew, 2003; Traore, 2007; Jha *et al*., 2009). Recall (4.82):

$$\ln Q_i = a_0^* - \mathbf{B}_{ij} \frac{1}{h\left(\mathbf{C}_{a_i}^c\right)} + \alpha_1 \ln L_{F_i} + \alpha_2 \ln LD_i + \alpha_3 \ln FE_i + u_i + \varepsilon_i \tag{5.32}$$

where

- Q is the value of farm output (Baht),
- $\mathbf{C}_a^c$ is the vector of nutrient intake,
- L_F is family labour,
- LD is the cultivated land (Ha),
- FE is the value of fertilizer used (Baht),
- μ is a household-specific unobserved error term, and
- ε is the iid error term.

We modify (5.32) by adding cross-product variables of inputs and their squared terms as:

$$\ln Q_i = a_0^* - \mathbf{B}_{ij}\frac{1}{h\left(\mathbf{C}_{a_i}^c\right)} + \alpha_2 \ln L_{F_i} + \alpha_3 \ln LD_i + \alpha_4 \ln FE_i + \alpha_5(\ln L_F \cdot \ln LD)_i + \alpha_6(\ln L_F \cdot \ln FE)_i$$
$$+\alpha_7(\ln L_F \cdot \ln FE)_i + \alpha_8(\ln LD \cdot \ln FE)_i + \alpha_9(\ln L_F)_i^2 + \alpha_{10}(\ln LD)_i^2 + \alpha_{11}(\ln FE)_i^2$$
$$+ u_i + \varepsilon_i \qquad (5.33)$$

If $\alpha_5 = \alpha_6 = \alpha_7 = \alpha_8 = \alpha_9 = \alpha_{10} = \alpha_{11} = 0$, then (5.33) reduces to (5.32).

In the efficiency wage hypothesis, farm productivity (Q) and consumption ($\mathbf{C}_a^c$) in (5.32) are simultaneously determined with bi-directional causality. This again is the problem of endogeneity. Equation (5.32) is treated as the structural equations between Q and $\mathbf{C}_a^c$ with an instrumented NL2SLS method of estimation. The structural equations (5.33) are:

$$\ln Q_i = a_0^* - \mathbf{B}_{ij}\frac{1}{h\left(\mathbf{C}_{a_i}^c\right)} + \alpha_2 \ln L_{F_i} + \alpha_3 \ln LD_i + \alpha_4 \ln FE_i + \alpha_5(\ln L_F \cdot \ln LD)_i + \alpha_6(\ln L_F \cdot \ln FE)_i$$
$$+\alpha_7(\ln L_F \cdot \ln FE)_i + \alpha_8(\ln LD \cdot \ln FE)_i + \alpha_9(\ln L_F)_i^2 + \alpha_{10}(\ln LD)_i^2 + \alpha_{11}(\ln FE)_i^2$$
$$+ u_i + \varepsilon_i \qquad (5.33)$$

$$\ln\frac{1}{\mathbf{C}_{a_i}^c} = \gamma_0 + \gamma_1 \ln Q_i + \gamma_2 \ln L_{F_i} + \gamma_3 \ln LD_i + \gamma_4 \ln FE_i + \gamma_5(\ln L_F \cdot \ln LD)_i + \gamma_6(\ln L_F \cdot \ln FE)_i +$$
$$\gamma_7(\ln LD \cdot \ln FE)_i + \gamma_8(\ln L_F)_i^2 + \gamma_9(\ln LD)_i^2 + \gamma_{10}(\ln FE)_i^2 + u_i + \varepsilon_i \qquad (5.34)$$

As $\mathbf{C}_a^c$ is the vector of nutritional variables, (5.33) can be expressed as:

$$\ln Q_i = \alpha_0^* - B_1\left(\frac{1}{Kcal_i}\right) - B_2\left(\frac{1}{Kcal_i^2}\right) - B_3\left(\frac{1}{VA_i}\right) - B_4\left(\frac{1}{VC_i}\right) - B_5\left(\frac{1}{Cal_i}\right) - B_6\left(\frac{1}{Ir_i}\right) -$$
$$B_7\left(\frac{1}{Phos_i}\right) - B_8\left(\frac{1}{B1_i}\right) - B_9\left(\frac{1}{B2_i}\right) - B_{10}\left(\frac{1}{B3_i}\right) - B_{11}\left(\frac{1}{Pro_i}\right) + \alpha_2 \ln L_{F_i} + \alpha_3 \ln LD_i +$$
$$\alpha_4 \ln FE_i + \alpha_5(\ln L_F \cdot \ln LD)_i + \alpha_6(\ln L_F \cdot \ln FE)_i + \alpha_7(\ln LD \cdot \ln FE)_i + \alpha_8(\ln L_F)_i^2 +$$
$$\alpha_9(\ln LD)_i^2 + \alpha_{10}(\ln FE)_i^2 + u_i + \varepsilon_i \qquad (5.35)$$

where B_i are the coefficients of nutrient intakes, i = 1,…, 11. (5.35) is a non-linear model. Since the variables in $\mathbf{C}_a^c$ are assumed to be endogenous, 2SLS can be applied to (5.34) and (5.35) with the instrumental set for $\mathbf{C}_a^c$, which are gender of the household heads (GEND), age of the household heads (AGE), livestock (LIVE), the educational levels of the household heads

(EDU), household size (HSIZE), region (RGN) and operating month (MTH). However, the estimated estimators are inefficient because the linear instrumental variables of $\mathbf{C}_a^c$ cannot identify any pattern of the parameters of the non-linearity in (5.35), so the predicted values may be constant or zero (Aziz, 1995), and we apply NL2SLS.

Additionally, Amemiya (1974) and Bowden and Turkington (1984, pp. 171) suggest that the second-order terms of the exogenous variables should be added to the NL2SLS instrument set. Strauss (1986) also suggests that quadratic terms and interactions of exogenous variables can be used as instruments. The final augmented sets of instruments consist of predetermined variables which are correlated with $\mathbf{C}_a^c$ together with the squared terms of the exogenous variables which are chosen to proxy non-linearity in the model (Strauss, 1986; Aziz, 1995). In addition, Hausman (1983, p. 440), Strauss (1986) and Aziz (1995) note that the use of a simple quadratic-augmented instrument set results in improved estimators by detecting the non-linearity in the model. However, Huasman (1983, pp. 440 – 441) and Strauss (1986) argue that there is no standard method for choosing instruments for non-linear models. The main purpose of the instrumental projection is to purge the regressors of their correlation with the residuals (Aziz, 1995) and our instrumental set comprises AGE, AGE^2, GEND, EDU, HSIZE, $HSIZE^2$, LIVE, RNG, and MTH.

Further, although the NL2SLS estimation requires as many instruments as the maximum number of parameters in any equations, Strauss (1986), Aziz (1995), and Trore (2007) note that we can have more instrumental variables than are needed if the number of observations is still greater than the number of instruments. Aziz (1995) also suggests that the benefit of instrument variables is achieved in large finite samples where there is an excess of observations over the number of instruments. Thus, adding more instruments can reduce the bias and the estimators are consistent and more efficient.

Labour is measured in terms of efficiency hours (Strauss, 1986; Deolalikar, 1988; Aziz, 1995, Traore, 2007). However, labour in this study is proxied by the number of effective labour which consumes sufficient calories since the working hours are not recorded in the SES. Thus, if the household's total energy requirement is over than 2,100 Kcal/day, labour in the household is effective labour. In the total sample, 1,585 rice-farming households reach the energy requirement at 2,100 Kcal/day. The GMM method is used to estimate the production function through STATA version 13th.

The validity of overidentifying restrictions imposed on a GMM estimator is tested by Hansen's (1982) J-statistic (Baum, 2006, p. 201). This statistic is similar to the Sargan test in the wage equation, but under the null that all instruments are uncorrelated with the error term, the Sargan test regresses the residuals from an IV or 2SLS regression on all instruments in **Z** where the residuals are iid and $J \sim \chi^2_{L\text{-}K}$ where L – K is the number of overidentifying restrictions (Buam *et al*, 2003). Rejection of the null implies that the instruments do not satisfy the required orthogonality conditions.

5.7 Summary

The simultaneous determination of nutrition-labour productivity relationship leads to the problem of endogeneity, and OLS is inconsistent. 2SLS can be applied to deal with this problem by choosing an instrumental variable for the endogenous regressor. 2SLS is also efficient in estimating simultaneous equations when there is no correlation between error terms. In using 2SLS, the endogenous variable is first regressed on all exogenous and instrumental variables using OLS to obtain its predicted variable. Second, the predicted value is then substituted into the main equation and estimated by OLS to obtain consistent estimates at the mean sample. Also, the 2SQR is applied to examine the link at different quantiles of the conditional distribution of earnings. Similar to the 2SLS procedure, the first step is a typical OLS regression of the endogenous variables on the instruments, while the second step performs quantile regressions of the dependent variable (household income per month) on the fitted value from the first step and on the exogenous variables. These two procedures are applied to analyse the relationship between household income per month and nutritional intakes through a semi-log wage equation and cross-sectional data of 2,781 farming households in the SES.

In the 2SLS procedure, the problem of internal instruments can occur when the predicted value obtained from the linear regression is substituted inside a non-linear regression and NL2SLS is preferred. NL2SLS is applied to estimate the non-linear link between farm productivity and nutritional intakes through GMM in which the link is formulated using the Cobb-Douglas production function. More significantly, the NL2SLS instrumental set combines the linear and second-order terms of the exogenous variables to detect the non-linearity in the model. The model is non-linear since effective-labour is used as an input which is defined as a function of the efficiency per hour worked function relating to caloric consumption and labour hours. Because of the data limitations, the number of effective-labour in households that consume over 2,100 kcal/day is used instead of the labour hours, and the sample size is 1,585 households.

Chapter 6 Data, Results and Discussion

6.1 Introduction

In this study, the estimation of the nutrition-labour productivity link in Thai rice-farming households employs econometric methods.[23] The empirical testing of the theoretical economic models depends on data availability and econometric methods and we need to understand the nature of the data and its limitations to choose appropriate techniques. The cross-sectional data used here are from the Socio-Economic Survey (SES) taken between January and December 2011 from the National Statistical Office (NSO), Thailand. Only data relating to rice-farming households are used. The chapter is organised as follows. Section 6.2 discusses the 2011-SES. We focus on food and nutrition data and discuss the data limitations. Section 6.3 provides descriptive statistics of the variables used; the results of semi-log wage equations are discussed in Section 6.4; the results of the production function are discussed in Section 6.5; and Section 6.6 summarises.

6.2 Thailand Household Socio-Economic Survey 2011

The SES was first conducted in 1957 and data was primarily collected as a cross-sectional survey with the initial purpose of collecting information on household income and expenditure, household consumption, housing characteristics, changes in assets and liabilities, and so on. Due to rapid economic expansion and social change, the SES now includes other purposes such as the consumer price index (CPI), poverty estimation, the analysis of food security, and so forth.

In this study, we use the SES undertaken from January to December 2011 to examine the nutrition-labour productivity link. Data requirements include household income and expenditure, household consumption and demographic information. Income data are assembled by different income sources which include agriculture, business, remittances, and interest, and expenditure comprising of non-food and food commodities. In Table 6.1, food consumption data are divided into 14 categories such as cereal products, fishes and seafood, meat and poultry, fruits, oils and fats, and vegetables. Also, the SES includes geographic location, household size, age, gender, economic activity, occupation, education and health service.

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[23] All estimation is carried out using STATA 13th version.

Table 6.1 Expenditure on Food, Beverage and Tobacco from the SES 2011

Commodities	Details
1. Grains and cereal products	Rice noodle/egg noodle, thin rice noodle, bread, bakery, cereal products, non-glutinous rice, glutinous rice, rice flour, wheat flour, curly rice noodle, clear noodle, soybean curd, macaroni/pasta, Sago palm, and others (15 food codes).
2. Meats and poultry	Pork meat, pork ribs, other parts of pork, beef meat/buffalo meat, other parts of beef/buffalo, chicken meat, cooked chicken meat, sausages, duck, other fresh/cooked meats, dried shredded pork, pork ball/chicken ball, minced pork, other preserved meats (14 food codes).
3. Fishes and seafood	Snakehead, catfish, Nile tilapia, tilapia, pomfret (black/silver), red snapper/giant seaperch, sheatfish, chub mackerel, Indian mackerel, shrimp, white shrimp, giant tiger prawn, squid, blood cockle, baby clam, green mussel, sea crabs, blue swimming crab, frog, steam chub mackerel, other fresh products, dried snakeskin gourami, dried snakehead, salted chub mackerel, salted Spanish mackerel, salted trevally, dried shrimp, salted crab, fish balls, fermented fish, and other preserved items (31 food codes).
4. Milk, cheese and eggs	Fresh milk, sour cream, soybean milk, hen eggs, duck eggs, salted eggs, other eggs, condensed milk, powdered milk, non-diary cream, cheese, margarine and others (13 food codes).
5. Oils and fats	Vegetable oil, lard oil, butter, coconut milk, coconut crud, and other oil and fat (6 food codes).
6. Fruits and nuts	Banana, orange, papaya, pineapple, rambutan, mango, melon, durain, grape, apple, guava, rose apple, grapefruit, longan, mangosteen, wollongong, lychee, other fresh fruits, preserved fruits, pickled/preserved/dried fruit, tinned fruits, ground nut, green pea, and other nuts (24 food codes).

Source: NSO (2013)

Table 6.1 Expenditure on Food, Beverage and Tobacco from the SES 2011 (continued)

Commodities	Details
7. Vegetables	Cabbage, cucumber, chine cabbage, Chinese broccoli, mushroom, Chinese water spinach, coriander, eggplant, tomato, string bean, gourd, ripe papaya, winter melon, pumpkin, lemon, chili pepper, celery, spring onion, mung bean, bean sprout, culinary herbs, tum leung, chive flowers, other fresh vegetables, onion/shallot (preserved), garlic, dried chili pepper, boiled bamboo shoot, pickled mustard, and other preserved vegetables (31 food codes).
8. Sugar and sweets	Candies, ice cream, Thai dessert, jelly/chocolate, white sugar, palm sugar, coconut sugar, jam, and other sweets (9 food codes).
9. Spices and condiments	Salt, fish sauce, vinegar, soy sauce, oyster sauce, chili sauce, tomato sauce, shrimp paste, tamarin paste, stock cube/paste, monosodium glutamate, curry paste, and other spices and seasonings (13 food codes).
10. Non-alcohol and beverage at home	Prepared products (such as tea leaf, coffee, cocoa) and preserved products (such as coke, instant coffee) (15 food codes).
11. Prepared food eaten at home	Ready-cooked food and preserved products (such as instant noodle) (10 food codes).
12. Food and non-alcoholic beverage away from home	Breakfast, lunch, dinner, snacks, western food and others (6 food codes).
13. Alcohol beverages	Drunk at home and drunk away from home (8 food codes).
14. Tobacco products	Cigarettes, cigar, and tobacco leaf.

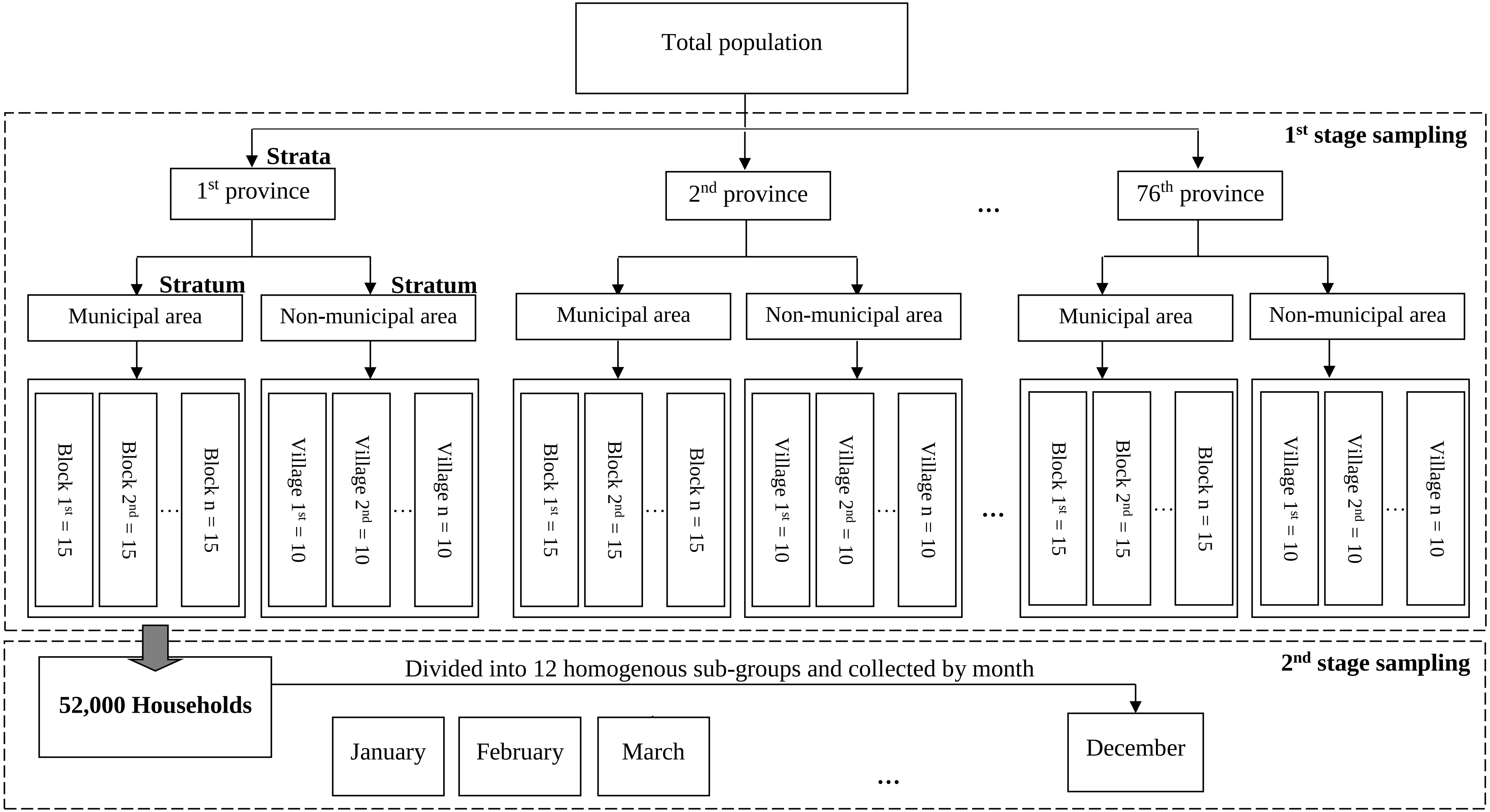
Source: NSO (2013)

The 2011 SES adopts a stratified two-stage sampling method. This method is widely employed in finite population sampling to divide the population into homogenous subgroups or strata (Hansen *et al*, 1953, p. 179; Lohr, 1999, pp. 95; Johnson and Turner, 2003). The different strata are independent (non-overlapping), so that each sampling unit solely belongs to one stratum (Lohr, 1999, p. 95). Within each stratum, an independent probability sample is drawn and the information is then pooled to obtain overall population estimates (Hansen *et al*, 1953, p. 179).

Barnett (1974) observes that dividing the population into homogeneous strata reduces the covariance of an estimator of a population mean or total. Additionally, the stratified sampling may be more convenient to administer and may result in a lower cost for the survey (Lohr, 1999, pp. 95 – 96).

In the 2011 SES, a province is constituted as stratum at the first-stage sampling, so there are 76 strata corresponding to the 76 provinces in which each stratum is divided into municipal and non-municipal areas according to the type of local administration. In each stratum, 15 households are selected from sample blocks in municipal areas and 10 households from sample villages in non-municipal areas. A systematic method is employed to select the number of households from each stratum which depends on the probability proportionate to size sampling. The total sample planned for the whole year is 52,000 households. At the second-stage sampling, the total sample is then divided equally into 12 subgroups due to periodicity (12 months), and each household in the subgroups is interviewed for a period of one-month (Figure 6.1). Data on 42,083 of the planned sample households are collected to be representative of the whole country, and 2,781 households (8,993 members) are rice-farming households which combine both households that can work on and/or off the farm.

Figure 6.1 Household Sample Design of SES



Source: Adapted from NSO (2013).

The food data in the 2011 SES is collected in terms of expenditure (monetary value) and quantity at the household level for 13 groups (tobacco products are excluded). Data on different types of food items from each group are collected as daily consumption using a seven-day recall diary. Data on dried food and canned food are collected separately from the daily consumption because they are sometimes stored for over one week. For the 12th group, only 6 food items are recorded for food consumed away from home due to a wide variety of food that is difficult to record. A total of 193 food items (codes) are collected in the survey.

For nutrient values, we convert the quantity of each food item into caloric intake, macronutrient (protein, fat, and carbohydrate) and micronutrient (calcium, vitamin A, iron, vitamin C, phosphorus, thiamin (B1), riboflavin (B2), and niacin (B3)) using the Nutritive Value of Thai Foods (NVTF) of the Department of Health, Thailand and the concise ASEAN Food Composition Tables (AFCT) designed by the Institute of Nutrition, Mahidol University, Thailand. The data from the NVTF and AFCT are derived from laboratory nutrient analysis, including Kjeldhal for protein analysis, acid hydrolysis, and the solvent extraction method for fat analysis. All reported quantities of individual food items are standardised into gram units for solid food items and millilitre units for liquid food items by field staff after receiving information from households. The matric quantity of the food items are converted to the appropriate nutrient values and dietary energy using the nutrient conversion factors of the Thai Food Composition Table (TFCT) which provides the nutrient values for each 100 grams of food. Volume of liquid and semi-liquid items (millilitre) are converted to their corresponding gram weight using the density factors of food items available in the FAO's Statistics Division database. These metric units provide an easy way of converting food quantities into nutrient values.

The SES, with collaboration from FAO, NSO, and Office of Agricultural Economics (OAE), Thailand is also used to examine the food security and nutrition status relationship. The data include a wide range of food consumption both in terms of quantities and monetary values. While the data measure food security at the household level, food distribution among family members is not considered. If food is not distributed according to need within the household, some family members who are classified as food-secure may not be receiving adequate food. Conversely, some people may be living in food-insecure households who are however able to obtain their food requirement. To investigate this issue, further research on dietary intake or food consumption is necessary to acquire a more comprehensive perspective on food security at the individual level.

Although the 2011 SES has information for the analysis of the interaction between nutrition and labour productivity where productivity is measured as wage received (wage/hour) and farm output, some information needs to be adjusted. These adjustments give rise to four limitations of the data. First, wages are recorded as average household wage per month but the survey does not provide details on labour market participation and cannot identify the sources of wages received, wage received per labourer, number of on-farm or/and off-farm labourers, and hours worked per day. When wage data are not available, we assume that labourers that have wages can work on- and/or off the farm. Further, average household income per month is employed instead of the wage received which is available for the whole sample.

Second, farm output is recorded in terms of the monetary value (Baht) of all products during the past 12 months as well as fertiliser consumption. Data on farm output are separated into three groups by a distribution for use, namely, for sale, for household consumption, and for others use. More than 90% of rice-farming households are semi-commercial households. Regarding the efficiency wage hypothesis, farm labour is assumed to be effective labour in which working hours are different from that of normal labour. Since the SES does not provide information about working hours, we assume that labour in the households that manage to attain the energy requirement of 2,100 kcal/day is effective labour, and here we use the number of labourers instead of hours worked per person for estimating the production function.

Third, the SES collects food data in terms of food items and food quantities for which metric conversion is performed in the field. Though, there are some food items which cannot be specifically recorded, so these items are aggregated as “other food item” codes for the 13 categories shown in Table 6.1 such as other meats and poultry, other vegetables, other grain and cereal products, for which exact nutrient values are hard to calculate. These items cannot be ignored because their quantities are relatively high and can influence nutritional values. To calculate the nutrient values of these codes for each category, we assume that household consumption of “other food item” codes has a similar trend to all food consumption listed for each category. So the amount of the “other food item” codes consumed is weighted by the total amount of all foods listed in each group, and then multiplied by the total amount of nutrient values for the total quantity of all food codes in each group, that is:

$$\mathrm{NVO_i} = \frac{\left(\sum_{j=1}^{n} \mathrm{NV_i}\right) \times \mathrm{OQ_i}}{\left(\sum_{j=1}^{n} \mathrm{Q_i}\right)} \tag{6.1}$$

where NVO is the nutrient value of the other food item code, OQ is the quantity of the other food item code, NV is the nutrient values of food items, Q is the quantity of food items, i is the food category, i^{th} category, and j is the number of food items listed in each category, j = 1, …, n. Further, the quantities of the 12^{th} category are collected, but they cannot be generated into particular food codes and are excluded from nutrient values to reduce bias.

Fourth, for nutritional data, only household consumption is collected and individual intakes are not recorded. If the share of nutrient intakes are not equal at the margin, the use of nutrient intakes at the household levels may lead to biased estimates of the impact of such nutrient intakes on labour productivity (Behrman, 1993; Weinberger, 2004). To address this issue, we require data on the number of household members (including age and gender), adult equivalents, and dietary reference intake (DRI), which is provided by the Department of Health, Ministry of Public Health, Thailand. The number of adult equivalents is used to adjust for individual household members for whom energy or food is available: individual food needs vary by gender and age which are taken into account. Thus, we require data on gender and age of each individual in the household and the energy requirements for all gender-age categories. This allows for comparisons across households that control for the difference between age and gender (Smith and Subandoro, 2007; Claro *et al*, 2010).

To calculate adult-equivalents using the adult male equivalent concept, we follow Smith and Subandoro (2007). In particular, we assign the calorie requirement for adult males aged 31-50 years as the calorie requirement for a reference adult (Table 6.2), then divide the energy requirement for each age-gender group by that of the reference adult. Using the same age-gender groups used for calculating the number of household adult equivalents, each household's total energy requirement is calculated by multiplying the number of household members in each age-gender category by the corresponding energy requirement and these are summed across household members. For each child who is younger than one year old, we add an extra 500 calories into energy intake due to the greater needs of breastfeeding from mothers (FAO/WHO/UNU, 1985). This is called the number of household adult equivalents for energy intake. We also adopt the same procedure for calculating the number of adult equivalents for all nutrient values in which their daily reference intakes are shown in Table 6.3.

Table 6.2 Daily Reference Intake (DRI) for Recommended Daily Calorie Intake, by Age-sex Group

Age group (years)	Energy intake (Kcal/day)	
	Male	Female
<1	800	
1 - 3	1,000	
4 - 5	1,300	
6 – 8	1,400	
9 – 12	1,700	1,600
13 – 15	2,100	1,800
16 – 18	2,300	1,850
19 – 30	2,150	1,750
31 – 50*	2,100	1,750
51 – 70	2,100	1,750
> 71	1,750	1,550

Source: Nutrition Division (2003)

Table 6.3 Daily Reference Intake (DRI) for Recommended Daily Micronutrients Intake by Age-Sex Group

Age group (years)	Vitamin A (µg/day)		Vitamin C (mg /day)		Iron (mg/day)		Calcium (mg/day)		Phosphorus (mg/day)		Vitamin B1 (mg/day)		Vitamin B2 (mg/day)		Vitamin B3 (mg/day)	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
<1	400		35		9.3		270		9.3		0.3		0.4		4	
1 - 3	400		40		5.8		500		5.8		0.5		0.5		6	
4 - 5	450		40		6.3		800		6.3		0.6		0.6		8	
6 – 8	500		40		8.1		800		8.1		0.6		0.6		8	
9 – 12	600	600	45	45	45	45	11.8	19.1	11.8	19.1	0.9	0.9	0.9	0.9	12	12
13 – 15	600	600	75	65	75	65	14.0	28.2	14.0	28.2	1.2	1.0	1.3	1.0	16	14
16 – 18	700	600	90	75	90	75	16.6	26.4	16.6	26.4	1.2	1.0	1.3	1.0	16	14
19 – 30	700	600	90	75	90	75	10.4	24.7	10.4	24.7	1.2	1.1	1.3	1.1	16	14
31 – 50*	700	600	90	75	90	75	10.4	24.7	10.4	24.7	1.2	1.1	1.3	1.1	16	14
51 – 70	700	600	90	75	90	75	10.4	9.4	10.4	9.4	1.2	1.1	1.3	1.1	16	14
> 71	700	600	90	75	90	75	10.4	9.4	10.4	9.4	1.2	1.1	1.3	1.1	16	14

Source: Nutrition Division (2003)

We apply the adult equivalent number to calculate the energy intake for each household:

$$HEI_h = \frac{TEI_h}{AE_h} \tag{6.2}$$

where HEI is the household energy intake (kcal/adult equivalent/ day), TEI is the total amount of household energy consumption (kcal/day), AE is the adult equivalent number, and h is the household. In (6.2), all members in each household are assumed to obtain the same level of energy intake at HEI.

A further limitation of the SES is that anthropometric variables such as height, weight, and body mass index (BMI) are not collected so only current calorie intake is considered to estimate the nutrition-labour productivity link. These variables can be related to an accumulative energy intake, and influence worker capability and should be taken into account in further research to study the nutrition-labour productivity in Thailand.

6.3 Descriptive Statistics

In using quantitative research methods, data errors, which may result from some steps of data collection, often influence data quality for data analysis, especially using large databases. The errors can contribute to meaningless or misleading problems of data, measurement errors and distillation errors (Hellerstein, 2008). To reduce interference of data errors, we apply the data cleaning technique, called trimmed mean which helps to reduce the scatter of prediction errors by removing some of the lowest and highest 5% of calorie intake among data of rice-farming households before doing the estimation (Rousseeuw and Leroy, 2005; Hellerstein, 2008; Osborne, 2012, p. 152). Thus, the total sample used in this study is 2,781 households.

Descriptive statistics on the socio-economic, demographic characteristics and nutritional values of the 2,781 sampled households is presented in Table 6.4. Household size ranges from 1-9 members with an average of 3.15. The mean dependency ratio is 0.23 which ranges from 0 (no dependents) to 0.89. Family labour ranges between 1-7 persons with an average of 2.27. Seventy-eight percent of household heads are male. The average age of household heads is 54 years and the range is 21-89 years. Eighty-six percent of household heads are educated to primary level, 9% have secondary education, 1% are graduates, and over 4% are illiterate. Mean income is 13,320 Baht/month/household with a range between 366-153,350 Baht. Households that attain at least 2,100 kcal/day are called "effective households", and their labour is "effective labour". Their average effective labour is 2.08 persons with a range of 1-6 persons. Farm output of effective households averages 122,293 Baht with a range of 3,000-2,024,800 Baht. The value of fertiliser consumption on effective households ranges from 0-983,660 Baht. Farm size effective households averages 13.20 Rai with a range of 0.5-20 Rai, while that of the other households is 13.64 Rai.

Table 6.4 Descriptive Statistics

Variable	Number of Observations	Mean	Standard Deviation (SD)	Minimum	Maximum
Calorie intake (kcal/day)	2,781	2,444.02	1117.93	961.08	8,856.91
Protein (g/day)	2,781	89.06	40.20	9.93	449.78
Calcium (mg/day)	2,781	328.97	227.21	4.41	5,658.07
Vitamin A (µg/day)	2,781	960.37	906.32	0.99	16,106.75
Vitamin C (mg/day)	2,781	101.48	91.73	0.00	1,333.71
Iron (mg/day)	2,781	25.31	86.79	1.01	4,076.44
Phosphorus (mg/day)	2,781	945.89	480.26	79.32	6,193.26
Vitamin B1 (mg/day)	2,781	2.79	3.03	0.12	32.95
Vitamin B2 (mg/day)	2,781	2.10	1.25	0.13	19.28
Vitamin B3 (mg/day)	2,781	18.88	8.73	1.75	109.64
Average household income (Baht/month)	2,781	13,319.87	11,179.89	366	153,350
Household size	2,781	3.15	1.37	1	9
Age of household head	2,781	54.49	10.20	21	89
Farm size (Rai)	2,781	13.64	13.59	0	120
Dependency ratio	2,781	0.23	0.23	0	0.86
Family labour	2,781	2.27	0.88	1	7
Education level of household head (=1 if attended, = 0 otherwise) - Primary level or below - Secondary level - Graduate level or above	2,781 2,381 238 32	- - - -	- - - -	0 - - -	1 - - -
Gender of household head (=1 if male, =0 if female) - Male - Female	2,781 2,163 618	- - -	- - -	0 - -	1 - -
Administrative area (=1 if municipal area, =0 if non-municipal area) -Municipal area -Non-municipal area	2,781 897 1,884	- - -	- - -	0 - -	1 - -
Effective labour	1,585	2.08	0.76	1	6
Fertiliser consumption (Baht)	1,585	45,722.57	74,608.63	0	983,660
Farm output (Baht)	1,585	122,292.5	151,237	3,000	2,024,800
Farm size for effective labour (Rai)	1,585	13.20	14.71	0.5	120

Source: Author’s calculations.

Nutritional values are calculated as per adult equivalent and are shown in Table 6.5. The average calorie intake of households is 2,444 kcal/day and ranges between 961-8,857 kcal. The greatest amount of energy intake for rice-farming households is predominantly from the consumption of grains and starches which is 64% of the average calorie intake. The average protein consumption is 90 grams/day and the average consumptions of phosphorus, calcium and iron are 946 mg/day, 329 mg/day and 25mg/day respectively. Average intake of vitamin A is 960 μg/day and the range is 0.99-16,107 mg/day. Average consumption of vitamin C is 102 mg/day.

Table 6.5 Energy Intake / Adult Equivalent / Day by Food Categories (kcal/day)

Variable	No. of Observations	Mean	SD	Minimum	Maximum
Grains and starch	2,781	1,567.45	947.37	603.12	6,128.57
Meat and poultry	2,781	160.20	131.85	36.23	1,781.10
Fishes and seafood	2,781	152.75	137.11	19.11	1,549.88
Milk, cheese and eggs	2,781	69.64	119.89	0	4,432.58
Oil and fat	2,781	135.34	139.67	0	2,427.62
Fruits and nuts	2,781	61.25	108.26	6.78	2,018.18
Vegetables	2,781	86.39	89.06	5.25	3,039.10
Sugar and sweets	2,781	74.27	102.86	0	2,249.76
Spices and condiments	2,781	21.69	24.29	1.02	325.95
Prepared food consumed at home	2,781	97.85	119.00	0	1,567.42

Source: Author's calculations.

All nutritional variables in Table 6.4 cannot be used in the wage equation and production function because of the problem of multicollinearity [24] so we choose the variables that are lower than the dietary reference intake (DRI) and related to the government's campaigns. The nutritional variables selected are shown in Table 6.6. The mean of calcium consumption is lower than the minimum requirement per day, while the average consumption of vitamin C is slightly over than that of the minimum requirement by 10%. Since vitamin A and iron are deficient in the Thai population, the government conducts several projects to prevent their deficiency (Tontisirin *et al*., 2013), and we include these micronutrients to investigate whether they are able to enhance productivity or not. More importantly, this study focuses only on the relationship between current nutritional intake and labour productivity.

[24] The correlations between the nutritional variables are shown in the Appendix (Table 6.14).

Table 6.6 Nutritional Variables

Variable	Mean	Minimum requirement (per day)
Calorie intake (kcal/day)	2444.02	2,100
Calcium (mg/day)	328.97	800
Vitamin A (μg/day)	960.37	700
Vitamin C (mg/day)	100.48	90
Iron (mg/day)	25.31	10.4

Source: Nutrition Division (2003).

Due to the above reason and literature review, the semi-log wage equation (5.31) and Cobb-Douglas production function (5.35) are rewritten as:

The wage equations to be estimated are:

Model I:

$$\ln W_i = \beta_0 + \beta_1 \widehat{Kcal}_i + \beta_2 \widehat{Kcal_i^2} + \beta_3 EDU_i + \beta_4 GEND_i + \beta_5 DR_i + \beta_6 AGE_i + \beta_7 LD_i + \beta_8 AREA_i + u_i \quad (6.3)$$

Model II:

$$\ln W_i = \beta_0 + \beta_1 \widehat{Kcal}_i + \beta_2 \widehat{Kcal_i^2} + \beta_3 \widehat{VA}_i + \beta_4 \widehat{VC}_i + \beta_5 \widehat{Cal}_i + \beta_6 \widehat{Ir}_i + \beta_7 EDU_i + \beta_8 GEND_i + \beta_9 DR_i + \beta_{10} AGE_i + \beta_{11} LD_i + \beta_{12} AREA_i + u_i \quad (6.4)$$

The production function to be estimated are:

Model III:

$$\ln Q_i = \alpha_0^* - B_1\left(\frac{1}{Kcal_i}\right) - B_2\left(\frac{1}{Kcal_i^2}\right) + \alpha_2 \ln L_{F_i} + \alpha_3 \ln LD_i + \alpha_4 \ln FE_i + \alpha_5 (\ln L_F \cdot \ln LD)_i + \alpha_6 (\ln L_F \cdot \ln FE)_i + \alpha_7 (\ln LD \cdot \ln FE)_i + \alpha_8 (\ln L_F)_i^2 + \alpha_9 (\ln LD)_i^2 + \alpha_{10} (\ln FE)_i^2 + u_i \quad (6.5)$$

Model IV:

$$\ln Q_i = \alpha_0^* - B_1\left(\frac{1}{Kcal_i}\right) - B_2\left(\frac{1}{Kcal_i^2}\right) - B_3\left(\frac{1}{VA_i}\right) - B_4\left(\frac{1}{VC_i}\right) - B_5\left(\frac{1}{Cal_i}\right) - B_6\left(\frac{1}{Ir_i}\right)$$
$$+\alpha_2 \ln L_{F_i} + \alpha_3 \ln LD_i + \alpha_4 \ln FE_i + \alpha_5 (\ln L_F \cdot \ln LD)_i + \alpha_6 (\ln L_F \cdot \ln FE)_i + \alpha_8 (\ln L_F)_i^2$$
$$+\alpha_9 (\ln LD)_i^2 + \alpha_{10} (\ln FE)_i^2 + u_i \qquad (6.6)$$

We first estimate the wage equation (6.3) and (6.4) using OLS, and results are significant but they are somewhat different from results elsewhere. Then, we test for endogeneity using Durbin-Wu-Hausman (DWH) test which shows that there is the endogeneity problem in the models which is often found in studies of nutrition-labour productivity links. This results in inconsistent estimators. In addition, we apply the Two-Step Heckman procedure for (6.3) and (6.4) in which this technique is generally used to tackle the endogeneity and selection bias when a dependent variable is available in some samples. However, the dependent variable in this study, household income, is available for all households. So we assign non-agricultural income, which is available for some households, as the dependent variable. The results of the Heckman procedure are not statistically significant because of the problem of model misspecification which results from data limitations and we may conclude that there is no relationship between non-agricultural income and nutritional status. Therefore, we only show the 2SLS results of wage equation which are in Section 6.4.

For the production function, we also apply OLS and DWH test for (6.5) and (6.6). The tests show the endogeneity problem in both models. Then, we estimate these equations using 2SLS, but testing for model validity shows that the models are invalid. As we mention in Section 5.5 and Section 5.6.2, substituting effective labour function in the Cobb-Douglas production function lead to the non-linearity in the models. Thus, we only estimate the production function using NL2SLS which is revealed in Section 6.5.

6.4 Results of Wage Equation

The results of the 2SLS wage estimation are shown in Table 6.7. The nutrients estimated in Model I (6.3) are energy and its square. Model II (6.4) additionally includes calcium, vitamin A, vitamin C and iron. Model I is conventionally estimated in most of the literature (Deolalikar, 1988; Sahn and Alderman, 1988; Thomas and Strauss, 1997; Ayalew, 2003), less so for Model

II that includes some other nutrients (Weinberger, 2003; Jha *et al*., 2009; Ashan and Ldrees, 2014).

Table 6.7 Impact of Nutrient Intake on Productivity using 2SLS Wage Equation: Dependent Variable - 1n(monthly household income)

Variable	**Model I**	**Model II**
	Coefficient	**Coefficient**
Constant	8.521^{***} (0.29)	8.265^{***} (0.39)
Estimated nutrient intake per adult equivalent		
- Energy (kcal/day)	-0.0003^{***} (0.00)	-0.0004^{***} (0.00)
- Energy squared	$3.76\times10^{-08**}$ (1.55×10^{-08})	$4.01\times10^{-08**}$ (2.09×10^{-08})
- Calcium (mg/day)	-	0.0008^{**} (0.00)
- Vitamin A (μg/day)	-	0.0007^{**} (0.00)
- Vitamin C (mg/day)	-	0.0016^{***} (0.00)
- Iron (mg/day)	-	0.0052^{*} (0.00)
Gender of household head (0=female, 1=male)	0.0888^{***} (0.03)	0.1637^{***} (0.04)
Educational levels of household head		
- Primary or below (0=not completed, 1=completed)	0.3616^{***} (0.05)	0.3585^{***} (0.06)
- Secondary or below (0=not completed, 1=completed)	0.5534^{***} (0.07)	0.5085^{***} (0.08)
- Graduated or above (0=not completed, 1=completed)	1.166^{***} (0.17)	0.9518^{***} (0.18)
Dependency ratio	0.1887^{***} (0.06)	0.2390^{***} (0.08)
Age of household head	0.0498^{***} (0.01)	0.0477^{***} (0.01)
Age of household head squared	-0.0004^{***} (0.00)	-0.0004^{***} (0.00)
Farm size (Rai)	0.1075^{***} (0.01)	0.0997^{***} (0.01)
Administrative areas (0=non-municipal area, 1=municipal area)	0.0254 (0.02)	0.0220 (0.03)
Number of observations	2,781	2,781
R^2	0.2587	0.2631
Regression Standard Error	0.5889	0.5877
Hansen's J-statistic (χ^2)	15.34	3.60

Notes: 1. *= significant at 10%, ** = significant at 5%, *** = significant at 1%.
2. Figures in parentheses are standard errors.

To check for model validity, the Durbin-Wu-Hausman (DWH) test is used to test for endogeneity: in Model 1, $F_{2,2767}$=164.16 (p=0.00); in Model 2, $F_{6,2759}$=60.77 (p=0.00); and both imply that the nutritional variables are endogenous. Hansen's J-test is used to test for overidentifying restriction: in Model 1, χ^2_5=15.34 (p=0.61); in Model 2, χ^2_9=3.60 (p=0.08) and each implies that the restriction is valid. The F-statistic on the first-stage regression is used to test for weak instruments, and the instrumental variables for both models are strong enough, that is F>10 for all variables as shown in Table 6.15 in Appendix. Overall, the models are adequate and are robust to alternative specifications.[25]

To compare the models, we apply a Wald version of the Chow test to test the null that there are no differences among the estimated coefficients of calcium, vitamin A, vitamin C and iron intake. The test shows that $F_{4, 2765}$=3.33 (p=0.00), the null is not rejected, and we conclude that these variables should be included. Accordingly, Model II is preferred.

In Model II, the associated elasticities, calculated at sample means, are shown in Table 6.8. Calcium, vitamin A, vitamin C, and iron have positive and significant effects on productivity as measured by monthly income. By contrast, energy intake has a negative and significant effect with an elasticity of -0.50, implying that a 1% increase in energy consumption leads to a fall in income of 0.50%. According to the nutrition-wage efficiency hypothesis, wages increase with nutrient intake. The finding here is similar to that of Weinberger (2004) in India where labour productivity is measured as the wages of agricultural households. Deolalikar (1988) also shows that the energy intake has a negative effect but insignificant in south India, and he argues that only weight-for-height is positively and significantly related to the wage rates at sample means.

[25] According to the efficiency wage hypothesis, the nutrition-labour productivity link is bidirectional which implies that increasing nutrient consumption leads to higher income and *vice versa*. Only the impact of nutrients on household income is discussed.

Table 6.8 Interpretation of the Estimated Coefficients in terms of Elasticities for the 2SLS Wage Equation

Variables	**Elasticity**	**Numerical value**
		Model II
Energy	$(\beta_1+2\beta_2\widehat{Kcal})\times\widehat{Kcal}$	-0.499
Calcium	$\beta_3\widehat{Cal}$	0.263
Vitamin A	$\beta_4\widehat{VA}$	0.672
Vitamin C	$\beta_5\widehat{VC}$	0.162
Iron	$\beta_6\widehat{Ir}$	0.132
Gender of household head	$e^{\beta_7}-1$	0.178
Educational levels of household head - Primary or below - Secondary or below - Graduated or above	 $e^{\beta_8}-1$ $e^{\beta_9}-1$ $e^{\beta_{10}}-1$	 0.431 0.663 1.590
Dependency ratio	$\beta_{11}DR$	0.187
Age of household head squared	$(\beta_{12}+2\beta_{13}AGE)\times AGE$	-0.224
Farm size	$\beta_{14}LAND$	0.032
Administrative areas	$\beta_{15}AREA$	--

Notes: 1. elasticities are calculated at mean values.
2. -- denotes that the coefficient is not significant.

The calcium elasticity is 0.26, implying that if calcium intake increases by 1%, then average productivity will rise by 0.26%. This supports Pitt and Rosenzweig (1985) who find that calcium consumption is effective in reducing illness among households in Indonesia where a 1% increase in calcium reduces the incidence of illness by 2.1%. Bhargava (2016) reports that calcium consumption is positively associated with height and weight among those aged between 2-22 years. Meschino (2002) also reports that a deficiency of calcium may lead to weakened bones and osteoporosis, and impacts on metabolic functions such as muscular function, enzymatic and hormonal activities, nervous stimuli, and the transport of oxygen.

The consumption of vitamin A positively determines labour productivity. The elasticity of vitamin A intake on household income is 0.67 and a 1% increase in vitamin A intake leads to an increase in household income by 0.67%. Jha *et al*. (2009) show that rural wages in India rise by around 0.30% if the level of vitamin A (carotene) intake increases by 1%. Wignaraja and Hussain (1989, p. 141) report that a deficiency of vitamin A leads to night blindness in Bangladesh. Lorch (2001) also argues that vitamin A deficiency (carotene) is a cause of serious malnutrition that deteriorates the immunologic system and may lead to blindness. However, Pitt and Rosenzweig (1985) find that the high consumption of vitamin A increases the incidence of sickness, and Weinberger (2004) shows that the effect of low vitamin A intake has a negative impact on wages. These studies include a number of nutrients into their regressions and the results may be confounded by multicollinearity, the extent of which is not reported.

The current level of vitamin C consumption is positively and significantly associated with household income with an elasticity of 0.16, and a 1% increase in the level of vitamin C intake increases household income by 0.16%. This result is similar to Weinberger's (2004) in which the vitamin C intake has a positive and significant impact on wages. Also, Pitt and Rosenzweig (1985) find that the consumption of vitamin C increases worker productivity by reducing the incidence of illness with an elasticity of 1.7. This is perhaps not surprising as vitamin C can enhance human health by improving the human immune system such as increasing antimicrobial and natural killer cell activities, boosting neurotransmitters biosynthesis, delayed-type hypersensitivity, and it prevents cold (Naidu, 2003; Wintergerst *et al*., 2006; Ströhle and Hahn, 2009).

The consumption of iron has a positive and significant impact on labour productivity with an elasticity of 0.13 which implies that a 1% increase in iron intake increases household income by 0.13%. Weinberger (2004) finds a similar elasticity in range 0.10-0.34. Jha *et al*. (2009) also report that iron consumption is positively related to rural wages among workers during the harvest season in India where elasticities for male and female workers are 0.78 and 0.68. Basta *et al*. (1979) find that taking 100mg of elemental iron for 60 days results in a significant improvement in the haematological status of anaemia, worker productivity and morbidity among rubber plantation workers in West Java, Indonesia. These results link to Hess (2010) who highlights the role of iron in redox reactions and improving oxygen transport which is essential for human health.

Turning to household characteristics, male heads have a positive and significant impact on household income, implying that they earn more than female-heads. The education of the household heads is positive and significant at primary, secondary and graduate levels, implying that higher education increases household income. The dependency ratio has a positive and significant impact on household income with an elasticity of 0.19. Farm size is positively and significantly associated with household income with the elasticity of 0.03. On the other hand, age is negatively associated with income, indicating that a one year increase in age reduces household income.

The (negative) sign of energy intake is counter-intuitive and the nutrition-labour productivity relationship may differ at different income levels. Accordingly, we examine the effects of energy intake and other nutrients at different quantiles of the conditional distribution of household income using the two-step quantile regression (2SQR) method via Model II (6.4). The income quantiles are set up as seven quantiles which are 5^{th}, 10^{th}, 25^{th}, 50^{th} (the median), 75^{th}, 90^{th}, and 95^{th} percentiles, and the marginal effects are shown in Table 6.9. The marginal effects indicate that returns to energy intake have a small magnitude ranging from -0.0005 at the 75^{th} and 90^{th} quantile to -0.0002 at the 25^{th} quantile, and a one kcal increase in average energy intake reduces household income between 0.000005% and 0.0005%. The results also imply that there are increasing returns at lower quantiles when coefficients of energy intake and its square are negative and positive respectively. Figure 6.2 shows that the lowest quantiles present a concave pattern between caloric intake and income and the relationship becomes convex at the higher quantiles. An income increases when caloric intake increases, and reach a peak at -0.0002 at 25^{th} quantile. Then it drops to around -0.0005 at 75^{th} and 90^{th} quantiles when increasing in energy intake, which is the lowest point. This implies that energy intake has a positive effect on income for the poorer households.

Table 6.9 Estimates of the Nutrition-labour Productivity Link using 2SQR Wage Equation: Dependent Variable - 1n(monthly household income)

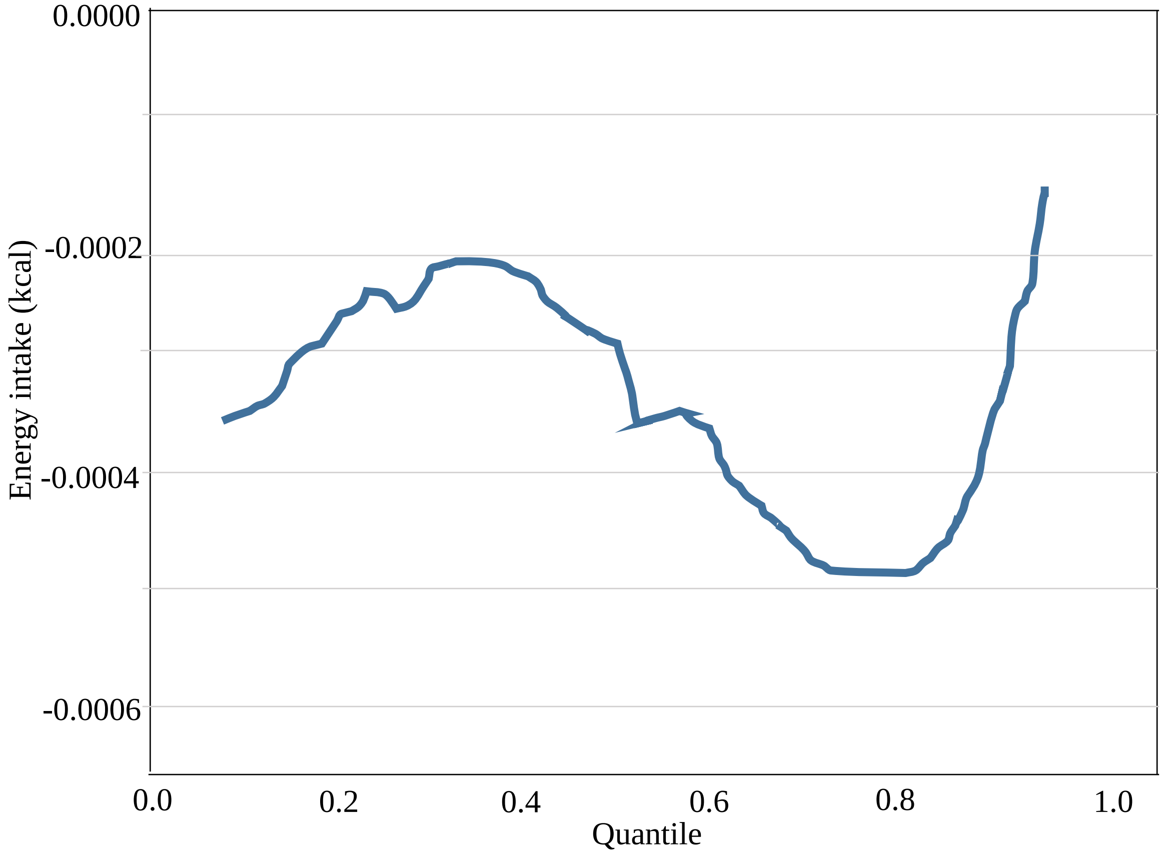
Variables	**Quantile**						
	0.05	**0.10**	**0.25**	**0.50**	**0.75**	**0.90**	**0.95**
Constant	7.177*** (0.86)	8.068*** (0.59)	8.178*** (0.53)	8.265*** (0.39)	9.122*** (0.36)	8.899*** (0.59)	9.074*** (1.04)
Estimated nutrient intake per adult equivalent							
- Energy (kcal/day)	-0.0004*** (0.00)	-0.0003*** (0.00)	-0.0002*** (0.00)	-0.0004*** (0.00)	-0.0005*** (0.00)	-0.0005*** (0.00)	-0.0001 (0.00)
- Energy squared	7.46×10^{-08}** (4.02×10^{-08})	7.21×10^{-08}* (3.72×10^{-08})	3.99×10^{-08}** (3.55×10^{-08})	5.40×10^{-08}** (2.30×10^{-08})	4.45×10^{-08} (2.32×10^{-08})	2.70×10^{-09} (2.68×10^{-08})	2.23×10^{-08} (7.03×10^{-08})
- Calcium (mg/day)	0.0030 (0.00)	0.0037** (0.00)	0.0019* (0.00)	0.0004** (0.00)	0.0003 (0.00)	-0.0030 (0.00)	0.0010 (0.00)
- Vitamin A (µg/day)	0.00003 (0.00)	0.0005 (0.00)	0.0007*** (0.00)	0.0007*** (0.00)	0.0008** (0.00)	0.0008** (0.00)	0.0011*** (0.00)
- Vitamin C (mg/day)	0.0065 (0.00)	0.0051 (0.00)	0.0003 (0.00)	0.0018** (0.00)	0.0037 (0.00)	0.0102** (0.00)	0.0092 (0.01)
- Iron (mg/day)	0.0119* (0.01)	0.0119** (0.01)	0.0072* (0.00)	0.0054* (0.00)	0.0017 (0.00)	0.0020 (0.001)	0.0063 (0.01)

Table 6.9 Estimates of the Nutrition-labour Productivity Link using 2SQR Wage Equation: Dependent Variable - 1n(monthly household income) (continued)

Variables	Quantile						
	0.05	**0.10**	**0.25**	**0.50**	**0.75**	**0.90**	**0.95**
Gender of household head (0=female, 1=male)	0.1582 (0.11)	0.1573* (0.08)	0.1717*** (0.04)	0.1315*** (0.04)	0.1604*** (0.04)	0.1996* (0.11)	0.2790*** (0.09)
Educational levels of household head							
- Primary or below	0.4279*** (0.14)	0.4654*** (0.08)	0.4037*** (0.11)	0.4371*** (0.07)	0.3445*** (0.06)	0.2951*** (0.10)	0.1537 (0.21)
- Secondary or below	0.7147*** (0.22)	0.6868*** (0.15)	0.6072*** (0.13)	0.5860*** (0.10)	0.4312*** (0.13)	0.3246** (0.15)	0.2951 (0.29)
- Graduate or above	0.7385* (0.41)	0.6058 (0.43)	0.7583*** (0.23)	1.154*** (0.26)	1.04192*** (0.18)	1.231*** (0.35)	0.9647*** (0.29)
Dependency ratio	0.3711 (0.15)	0.3095** (0.15)	0.1858** (0.08)	0.2104*** (0.08)	0.2257*** (0.07)	0.2950 (0.22)	0.4160* (0.22)
Age of household head	0.0710*** (0.03)	0.0451*** (0.02)	0.0446*** (0.02)	0.0366*** (0.01)	0.0416*** (0.01)	0.0483*** (0.01)	0.0440** (0.02)
Age of household head squared	-0.0007*** (0.00)	-0.0002*** (0.00)	-0.0004*** (0.00)	-0.0003*** (0.00)	-0.0004*** (0.00)	-0.0004*** (0.00)	-0.0004** (0.00)
Farm size (Rai)	0.0775*** (0.02)	0.0866*** (0.01)	0.0907*** (0.01)	0.1058*** (0.01)	0.1136*** (0.01)	0.1109*** (0.01)	0.1055*** (0.02)
Administrative areas (0=non-municipal area, 1=municipal area)	-0.0456 (0.05)	-0.0151 (0.04)	0.0198 (0.03)	0.0354 (0.03)	0.0328 (0.03)	-0.0016 (0.04)	-0.0094 (0.06)
Number of observations	2,781						
Pseudo R^2	0.0997	0.1238	0.1670	0.1715	0.1685	0.1672	0.1661

Notes: 1. *= significant at 10%, ** = significant at 5%, *** = significant at 1% level.
2. Figures in parentheses are bootstrap standard errors.

Figure 6.2 Estimated Energy Intake by Quantiles for Household Income (Natural Log)



Note: Other variables are shown in the Appendix (Figure 6.3).

The negative impact of energy consumption on household income seems robust between estimation methods and it may be explained by household circumstances. First, more than 90% of rice-farming households in Thailand are semi-commercial, and caloric consumption is not dependent merely on household income because low-income households can produce for their own consumption (NSO/OAE, 2012). Second, farm households may be in an imperfect labour market where labour does not get paid its marginal product, so household income or wages may be lower (Deolarikar, 1988; Ayalew, 2003). Also, Benjamin and Kimhi (2006) suggest that a decrease in household income possibly results from substitution between off-farm and family labour, but we cannot examine this because the data off- and on-farm are not recoded separately. Also, Deolarikar (1988) suggests that productivity may not be dependent only on current energy intake, but also on anthropometrics such as weight, height and BMI. This may imply that a higher caloric consumption does not always increase labour productivity. Moreover, Haddad and Bouis (1991) and Weinberger (2004) argue that a better nutritional status may be related to higher wages or income through several mechanisms. These include the enhanced ability of farmers to undertake piece-rate work, payment being based on performance, and payment being based on the perceived work potential labourers. Information about the decision-making process of employers is unavailable here, and we cannot examine the relationship via these mechanisms.

As the effect of calorie intake on household income is not in line with the efficiency wage hypothesis, we now need to explore where the negative effect of the calorie intake-income link comes from by dividing total calories into calories by each food item since calorie intake is generated from different food items. Thus, (5.31) is rewritten as:

$$\begin{aligned}\ln W_i = {} & \beta_0 + \beta_1 \widehat{GRN}_i + \beta_2 \widehat{MEAT}_i + \beta_3 \widehat{FSH}_i + \beta_4 \widehat{MLK}_i + \beta_5 \widehat{OIL}_i + \beta_6 \widehat{FRT}_i + \beta_7 \widehat{VEG}_i \\ & + \beta_8 \widehat{SUG}_i + \beta_9 \widehat{CON}_i + \beta_{10} \widehat{PERP}_i + \beta_{11} EDU_i + \beta_{12} GEND_i + \beta_{13} DR_i + \beta_{14} AGE_i \\ & + \beta_{15} LD_i + \beta_{16} AREA_i + u_i \end{aligned} \tag{6.7}$$

where GRN is calorie intake of grain and starch per adult equivalent,
MEAT is calorie intake of meat and poultry per adult equivalent,
FSH is calorie intake of fish and seafood per adult equivalent,
MILK is calorie intake of milk, cheese and eggs per adult equivalent,
OIL is calorie intake of oil and fat per adult equivalent,
FRT is calorie intake of fruits and nuts per adult equivalent,
VEG is calorie intake of vegetables per adult equivalent,
SUG is calorie intake of sugar and sweet per adult equivalent,
CON is calorie intake of condiment and seasoning per adult equivalent,
PREP is calorie intake of prepared food consumed at home per adult equivalent,

Results and their elasticities are shown in Tables 6.10 and 6.11. Grain and starch, spices and condiments have a negative impact on household income at the 5% significant level, whereas meat and poultry, vegetables, fruits and nuts, and prepared food consumed at home are positively and significantly associated with income. In addition, fish and seafood, milk, cheese and eggs, oil and fat, plus sugar and sweets have expected signs, but are insignificant.

Table 6.10 Estimates of the Nutrition-labour Productivity Link by Food Categories using 2SLS Wage Equation: Dependent Variable - ln(household monthly income

Variable	**Coefficient**	**SE**
Constant	7.856***	0.2472
Estimated nutrient intake per adult equivalent (kcal/day)		
- Grains and starch	-0.0012**	0.0006
- Meat and poultry	0.0149**	0.0073
- Fishes and seafood	0.0019	0.0045
- Milk, cheese and eggs	0.0012	0.0010
- Oil and fat	-0.0003	0.0028
- Fruits and nuts	0.0099*	0.0006
- Vegetables	0.0114**	0.0066
- Sugar and sweets	-0.0018	0.0078
- Spices and condiments	-0.0397**	0.0172
- Prepared food consumed at home	0.0028**	0.0016
Gender of household head (0=female, 1=male)	0.1118**	0.0483
Educational levels of household head (0=illiteracy)		
- Primary or below	0.3926*	0.2098
- Secondary or below	0.5068**	0.2488
- Graduated or above	1.384***	0.2542
Dependency ratio	0.2828***	0.1004
Age of household head	-0.0041	0.0391
Age squared	0.0002	0.0004
Farm size (Rai)	0.0970***	0.0121
Administrative areas (0=non-municipal area, 1=municipal area)	-0.0989	0.0254
Number of observations	2,781	
R^2	0.2657	
Regression Standard Error	0.5869	
Hansen's J-statistic (χ^2)	0.09	

Note: *= significant at 10%, ** = significant at 5%, *** = significant at 1%.

Table 6.11 Interpretation of the Estimated Coefficients in terms of Elasticity Coefficients for the 2SLS Wage Equation

Variables	**Elasticity**	**Numerical value**
Grains and starch	a_1GRN	-1.881
Meat and poultry	a_2MEAT	2.387
Fishes and seafood	a_3FISH	--
Milk, cheese and eggs	a_4MILK	--
Oil and fat	a_5OIL	--
Fruits and nuts	a_6FRT	0.606
Vegetables	a_7VEG	0.985
Sugar and sweets	a_8SUG	--
Spices and condiments	a_9SPI	-0.861
Prepared food consumed at home	$a_{10}PREP$	0.274
Gender of household heads	$e^{a_{11}} - 1$	0.118
Educational levels of household head		
- Primary or below	$e^{a_{12}} - 1$	0.481
- Secondary or below	$e^{a_{13}} - 1$	0.660
- Graduated or above	$e^{a_{14}} - 1$	2.991
Dependency ratio	$a_{15}DR$	0.065
Age	$(a_{16}+a\beta_{17}AGE)\times AGE$	--
Farm size	$a_{18}LAND$	0.212
Administrative areas	$a_{19}AREA$	--

Notes: 1. Elasticities are calculated at mean values.
2. – denotes that the coefficient is not significant.

In Table 6.11, a 1% increase in the household consumption of grains and starch per day reduces household income by 1.88%. Although cereal grains and starch are an important source of calories, they are often considered particularly harmful with respect to metabolic systems (Aller *et al*., 2011). Also, an excessive consumption of starches contributes to obesity and other diseases later in life, such as heart disease, diabetes, strokes, and high blood pressure, (Echel, 1997; Aller *et al*., 2011). An increase of 1% in the consumption of seasoning and condiments reduces household income by 0.86%: an excessive amount of high sodium products such as salt, fish sauce, soy sauce, ketchup and so on, leads to hypertension and subsequent pathologies, and an increase in blood pressure (Ruusunen and Puolanne, 2005; Liem, 2011).

A 1% rise in meat and poultry consumption increases household income by 2.39%. Speedy (2003) and Williams (2007) report that meat is a good source of high-quality protein and other nutrients such as zinc, iron and so on. In addition, protein is an essential element to produce red blood cells, to build antibodies, to construct enzymes and hormones for growth, and to repair and maintain body tissue (Young, 2001; Bilsborough and Mann, 2006; Shenoy and Jayaram, 2010). Likewise, a 1% increase in fruit and vegetable consumption increases income by 0.61%

and 0.99%. Fruits and vegetables are an essential source of fibre and vitamins C and A (carotenoid). Hu (2003) and Lin and Yen (2007) also report that a higher consumption of plant-based food, such as vegetables, fruits, and whole grains, results in a lower risk of coronary artery disease, cancers of the lung and colon, and stroke.

For prepared food consumed at home (including prepared food taken home), a 1% increase in consumption increases household income by 0.27%. Bhadrakom, (2008) and Suddeephong *et al*., (2010) observe that prepared food consumed at home, prepared food taken home and food eaten away from home have become increasingly popular. Bhadrakom (2008) reveals that the food at home and prepared food taken home are necessity goods, whereas the food away from home is likely to be a luxury. Our result is similar to the Bhadrakom's study that food consumed at home are necessity goods. However, we do not estimate food away from home here because this group cannot be divided into different food items, so it is difficult to calculate them in terms of energy intake.

6.5 Results of Production Function

In a competitive market, the nutrition-labour productivity hypothesis predicts nutrition to be determined by wages. But, when labour markets are imperfect, the presence of such a relationship is not proof that this hypothesis is valid, and conversely neither does its absence become the invalid hypothesis. An alternative hypothesis can be determined by examining the direct impact of nutrition on farm output. Here, we estimate the relationship between nutrient intake and farm output through a Cobb-Douglas production function (as in 6.5 and 6.6).

To estimate the Cobb-Douglas production function with the efficiency labour function (4.80), NL2SLS is applied to accommodate simultaneity and non-linearity. The GMM technique is then employed to regress this non-linear model, and the results are shown in Table 6.12. We do not include cross-product and squared terms to avoid the multicollinearity problem.[26] Again, we estimate two models with Model III (6.5) excluding micronutrients and Model IV (6.6) including them. Model validity is tested using Hansen's J-test which is a test of overidentifying restriction: χ^2_{12}= 16.752 (p = 0.16) for Model III, χ^2_{26}= 35.997 (p = 0.06) for Model IV, and the models are valid.[27] We also apply the Wald test to compare fit between the two models fit: χ^2_4=

[26] The correlation of production is shown in the Appendix (Table 6.17).
[27] Although the Hansen's J-test from Model IV is acceptable, its test statistic is close to the critical point (p>0.05). To obtain better results, a new instrumental set is needed but some related variables such as food price index and health proxies are not available.

9.03 (p=0.032), and the null that there is no difference among the nutrient coefficients is not rejected. Model IV is therefore then preferred.

Table 6.12 Estimates of the Nutrition-labour Productivity Link using Cobb-Douglas Production Function (ln(farm output))[28]

Variable	Model III	Model IV
Constant	2.4440*** (0.14)	2.265*** (0.14)
Estimated nutrient intake per adult equivalent		
- Energy (kcal/day)	376.38*** (173.23)	206.03*** (185.04)
- Calcium (mg/day)	-	118.66* (113.42)
- Vitamin A (μg/day)	-	68.08*** (53.65)
- Vitamin C (mg/day)	-	5.056* (2.68)
- Iron (mg/day)	-	1.925*** (1.88)
Family labour	0.2139*** (0.05)	0.2072*** (0.04)
Fertiliser (Baht)	0.5667*** (0.03)	0.5790*** (0.04)
Farm size (Rai)	0.0125*** (0.00)	0.0122*** (0.01)
Farm size-fertiliser interaction	-0.0014** (0.00)	-0.0018** (0.00)
Number of observations	1,585	1,585
Hansen's J-statistic (χ^2)	16.7516 (0.16)	35.9965 (0.06)

Notes: 1. *= significant at 10%, ** = significant at 5%, *** = significant at 1%.
2. Figures in parenthesis are standard errors.
3. Figures in square brackets are p-values.

The results show that that energy, vitamin A and iron intake have a positive and significant relationship with farm output at the 99% significance level, while vitamin C and calcium intake have a positive and significant association with output at the 90% significance level. Thus nutrients are important factors that can improve labour productivity. The results of relationship between nutrient intake and farm output support the efficiency wage hypothesis in which an increase in consumption can enable labour work more productively. Thus, here, we do not

[28] We do not include Kcal^2 and all interactions among farm input variables in the models because of the multicollinearity problem.

estimate the effect of calorie intake on farm productivity by food items through the production function.

Table 6.13 presents marginal productivities and elasticities. For marginal productivities, an increase of one kcal/day of calorie consumption increases the value of farm production by 2.62 Baht. Other micronutrients positively affect farm production. Extra consumption of vitamin A by 1µg/day increases the value of farm productivity by 6.85 Baht. Also, a 1mg increase in vitamin C, calcium, and iron intake per day increases farm output by 43.70, 98.05, and 167.65 Baht respectively. Additionally, the marginal products of effective labour, fertiliser, and farm size are 12,182, 1.53 and 82.25.

Table 6.13 Output Elasticities and Marginal Products at Sample Means

Variables	Marginal Product		Elasticity	
	Formula	**Value**	**Formula**	**Value**
Energy	$QB1/Kcal^2$	2.6155	B1/Kcal	0.0664
Calcium	$QB3/Ca^2$	98.0522	B3/Ca	0.3084
Vitamin A	$QB4/VC^2$	6.8471	B4/VA	0.0617
Vitamin C	$QB5/VC^2$	43.6946	B5/VC	0.0425
Iron	$QB6/Ir^2$	167.6477	B6/Ir	0.0431
Family labour	Qα2/LAB	12,182.21	α2	0.2072
Fertiliser	Qα3/FERT	1.5486	α3	0.5790
Farm size	Qα4/LAND	81.1580	α4	0.0122

Note: Elasticities and marginal products are calculated at mean values.

The elasticity of farm output with respect to energy intake implies that a 1% increase in energy intake increases the value of output by 0.07%. Corresponding elasticities of Strauss (1986) in Sierra Leone and Aziz (1995) in India are 0.33 and 0.45. Ayalew (2003) and Traore (2007) also report that current calorie consumption is a positive and important determinant of labour productivity in which the calorie elasticity of agricultural output is 0.48 and 0.30 respectively. Our elasticity is smaller than those of Strauss (1986), Aziz (1995), Ayalew (2003) and Traore (2007). A reason for this point may be our use of effective labour that is the number of workers rather than effective working hours. By contrast Deolalikar (1988) finds that calorie intake is an insignificant determinant of farm production in rural south India, although weight-for-height is significant. We cannot estimate the relationship between anthropometric variables and labour productivity as data are not available. The elasticities of farm output with respect to calcium, vitamin A, vitamin C and iron intake are 0.31, 0.06, 0.04, and 0.04.

The elasticity of farm output with respect to effective labourers is 0.21, indicating that a 1% increase in the number of labour contributes to increase the value of farm output by 0.21%. This elasticity is quite similar to those of Strauss (1986) and Aziz (1995) which are 0.60 for household labour hours and 0.14 and 0.16 for female and male labour hours, respectively. The farm output elasticities of fertiliser and farm size are 0.57 and 0.01, implying that a 1% rise in fertiliser use and farm size lead to increase the value of farm output by 0.57% and 0.01% respectively.

6.6 Summary

This chapter discusses the data used in this study and the empirical results of the nutrition-labour productivity link. The data are cross-sectional SES data of NSO taken from January to December, 2011. Socio-economic and demographic information, and food consumption at the household levels are applied to test the nutrition-labour productivity relationship. Household food consumption is then converted into nutrient values using the Nutritive Value of Thai Foods (NVTF) of the Department of Health, Thailand and the concise ASEAN Food Composition Tables (AFCT) designed by the Institute of Nutrition, Mahidol University, Thailand. Due to a lack of data at individual level, nutritional values are estimated in terms of adult equivalents to avoid differences of age and gender among members of the households. Our sample contains 2,781 rice-farming households and independent variables include calories, calcium, vitamin A, vitamin C and iron.

The analysis of the nutrition-labour productivity link is estimated by a semi-log wage equation and Cobb-Douglas production function. For the wage equation, we use 2SLS and 2SQR methods, and the average monthly household income as the dependent variable. The 2SLS results show that the consumption of calcium, vitamin A, vitamin C and iron make a positive and significant contribution to higher household income, while the calorie intake has a negative impact. Results from 2SQR again show the negative impact of energy intake on household income at different quantiles with increasing returns at the lower quantiles. This implies that energy intake has a positive effect on income for the poorer households.

As the results of the calorie intake-income link do not support the efficiency wage hypothesis, the negative impacts are then examined through food categories using 2SLS and results reveal that an increase in grains and starches lower household income, whereas extra consumption of meat and poultry, fruits, vegetables and nuts, and prepared food consumed at home increases household income.

As in the wage equation, households may not receive wages or income equal to their true marginal products and the production function is estimated. NL2SLS is applied to address non-linearity in the relationship between nutrition and labour productivity in the production function. The sample size is restricted to 1,585 households because of our use of effective labour. Results show that all nutrient variables have positive and significant effects on farm productivity which strongly support the efficiency wage hypothesis.

Appendix

Table 6.14 the Correlations among Nutritional Variables in the Wage Equation

	Energy	Energy squared	Protein	Calcium	Phosphorus	Iron	Vitamin A	Vitamin B1	Vitamin B2	Vitamin B3	Vitamin C	Pro×Ca*	Ir×C**
Energy	1.000												
Energy squared	0.5829	1.000											
Protein	0.7917	0.6576	1.000										
Calcium	0.3995	0.3061	0.5686	1.000									
Phosphorus	0.7655	0.6510	0.8444	0.6015	1.000								
Iron	0.1560	0.1386	0.2135	0.5706	0.3110	1.000							
Vitamin A	0.2984	0.2475	0.4945	0.4512	0.4437	0.2223	1.000						
Vitamin B1	0.6030	0.5430	0.3678	0.1834	0.3280	0.0413	0.1535	1.000					
Vitamin B2	0.5846	0.5254	0.5856	0.5599	0.7239	0.3302	0.6485	0.2323	1.000				
Vitamin B3	0.8041	0.6849	0.8257	0.4884	0.7171	0.0641	0.5216	0.3364	0.6202	1.000			
Vitamin C	0.3066	0.2299	0.4014	0.3862	0.3760	0.0214	0.3809	0.2225	0.3386	0.4274	1.000		
Pro×Ca	0.4793	0.4168	0.6646	0.8842	0.6588	0.6878	0.4869	0.2107	0.5838	0.5219	0.3429	1.000	
Ir×C	0.3133	0.2748	0.4103	0.5891	0.4530	0.6805	0.3629	0.1542	0.4030	0.3017	0.4934	0.6322	1.000

Notes: * is the interaction between protein and calcium

** is the interaction between iron and vitamin C

Table 6.15 First-stage Regression Summary Statistics for 2SLS Wage Equation

Variables	R^2	Adjusted R^2	Partial R^2	Robust $F_{11,2760}$	p-value
Energy	0.2018	0.1960	0.1484	36.9504	0.000
Energy squared	0.1354	0.1291	0.1004	23.3102	0.000
Calcium	0.1153	0.1089	0.0920	26.0049	0.000
Vitamin C	0.1069	0.1005	0.0801	24.3939	0.000
Vitamin A	0.0642	0.0574	0.0409	11.1357	0.000
Iron	0.0177	0.0106	0.0115	10.5429	0.000

Figure 6.3 Estimated All Variables by Quantiles for Household Income (Natural Log) using 2SQR

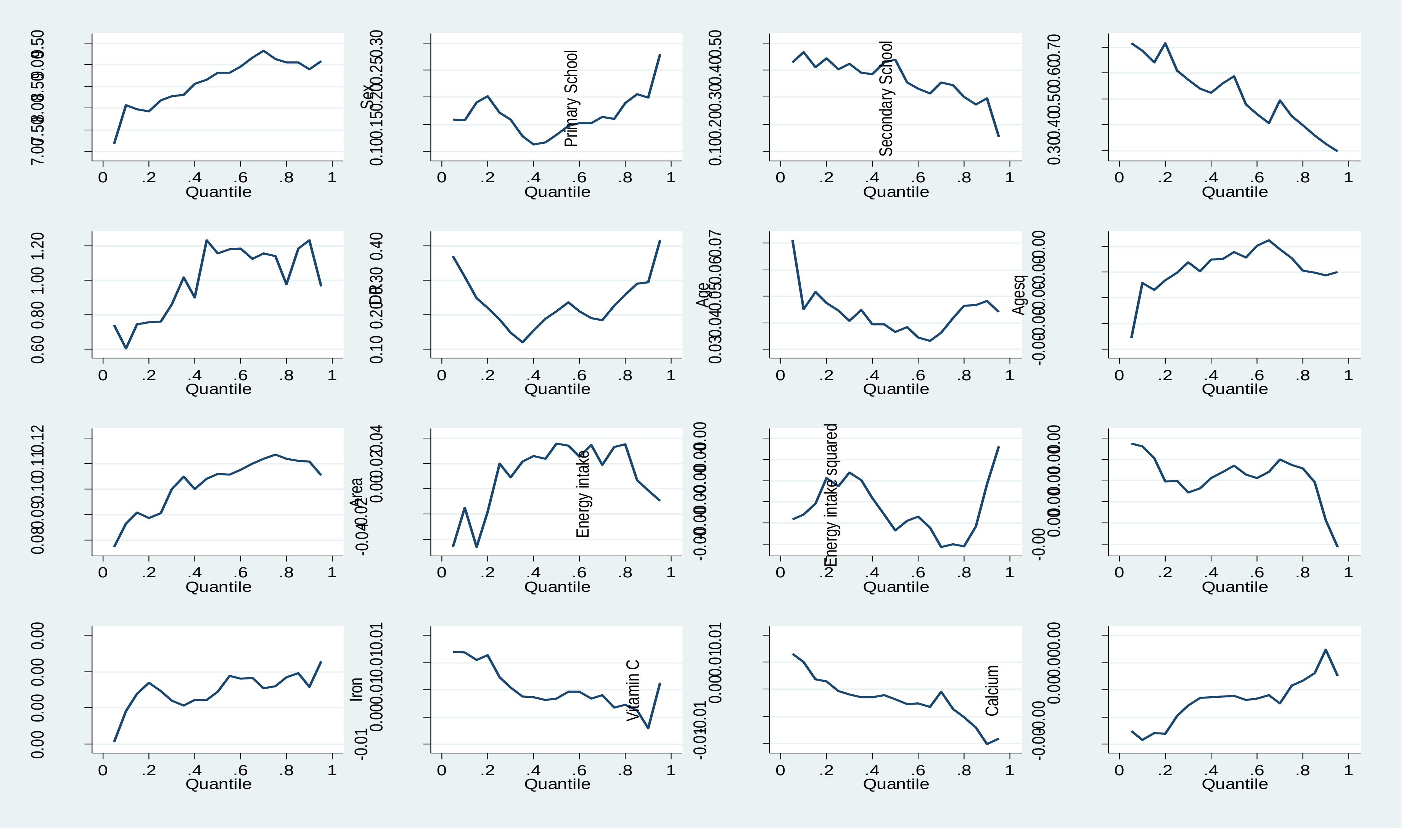


Table 6.16 the Correlations among Food items in the Wage Equation

	Grain	Meat	Fish	Milk	Oil	Fruit	Vegetable	Sugar	Condiment	Prep*
Grain	1.000									
Meat	0.0918	1.000								
Fish	0.2079	0.1739	1.000							
Milk	-0.0091	0.0803	0.0469	1.000						
Oil	0.0567	0.1782	0.1078	0.1252	1.000					
Fruit	0.0772	0.1436	0.1356	0.0778	0.1180	1.000				
Vegetable	0.1463	0.2001	0.1978	0.0400	0.1853	0.1571	1.000			
Sugar	-0.0318	0.1578	0.0747	0.1533	0.2827	0.1573	0.0936	1.000		
Condiment	0.0290	0.1984	0.1111	0.1067	0.4098	0.1544	0.2443	0.2884	1.000	
Prep	-0.0078	0.0566	0.0077	0.0537	0.0211	0.1031	-0.0477	0.1454	0.0466	1.000

Note: * is prepared food consumed at home

Table 6.17 Correlations among Explanatory Variables (Natural Log) in the Production Function

	Labour	Fertiliser	Land	Land squared	Fertiliser squared	Labour squared	Land×Lab*	Land×Fer**	Labour×Fer***
Labour	1.000								
Fertiliser	0.1357	1.000							
Land	0.1150	0.3989	1.000						
Land squared	-0.0049	0.0682	0.0631	1.000					
Fertiliser squared	0.1416	0.9914	0.3908	-0.0741	1.000				
Labour squared	0.9172	0.0880	0.1062	0.0020	0.0951	1.000			
Land×Lab	0.6392	0.0294	0.1135	0.6393	0.0280	0.6953	1.000		
Land×Fer	0.0214	0.1154	0.1335	0.9069	0.1092	0.0251	0.6787	1.000	
Labour×Fer	0.9686	0.3484	0.1886	-0.0193	0.3489	0.8875	0.6054	0.0439	1.000

Notes: * is the crossed-product between farm size and labour, ** is for farm size and fertiliser, *** is for labour and fertiliser.

Chapter 7 Determination of Household Food Security in Thailand

7.1 Introduction

Approximately 800 million people worldwide cannot meet their basic nutritional needs due to inadequate food consumption, particularly in low- and middle-income countries (FAO, 2015). Although food supplies have increased considerably, constraints on food accessibility and the insufficiency of household and national incomes as well as the instability of supply contribute to problems of hunger and food insecurity. The existence of these problems means that an access to adequate and nutritious food still remains the principal challenge facing policy makers for food security (WFP, 2015).

Thailand is a food surplus country but food accessibility at the household level remains a significant problem in remote rural areas, particularly for rice-farming households (Wangthamrong, 2010). An increase in food prices and production costs affect the rural poor due to declining purchasing power (Isvilanonda and Bunyasiri, 2009). Poor households face the risk of food insecurity as they may not be able to provide sufficient food for all members to lead a productive and healthy life, and it is essential to understand the factors that influence food security. Our concern here is with identifying the factors that influence food security, especially food accessibility among rice-farming households.

Households can be either food-secure or food-insecure, and the status of household food security is a binary variable. Thus, the impact of determinants of food security status for farm households is estimated by a binary logit (logistic) model, and this affects production and consumption systems and hence accessibility and utilisation (Feleke *et al*., 2005; Omotesho *et al*., 2006; Bashir *et al*., 2012; Aidoo *et al*., 2013; Hussein and Janekarnkij, 2013).

This chapter is organised as follows. Section 7.2 reviews the literature on food security, focusing on the definition of food security and its determinants at the household level. The methodology framework is discussed in Section 7.3. Section 7.4 discusses the results and Section 7.5 summarises.

7.2 Literature Review on Food Security

7.2.1 Defining Food Security

Food security has more than 200 definitions in the literature (Maxwell and Smith, 1992; Clay, 2003; Kidane *et al*., 2005). Food security originated as a concept in 1974 at the World Food Summit, focusing on food supply as "*availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices*" (UN, 1975).

In 1983, the concept was further developed by the FAO to include secure access to available supplies among vulnerable people, highlighting the interaction between supply and demand. In particular, food security should be balanced by "*ensuring that all people at all times have both physical and economic access to the basic food that they need*" (FAO, 1983). In 1986, the difference between chronic and transitory food insecurity was highlighted by the World Bank. Hence, the definition became "*access of all people at all times to enough food for an active, healthy life*" (World Bank, 1986; FAO, 2003; Clay, 2003).

By the mid-1990s, the focus of food security shifted from global and national levels to household and individual levels; and a key focus was on access to sufficient food which included protein-energy malnutrition (FAO, 2003). Thus, the definition was extended to cover nutritional balance and food safety, specifically focusing on food composition, nutrient needs, and food preferences (Clay, 2003). A further development was from the United Nations Development Programme (UNDP) which promoted the construction of a human security indicator. This is closely associated with the development of human rights perspective that influences, in turn, food security since it concentrates on wider components of social security which includes nutrition and health (Dreze and Sen, 1989).

In 1996, FAO (1996) incorporated previous definitions and provided a revised explanation: "*Food security, at the individual, household, national, regional and global levels [is achieved] when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life*". This explanation, although more complex, was later enhanced as "*Food security is a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life*" which focused more on food consumption, food demand and food accessibility by the vulnerable (FAO, 2002; Clay, 2003). The common goals in this definition are increasingly accepted by international communities, for example the Millennium Development Goals (MDGs) has a principle target related to food security to halve the proportion of undernourished people (FAO/IFAD/WFP, 2015, p. 9).

The definition can then be disaggregated into four key dimensions, namely food availability, food access, utilisation, and stability. Recent studies concentrate on food availability and food accessibility of dietary requirements at the household and/or individual levels (Haile *et al.*, 2005; Bogale, 2012; Aidoo *et al*, 2013; Hussein and Janekarnkij, 2013). This study only focuses on the factors that determine food accessibility to achieve food security at the household level.

7.2.2 Determinants of Food Security

The determinants of food security/insecurity are widely studied in present research, particularly focusing on the household level. In this section, concepts, determinants and analytical techniques of household food security are reviewed.

Feleke *et al.* (2005) develop a supply-demand model of the determinants of household food security for southern Ethiopia. Primary data for 247 households were collected by the Ethiopian Agricultural Research Organisation in 1999. The difference between caloric availability and needs is used to classify the status of household food security. If the amount of the former is more than that of the latter, households are food-secure, otherwise they are food-insecure. This is then used as a binary dependent variable of food security and a logit model is estimated. Results show that farm size, technology adoption, and the quality of land improve household food security, whereas farming system, household size, access to market, and *per capita* aggregate production lead to a decrease in household food security. The authors conclude that a change in supply-side determinants on household food security is more influential than a change in demand-side determinants.

Haile *et al.* (2005) also analyse factors that affect food security at the household level using a logit model and data collected from 108 households in the Oromia region of Ethiopia. The status of household food security is classified by the difference between calorie availability and demand. The binary dependent variable of food security is defined as follows: if calorie availability is greater than calorie demand *per capita*, then the household is food-secure, otherwise it is food-insecure. The results of logit model show that farm size, fertiliser consumption, ox ownership, *per capita* production, household size, and the household head’s educational level are a significant factor of household food security. For food-insecure households, they are increases in land size, ox ownership, *per capita* production, fertiliser use, and education, and a decrease in family size.

Amaza *et al.* (2006) analyse the determinants of food security using 1,200 households from Nigeria, using the cost-of-calories method and a logit model. The level of daily energy requirement of 2,250 kcal or 176.87 US Dollar/adult equivalent/year is used to classify the status of household food security. Fifty-eight percent of the sample households are thus estimated to be food-insecure. The results of the logit model reveal that household size, the educational level of household heads, farm size, the ratio of quantity produced to the ratio of quantity consumed, access to an extension agent[29], co-operative membership of household heads, the asset value of the household, gender of household heads, type of household enterprises, expenditure on education, commercialisation, and remittances received/adult equivalent/annum all have significant impacts on food security/insecurity. This study emphasises strengthening agricultural development for quick transfer of production technologies, and raising the production efficiency which can improve household food security.

Babatunde *et al*. (2007) apply a logit model to analyse determinants of household food security in Kwana State, Nigeria, using cross-sectional data of 94 farming households conducted in 2005. Using the difference between calorie availability and calorie requirement, more than 60% are estimated as food-insecure households. The results of logit model show that household income, household head’s educational levels, and household food production have a positive relationship with household food security, while household size has a negative impact on household food security, implying that an increase the number of household members decrease the probability of household food security.

Maharjan and Joshi (2011) also apply a logit model to investigate factors affecting food security at the household level in Nepal. Cross-sectional survey data of 430 households are collected from 12 districts based on stratified random sampling. Food security is measured by the food self-sufficient month index and food security threshold income following World Bank (2002). Approximately 10% of the total households are chronically food-insecure. From a logit model, results show that landholding, irrigation availability, households in Tarai, occupational caste, participation in communities, and male-headed households have a negative impact on food

[29] An extension agent is a person who intervenes to bring about change to help improve the lives of the farmers and their families (FAO, 1985).

insecurity, which implies that an increase in these variables significantly reduce the probability of household food insecurity. Family size and the dependency ratio have a positive effect on food insecurity, indicating that an increase in family size and the number of dependents contribute to an increase in the likelihood of household food insecurity.

Bogale (2012) applies three-step feasible generalized least squares to determine household level vulnerability to food insecurity using cross-sectional data of 277 households collected from three districts, Haramaya, Kersa and Tulo in eastern Ethiopia. The level of vulnerability to food insecurity is based on the capacity of households to spend a predetermined amount of money on the food required to achieve the daily minimum dietary requirement of 2,100 kcal/adult equivalent/day. The results indicate that susceptibility to food insecurity depends on family size, cultivated area, soil fertility, tenure status, access to irrigation, fertiliser use, improved seed and extension services. The results also reveal that 33% of households are food-insecure as their food consumption expenditure is below the poverty line and are identified as highly susceptible to food insecurity, while over 60% of the households are food-secure and not vulnerable.

Bashair *et al*. (2012) examine factors determining the food security status of landless households using data of 576 households which is collected from 12 districts in Punjab province, Pakistan. The status of household food security is measured by comparing calorie intake/adult equivalent/day to a threshold level defined by the Pakistan Government for its rural areas. Twenty-seven percent of the sample is food-insecure because the level of calorie intake is lower than the threshold level, and 73% is food-secure. A logit model is then applied to estimate the food security status. Results indicate that household income and its head’s educational level are positively associated with food security, while family size and the age of household heads are negatively associated with food security.

Aidoo *et al* (2013) apply a logit model to examine factors that determine household food security in Ghana using data from 100 households in the Sekyere-Afram Plains District. Each household is classified to be either food-secure or food-insecure using the USDA's household food security scale. Approximately 70% of the total households are food-insecure. The results of the logit model show that off-farm income, farm size, and credit access have a positive impact on household food security, whereas household size, and marital status have a negative association with the food security status of households. Thus, off-farm business activities as well as rural credit markets are needed to improve the food security status.

Hessein and Janekarnkij (2013) also apply a logit model to examine the determinants of household food security in Ethiopia using data from 160 households in the Jigjiga district. They classify household food security status using the recommended daily calorie intake for an adult of 2,100 kcal/day, set by the Federal Democratic Republic of Ethiopia. Sixty-three percent and 37% of the households are food-secure and food-insecure respectively. The results show that household income, access to extension services, fertiliser use, access to credit, and access to veterinary services positively influence food security.

In Thailand, Piaseu (2005) investigated socio-economic factors and living conditions that contribute to household food insecurity among the poor in slum areas in Bangkok using a multiple regression analysis. Cross-sectional survey data are collected from 199 female food providers of households. Results show that household income, the number of children in households, and social networks, such as community groups linked to resource management, are statistically significantly associated with the status of household food insecurity. An increase in household income and participation in social networks reduce the status of household food insecurity, while a rise in the number of children in the households increases the risk of the households being food-insecure.

Wangthamrong (2010) determines factors affecting the probability of households being in food-poverty using a probit model and cross-sectional data from the Socio-Economic Survey (SES) data collected by NSO in 2006.[30] The 11,805 households in the agricultural sector are classified into two groups using the calculated household national food poverty line of 779 Bath (22.58 US Dollar)/person/month for 2006. The results show that household size, the educational level of household heads, gender of household heads, and household income have significant impacts on the ability to access food. In addition, the health care coverage programme, which is provided by the Thai government, does not significantly reduce food poverty.

Cho *et al*. (2012) study the differences of prevalence of food security among Thai and non-Thai households and the impact of local buffering mechanisms on household food security using a backward-stepwise logit model. Cross-sectional survey data are collected for 211 households from the Nong Loo Sub-district in Kanchanaburi Province, comprising of 120 Thai and 91 non-Thai households. Seventy-six percent of households are found to be food-insecure and 24% are food-secure. The logit regression results reveal that non-Thai households are significantly more

[30] In this study, we use the 2011 data from this Survey.

food-insecure than Thai households, which suggests that non-Thais do not have access to buffering mechanisms. Nonetheless, the lack of access to buffering mechanisms is not statistically significant.

Bumrungkit (2014) examines household determinants and vulnerability to food insecurity using SES data collected by NSO in 2010. The 33,204 households are classified into two groups, which are food-secure and food-insecure, using the estimated minimum dietary requirement of 1,874 kcal/adult equivalent/day following the Organisation for Economic Co-operation and Development's (OECD) method and Akinson's study (ibid). It is found that approximately 95% of households are food-secure whereas 5% are food-insecure. A binary probit model is then applied to examine factors affecting household food insecurity. Findings reveal that the significant factors are household size, the household head's age, home-produced food, farm size, income from farm profits, landholding (own, and renting), access to financial credit, occupation (heavy labour, manufacturing, and professional), health issues, dependency ratio, and region.

Table 7.1 summarises these above studies, all of which use cross-sectional data. It is clear from this selected literature review that there is a need for more research into the determinants of food security status of rice-farming households in Thailand to guide Thai policy makers.

Table 7.1 Summary of the empirical studies of household determinants on food security

Authors	Study areas	Method of estimation	Significant variables on food security	
			Positive	**Negative**
Feleke *et al.* (2005)	Ethiopia	Logit regression	Technology adoption, farm size, land quality	Household size, farming system, *per capita* aggregate production
Haile *et al.* (2005)	Ethiopia	Logit regression	Fertiliser application, farm land, ox ownership, *per capita* production	Household size
Piaseu (2005)	Thailand	OLS	Household income, social networks	The number of children in households
Amaza *et al.* (2006)	Nigeria	Binary logit regression	Household size, educational level, farm size, access to extension agent, member of co-operative societies, the value of household assets, the ratio of quantity produced to ratio of quantity consumed	Extend of output commercial sector, expenditure on education,
Omotesho *et al*. (2006)	Nigeria	Binary logit regression	Farm size, annual farm income, Off-farm income	Household size
Babatunde *et al*. (2007)	Nigeria	Binary logit regression	Annual household income, food quality from own production, educational level	Household size, age of household head
Wangthamrong (2010)	Thailand	Probit multiple regression	Income earning members, household income, household asset, educational level, urban area	Household size, male household head, age of household head, household agricultural land
Maharjan and Joshi (2011)	Nepal	Logit regression	Male-headed household, landholding, participation in community organisations, Tarai ecological region, Irrigation	Family size, occupational caste, dependency ratio

Source: Author (2015)

Table 7.1 Summary of the empirical studies of household determinants on food security (continued)

Authors	Study areas	Method of estimation	Significant variables on food security	
			Positive	Negative
Bogale (2012)	Ethiopia	Feasible generalized least squares	The number of visits by extension agent, fertilizer use, seed improvement, soil fertiliser status, crop diversification, landholding, irrigation	Household size, the number of individual to rely upon during shocks.
Cho *et al*. (2012)	Thailand	Backward stepwise logit regression	-	Nationality, number of children in the household, access to Universal Healthcare
Bashair *et al*. (2012)	Pakistan	Multinomial logit regression	Household's monthly income, livestock assets, educational level	Household size, household type, Age of household head
Aidoo *et al* (2013)	Ghana	Binary logit model	Farm size, off-farm activities and credit access	Marital status, household size
Hessein and Janekarnkij (2013)	Ethiopia	Logit model	Household income, fertiliser use, credit access, access to veterinary services, access to extension services	Agro-ecology stratum where households are located
Zakari *et al*. (2014)	Niger	Logit regression	Gender, labour, distance from the main road	Diseases and insects, floods, lack of money, market access, food aid
Bumrungkit (2014)	Thailand	Probit model	Farm size, own landholding, home-produced food, income from farm profits, access to financial credit, occupation (professional, and manufacturing)	Household size, dependency ratio, heavy labour, land renting, and health issues and illness

Source: Author (2015)

7.3 Methodology Framework

Following the AHM of Singh *et al*. (1986), household food security is modelled under a framework of production and consumption behaviour. Households' maximise utility which is defined over leisure and food consumption, where the latter is both home-produced and market purchased goods as well as nutrients consumed (Feleke *et al.*, 2005; Haile *et al.*, 2005). To determine the household's demand for food consumption, we calculate the amount of calories available/adult equivalent/day for all food items. The status of food security is then estimated by the distinction between calories available and requirements.

In determining the demand for food consumption, the USDA and US Agency of International Development (USAID) estimate a minimum average daily energy requirement of around 2,100 kcal for developing countries, such as Thailand (Gibson, 2012, p. 40), and we use this recommended daily energy intake as a benchmark.[31] Thus, rice-faming households are either food-secure or food-insecure on the basis of reaching an energy requirement of 2,100 kcal/adult equivalent/day or not. Our analysis of the factors that affect household food security uses a logit model to estimate the food security status because of its binary measure (Feleke *et al.*, 2005; Haile *et al.*, 2005; Omotesho *et al.*, 2006; Babatunde *et al.*, 2007; Maharjan and Joshi, 2011; Aidoo *et al.*, 2013; Hussein and Janekarnkij, 2013). In particular, our purpose is to identify the significant factors of the likelihood of a household being food-secure. The model compares the probability of a household being food-secure to that of being food-insecure (Feleke *et al.*, 2005).

To specify a logit regression, we need to transform household food security status into a logit variable (binary outcome). To achieve this, households are classified into two groups based on the reference energy requirement: it has a value of one if households are food-secure, and zero otherwise. A logit regression is used because it can predict the probability of a binary outcome (case occurring and case not occurring) from a set of independent variables using maximum likelihood estimation techniques (Hailu and Regassa, 2007; Greene 2013, pp. 763 – 766). The logit regression estimates the odds of being a particular case based on the values of the independent variables. The odds are defined as the probability of case occurring divided by that of case not occurring (Gujarati and Porter, 2009, pp. 554 – 555).

Following Feleke *et al*. (2005), Bogale (2009), Aidoo *et al*. (2013) and Hussein and Janekarnkij (2013), to generate an odds ratio of a certain case, a probability model is required to satisfy the condition that:

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[31] This amount of energy intake is also used in the estimation of the production function as an energy requirement for labour which is calculated by the Bureau of Nutrition, Ministry of Public Health, Thailand.

$$P_i = E(HFS_i = 1|\mathbf{Z}_i) = \frac{1}{1 + e^{-\mathbf{Z}_i}} \tag{7.1}$$

where

- P is the probability of the ith-household being food-secure given **Z**,
- **Z** is a vector of explanatory variables where Z=1 if a household is food-secure and =0 otherwise,
- HFS is the status of household food security, and
- ε is an error term.

Z_i is a function of n-independent variables (X_i) which can be expressed in linear form as:

$$Z_i = d_0 + d_1X_1 + \ldots + d_nX_n + \varepsilon_i, \qquad i = 1, \ldots, n \tag{7.2}$$

Equation (7.1) can be re-written as:

$$P_i = E(HFS_i = 1|\mathbf{Z}_i) = \frac{1}{1 + e^{-(d_0 + d_1X_1 + \ldots + d_nX_n + \varepsilon_i)}} \tag{7.3}$$

From (7.1), the probability of a household being food-insecure is (1 – P) which can be written as:

$$1 - P_i = 1 - \frac{1}{1 + e^{-\mathbf{Z}_i}} = \frac{(1 + e^{-\mathbf{Z}_i}) - 1}{1 + e^{-\mathbf{Z}_i}} = \frac{e^{-\mathbf{Z}_i}}{1 + e^{-\mathbf{Z}_i}} \tag{7.4}$$

Dividing (7.1) by (7.4), we have the odds ratio (OR) or the probability of a household being food-secure, that is, the ratio of the probability a household being food-secure to that of the household being food-insecure:

$$\frac{P_i}{1 - P_i} = \frac{1 + e^{\mathbf{Z}_i}}{1 + e^{-\mathbf{Z}_i}} = e^{\mathbf{Z}_i} \tag{7.5}$$

In (7.5) P_i is non-linear not only in Z_i but also in the parameters d_i which leads to an estimation problem. Taking natural logarithms (ln) of (7.5) gives:

$$\ln\left[\frac{P_i}{1-P_i}\right] = Z_i = d_0 + d_1X_1 + \ldots + d_nX_n + \varepsilon_i \qquad (7.6)$$

In (7.6), the log of the odds ratio is now linear in variables and parameters and this is the logit model. The logit model refers to the logit regression comparing food-secure households to those that are food-insecure. It can be re-written as:

$$\text{Logit}(P_i) = \ln\left[\frac{P_i}{1-P_i}\right] = d_0 + d_1X_1 + \ldots + d_nX_n + \varepsilon_i \qquad (7.7)$$

In (7.7), the explanatory variables, $X_1 \ldots X_n$, are specified in our model of rice-farming households as:

$$\begin{aligned}\text{Logit}(P_i) = {} & d_0 + d_1W + d_2GEND + d_3AGE + d_4HSIZE + d_5EDU + d_6DR + d_7HEXP + d_8FEXP \\ & + d_9SALE + d_{10}HCONS + d_{11}LIVE + d_{12}LAND + d_{13}FE + d_{14}UHC + d_{15}L_F \\ & + d_{16}CREDIT + \varepsilon_i \qquad (7.8)\end{aligned}$$

Where:

- W is the household income per month (Baht),
- GEND is gender of household heads where GEND=0 for female and =1 for male,
- AGE is age of household heads,
- HSIZE is household size,
- EDU is educational levels of household heads,
- DR is the dependency ratio where DR=$\frac{\text{number of dependents}}{\text{total number of family members}}$,
- HEXP is household expenditure (Baht),
- FEXP is food expenditure (Baht),
- SALE is output that is produced for sale (Baht),
- HCONS is output that is produced for household consumption (Baht),
- LIVE is livestock ownership where LIVE = 1 if livestock is owned and = 0 otherwise,
- LD is farm size (Rai),
- FE is fertiliser application where FE=1 if yes and =0 otherwise,
- UHC is ownership of a universal health coverage card (30 Baht) where UHC = 1 if the household receives this health service and = 0 otherwise,

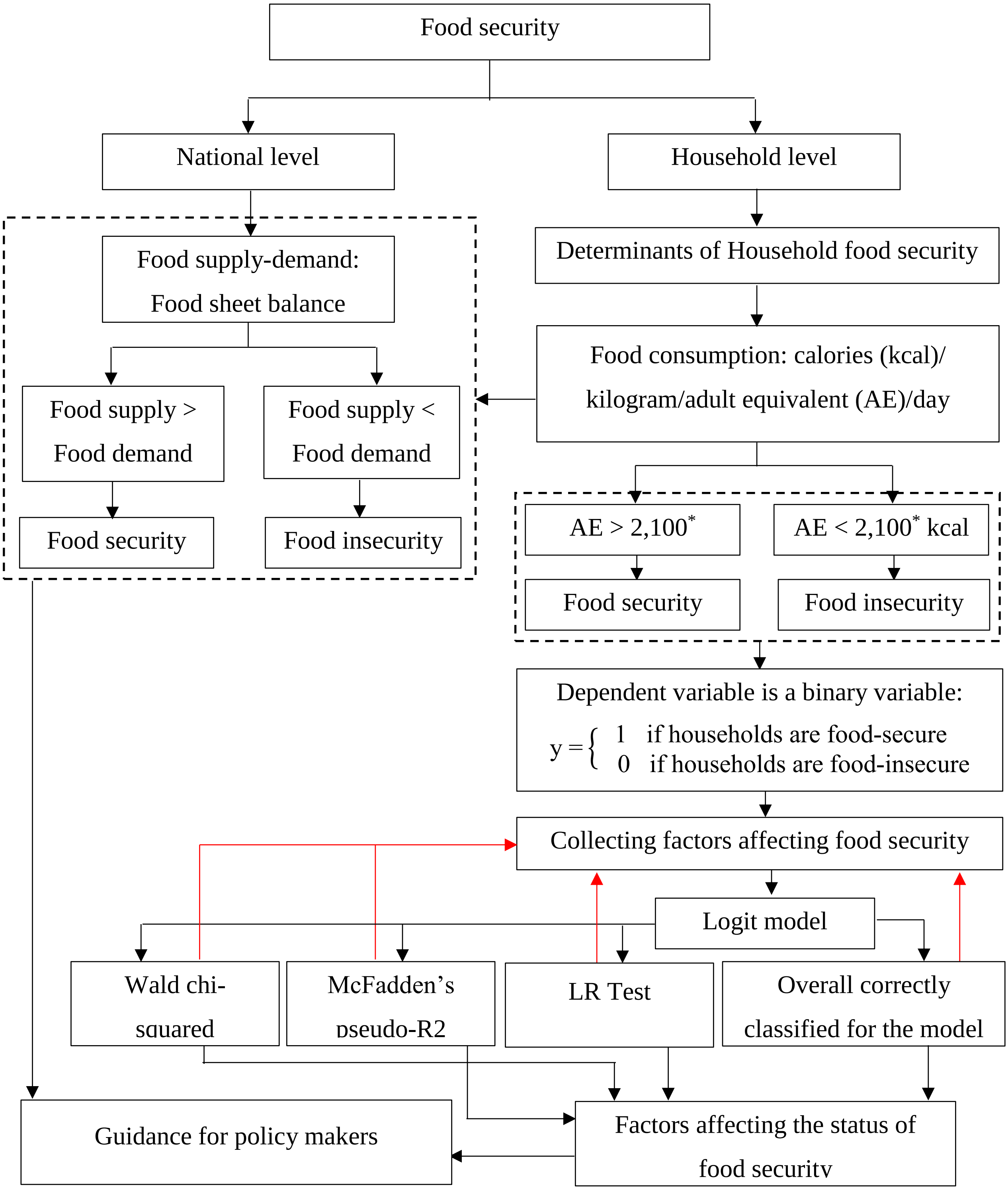
- L_F is family labour,
- CREDIT is a government credit access for agricultural purposes which = 1 if yes and = 0 if no,
- ε is an error term.

Since the estimated coefficients d_i in logit models are not directly interpretable, Greene (2013, p. 730) suggests that we should calculate the marginal effects of regressors to explain a unit change in the value of each regressor. For the logit model, marginal effects can also be presented directly in the form of odds, or more precisely, in the OR form because the ratio is equal to the probability of the event on the probability of the opposite event (Gujarati and Porter, 2009, pp. 571).

To sum up, this chapter applies the logit model to analyse the determinants influencing the status of food security at the household level because it is a binary variable, as shown in Figure 7.1.[32] Socio-economic variables for 2,781 rice-farming households from the 2011-SES dataset are chosen to model the equation (7.8). Then, (7.8) is regressed using STATA version 13. To obtain the best-fit model, we test the goodness of fit using a likelihood ratio (LR) statistic, McFadden's pseudo-R^2, overall case correctly predicted technique, and Wald chi-squared. If the model is not appropriate, the variables need to be re-collected.

[32] Food security at the national level is described in Chapter two.

Figure 7.1 Analytical Framework for Food Security



Source: Author (2015)

7.4 Results and Discussion

7.4.1 Socio-economic and Demographic Characteristics of the Households

A summary of statistics on the socio-economic and demographic characteristics of the sampled households is presented in Table 7.2. For the sample of 2,781 households, 1,585 are food-secure (57%) and 1,196 are food-insecure (43%). The average size of the food-secure households is smaller than that of food-insecure households, with 2.75 members for the former and 3.68 for the latter. The average ages of household heads for both households are the same at 54.5 years. Eighty percent of food-insecure households are headed by a male and 76% for food-secure households.[33] The dependency ratio of food-secure households is lower (0.18) than that of food-insecure households (0.28). The percentage of food-secure household heads completing secondary or upper level is greater than that of food-insecure household heads. Whereas the percentage of food-secure households with illiterate, primary level or below household heads is lower than that of food-insecure households.

[33] Wangthamrong (2010) and NSO/OAE (2012) also report that the households that are headed by a female manage to attain a better energy diet than male-headed households.

Table 7.2 Socio-economic and Demographic Characteristics of the Rice-farming Households in Thailand

Household characteristics	Food-secure	Food-insecure
Food security status (%)	56.99	43.01
Household size (NO.)	2.75	3.68
Age of household head (years)	54.45	54.53
Male head of household (%)	76.21	79.85
Dependency ratio	0.18	0.28
Educational level of household head		
- Illiterate (%)	1.39	4.52
- Primary or below (%)	85.17	86.20
- Secondary or equivalent (%)	10.47	8.03
- Graduate or above (%)	2.97	1.25
Household income (Baht)	14,087	13,231
Household expenditure (Baht)	11,880	11,338
Household food expenditure (Baht)	5,359 (45.11%)	4,581 (40.40%)
Consumption expenditure and other household expenditure (Baht)	6,521 (56.89%)	6,657 (58.71%)
Household production (Baht)	123,371	110,144
- for sale (Baht)	93,219 (75.56%)	90,053 (81.76%)
- for household consumption (Baht)	19,345 (15.68%)	12,633 (11.47%)
Livestock ownership (%)	20.04	16.48
Farm size (Rai)	13.66	13.62
Fertiliser consumption (Baht)	53,531	45,723

Source: SES (2011).

7.4.2 Determinants of Food Security

The binary logit regression results on determining the probability of a household being food-secure are presented in Table 7.3. This logit model explains 75% of the total variation in the food security status of households which is relatively high. The McFadden's pseudo-R^2 is 0.23 which is considered highly satisfactory[34]. The chi-square statistic (χ^2_{18} = 475.30 with df = 18) and LR statistic ($p < 0.00$) show that all explanatory variables are significantly different from zero at the 1% significance level, implying that this model is statistically significant.

[34] The R-square statistic (R^2) is not particularly meaningful in binary regression models (Gujarati and Porter, 2009, pp. 562 – 563). Using McFadden's pseudo-R^2 can be indicated the goodness of fit for these models with values of 0.2 to 0.4 for excellent fit (McFadden, 1979, p. 360).

Table 7.3 Parameter Estimates of the Logit Regression on Food Security Status

Variable	Coefficient	Odds Ratio (OR)
Constant	0.2030 (0.64)	N/A
Household income (W)	0.00002*** (8.28×10^{-06})	1.000024
Household size (HSIZE)	-0.6145*** (0.16)	0.539732
Gender of the household head (GEND)	0.0979 (0.11)	1.093305
Age of the household head (AGE)	-0.0056 (0.01)	0.994622
Dependency Ratio (DR)	-2.362*** (0.62)	0.094262
Educational level of the household head (EDU) - Primary or below - Secondary or below - Graduate or above	 0.8328*** (0.24) 0.9456*** (0.29) 2.233*** (0.59)	 0. 415630 0. 375048 0.102079
Total household expenditure (HEXP)	-0.00001*** (0.00)	0.999986
Household food expenditure (FEXP)	0.00059*** (0.00)	1.000587
Household production for sale (SALE)	-0.00003*** (0.00)	0.999977
Household production for household consumption (HCONS)	0.00020*** (0.00)	1.00020
Livestock ownership (LIVE)	0.2611** (0.12)	1.073351
Farm size (LD)	0.0461** (0.02)	1.024435
Fertiliser consumption (FE)	0.0016* (0.00)	1.000742
Universal health coverage card (UHC)	1.198 (0.23)	1.217606
Labour in the household (L_F)	0.3921*** (0.08)	0.398797
Government credit access for agricultural purposes (CREDIT)	0.0708 (0.11)	1.073351
The number of observations	2,781	
McFadden's pseudo-R^2	0.2265	
Probability (LR statistic)	0.0000	
Overall case correctly predicted	74.47%	
Model Wald chi-squared (df=18)	475.30	

Notes: 1. Standard errors in parentheses.
2. *, **, *** denote significance at 10%, 5% and 1% respectively.

Among the 17 independent variables in the model, 11 variables have a significant relationship with the probability of food security at the household level. They are household size, the dependency ratio, the educational level of the household's head, monthly income, total expenditure, food expenditure, household production for sale, household production for own consumption, farm size, fertiliser consumption, and household labour.

Household size is negatively related to household food security at the 1% significance level, revealing that a rise in household size contributes to a decline in the probability of household food security. The odds ratio (OR) in favour of food security declines by a factor of 0.5397 or 46.03% as household size increases by one member. An increase in household size indicates that there are more people to feed, and indirectly this reduces *per capita* income, *per capita* expenditure and *per capita* consumption (Aidoo *et al*., 2013). Sikwela (2008) explains that in Zimbabwe where farm household's consumption is only dependent on its own production, an increase in household size results in a rise in food demand. Thus, if the supply from own production is insufficient to meet this demand, then households become food-insecure. In addition, Wanthamrong (2010) and Bumrungkit (2014) report that an increase in household size tends to increase household vulnerability to poverty and food insecurity in Thailand. It is also worthy of note that Bogale (2012) recommends that information on family planning should be provided to the poor.

The dependency ratio has a significant negative impact on the likelihood of household food security at the 1% significance level. The OR implies that a 1% rise in the dependency ratio leads to lower the probability of household food security by 90.57%. This result is similar to the findings of Omotesho *et al*. (2007) and Bashir *et al*. (2012). However, the household head's educational level has a significant positive impact on the probability of household food security status at the 1% significance level. The results show that households whose head is educated to at least graduate level have a 89.79% likelihood to be food-secure; the corresponding OR for secondary level education or below is 62.50%; and that for primary education or below is 58.44%. Haile *et al*. (2005) and Bashir *et al*. (2012) also report that an improvement in education results in a higher probability of household food security.

Household income per month is hypothesised to possess a positive effect on household food security (Omotesho *et al*., 2006; Bashir et al., 2012; Aidoo *et al*., 2013; Zakari *et al*., 2014). Our result reveals that its influence is positively associated with the likelihood of household food security at the 1% significant level, but the magnitude is small (0.00002). The OR indicates that a rise in household income leads to a rise in the likelihood of household food security by a factor of 1.000024. Thus, a 100 Baht rise in household income leads to a higher the probability of household food security by 0.24% (100×(OR-1)).

The relationship between total household expenditure and the probability of household food security is negative and statistically significant at the 1% significance level. If total household expenditure rises by 100 Baht, the probability of household food security decreases by 0.14%. By contrast, food expenditure has a positive and significant relationship with household food security at the 1% significance level. The OR reveals that the probability of a household being food-secure increases by a factor of 1.0006 with a rise in food expenditure, which is also small, and a 100 Baht increase in food expenditure leads to a higher probability of household food security by around 6%.

An increase in the value of household production for sale leads to a decrease in the probability of household food security. Production for own consumption influences food security positively and significantly at the 1% significance level though the magnitude of the estimated coefficient is small: i.e. the OR indicates that a 100 Baht increase in the value of production for household consumption rises the probability of household food security by 2%.

Livestock ownership is positively associated with household food security at the 5% significance level. The OR indicates that livestock ownership (as opposed to not owning livestock) leads to an increase in the probability of a household being food-secure by a factor of 1.0734. Thus, households that own livestock are 7.34% more likely to become food-secure. Bashir *et al*. (2012) also find that livestock ownership, especially small animals (goats and sheep) can enhance the food security status of farm households.

Family labour, farm size, and fertiliser consumption are all hypothesised to possess a positive effect on food security (Feleke *et al*., 2005; Haile *et al*., 2005; Omotesho *et al*., 2006; Bashir *et al*., 2012; Aidoo *et al*., 2013; Zakari *et al*., 2014). Our results show that these effects are significantly positive at the 1%, 5% and 10% significance levels respectively. The addition of one worker raises the probability of household food security by 60.12%. The probability of a household being food-secure increases by 2.44% with a one Rai rise in farm size. If the value of fertiliser consumption increases by 100 Baht, the probability of a household being food-secure rises by more than 7%.

Moreover, the Universal Health Coverage program and Government Credit Access for agricultural purposes have the expected positive sign but they are not statistically significant. One possible explanation of this may be that there is very small variation in these variables in the sample (Wangthamrong, 2010). The dataset also reveals that more than 95% of the sample are covered by these two programmes.

7.5 Summary

Thailand is a food-secure country at the national level. However, food accessibility at the household level is still problematic among the poor, including rice-farm households. Household food security is classified into food-secure and food-insecure using the minimum average energy for developing countries estimated by USDA and USAID. In our cross-sectional sample of 2,781 rice-farming households in Thailand in 2011, approximately 56% are food-secure and 44% are food-insecure. To explain this binary dependent variable, a logit regression is applied to examine its determinants which are identified as a set of potential explanatory variables based on the empirical literature.

The results show that households which have a higher income are more food-secure. Those with relatively better educated household heads are also more likely to be food-secure than those whose heads have lower levels of education. An increase in household food expenditure also leads to achieve a higher probability of food security. Additionally, households that produce more food for their own consumption are more likely to be food-secure than those which sell a higher proportion of what they produce. Households owning livestock are also more likely to meet food security criteria. Moreover, an increase in farm inputs, such as farm size, fertiliser and labour improves the probability of households being food-secure. On the other hand, household size, the dependency ratio, and total household expenditure have negative effects on food security, indicating that if these factors increase, households are more likely to be food-insecure.

Chapter 8 Summary and Conclusions

8.1 Introduction

Thailand is a food surplus country where domestic food supply exceeds domestic demand. However, some low-income households suffer from food insecurity which is defined as living without reliable access to a sufficient quantity of nutritious food. It is a major cause of undernourishment and malnutrition in low-income households, and may contribute to poor health, and reduce worker capacity which results in low labour productivity. The aim of this thesis is to examine the impact of nutrient intake on the productivity of households engaged in rice production in Thailand to reach food security. The objectives are: first, to analyse the relationship between nutrient intake and labour productivity; second, to examine factors affecting the nutrition-labour productivity relationship; and third, to study the link with food security status. The remainder of the chapter is structured as follows. Section 8.2 presents a summary and the main results. Section 8.3 concludes and provides some policy recommendations. Section 8.4 highlights the contribution to the agricultural economics literature and considers the limitations of the study as well as providing some suggestions for future research.

8.2 Summary and Main Results

The study is divided into two main parts: the first examines the nutrition-labour productivity link, and the second examines the link to food security. Agricultural household models are used to model the decision-making behaviour of rice-farming households, namely decisions about production, consumption, and labour allocation. In addition, the efficiency wage hypothesis is considered in which an increase in consumption enables workers to work more productively. Accordingly, labour is treated as effective labour which is associated with caloric consumption, and nutritional consumption directly affects labour productivity.

Econometric models are employed to analyse the relationship between nutritional intake and labour productivity. First, a semi-log wage equation and a Cobb-Douglas production function are estimated using cross-sectional SES data collected by NSO, Thailand, for January to December 2011 for 2,781 rice-farming households. The wage equation is estimated by both 2SLS and 2SQR methods, while the Cobb-Douglas production function is estimated by NL2SLS using only data of 1,585 households who manage to attain the daily energy level of 2,100 kcal/day. Second using a 2,100 kcal/day threshold, a household is either food-secure or food-insecure and a logit model is estimated to examine the determinants of food security that affect production and consumption decisions.

The results of the wage equation using 2SLS show that consumption of calcium, vitamin A, vitamin C and iron have positive and significant effects on household income, while calorie intake surprisingly has a negative effect. The results from 2SQR show a negative effect of energy intake on household income at different quantiles, and there are increasing returns at lower quantiles. These negative effects are examined through food categories using 2SLS and results reveal that an increase in grains and starches contribute to lower household income, whereas additional consumption of meat and poultry, fruit, vegetables and nuts, and food prepared and consumed at home leads to an increase. In addition, male household heads earn more than female-heads. The effect of the education of household heads is positive and significant; and age, the dependency ratio, and farm size have positive and significant effects on household income.

Production function results show that all nutrients have positive and significant contributions to farm productivity. A 1% increase in calorie intake increases the value of farm output by around 0.1%. Higher nutrient consumption leads to higher farm output which provides support for the efficiency wage hypothesis. Also, family labour, farm size, and fertiliser consumption have positive and significant effects on farm output.

Approximately 56% of rice-farming households are food-secure, and 44% are food insecure. The logit results show that income, education levels of household heads, food expenditure, owning livestock, own-consumption, farm size, fertiliser use, and the use of family labour improve the probability of food security status of households. Conversely, household size, the dependency ratio, and total household expenditure have negative effects on food security, indicating that if these factors increase, then households are more likely to be food-insecure.

8.3 Policy Recommendations

The policy implications of our empirical estimation of the nutrition-labour productivity link and food security status in Thailand should be useful to government policy makers. In particular, the results may aid policy makers in their design and monitoring of both current and future policies to enhance labour productivity and food security.

We provide strong evidence that enhancing micronutrient intake can contribute to labour productivity and hence to overall economic growth and development. Estimated elasticities of household income and farm output with respect to calcium, vitamin A, vitamin C, and iron intake are significant and positive, and policies which enhance micronutrient intake can be effective in increasing income and improving productivity, and this is particularly beneficial to the poor. Thus, the Thai government should promote micronutrient-rich diets and provide micronutrient supplementation for low-income households. Our suggestions support the strategies of the national nutrition plan of Ministry of Public Health (MOPH) (2010-2013) about promoting iron rich diets and iron and iodine supplementation. These strategies are implemented by the collaboration between government and food companies to fortify iron and iodine into food products such as instant noodles, snacks, and so on. These policies should be continued and expanded to cover more micronutrients such as calcium, vitamin A, and vitamin C. Moreover, the government should provide alternative patterns of micronutrient supplements for low-income households such as providing free tablets.

Estimated elasticities of household income with respect to grains and starches, and seasoning and condiment consumption are significant and negative. This implies that grains and starches, and seasoning and condiments are inferior goods, that is, demand for these food items decrease as household income increases (and conversely, rises in demand when household income decreases). Grains and starches, and seasoning and condiments are predominantly consumed by Thai farm households because most of them have low incomes. The Thai government should focus on building awareness of nutrition in diets, and should provide food-based dietary guidelines with practical knowledge about nutritionally balanced diets and a healthy lifestyle. This could lead to more desirable eating behaviours, especially for farm households by reducing the proportion of these food items and increasing the proportion of healthy food such as meat, vegetables and fruit. Accordingly, the national nutrition plan of MOPH (2010–2013) about a healthy menu for all Thais and 2:1:1 Thai dishes (vegetable: rice: meat) should be continued. In addition, the national nutrition plan of MOPH (2010–2013) provides policies on the fortification of fish sauce by adding iron and iodine because fish sauce is a good vehicle for micronutrient fortification (Preedy *et al*., 2013). However, fish sauce is high in sodium which can aggravate rates of hypertension and non-communicable diseases. Thus, policy makers should consider both its benefit and drawback and assess appropriate levels and content of fish sauce fortification to improve nutrient availability for consumers.

Additional consumption of fruits, vegetables, meat and poultry is significantly and positively associated with household income. This could be a key element for future policy, namely to promote a sufficient daily consumption of fruits, vegetables, and meat. This supports the national nutrition plan of MOPH (2010-2013) in its dietary diversification campaign, which is to encourage greater consumption of fruit and vegetables, and 2:1:1 Thai dishes (vegetables: rice: meat). These policies may help to decrease the risk of non-communicable diseases such as cardiovascular disease, diabetes, cancer and so on, and provide a healthier diet because fruit and vegetables are an essential source of vitamins, minerals and fibre. Additionally, these policies should be expanded to cover meat consumption by encouraging low-income households to increase the proportion of meat in their meals because meat is an important source of protein which is beneficial to building and repairing the human body such as building muscles, creating enzymes and hormones, and repairing damaged tissues.

We find that the estimated elasticity of household income with respect to prepared food consumed at home items is significant and positive. These items cover prepared food taken home which are often purchased from restaurants, street venders, and local markets. Thus, quality and safety of these products should be a primary concern. The government should provide policies on food quality and safety standards which are important to improve accessibility to nutritious and safe food. These policies could promote healthy food choices particularly because of the increasing trend towards eating food not prepared at home. Our suggestions support the food quality and safety policies of the National Food Committee (NFC) and Ministry of Agriculture and Cooperatives (MOAC) which are implemented by improving the quality and safety of primary food production from small community levels to large-scale industrial levels. However, these policies focus only on good practices of food production at farm and primary producer levels, they do not cover all the food chain. Then, MOPH launched two projects called “Clean Food Good Taste” for restaurants and food street venders and “Healthy Market” for fresh markets in 1999 by providing logos for all restaurants and street venders, and fresh markets where they can meet the standards of the projects such as not using foam food containers, providing serving spoons, and environmental sanitation (Kongchuntuk, 2002; Department of Health (DOH), 2005b). These policies and projects should be continued to promote safe food from farm to table, and expanded to cover food quality, such as providing information of estimated calories and nutritional values per meal. This could help them in particular by choosing a good quality of food to consume and protecting them from adverse health effects of low quality and/or unsafe foods, such as that contaminated with toxins, since the main food sources of the poor are from local markets. Alleviating poor health will lead to higher labour productivity.

The age of household heads is found to be negatively and significantly associated with household income, suggesting that the government should encourage a young generation to work in the agricultural sector. This supports the 11th agricultural development plan (2012 – 2016) of MOAC about promoting the quality of life of farmers by encouraging young farmers to engage in farming and the food production and security strategies (2012 – 2016) of NFC about creating the motivation for a new generation to work in agriculture. These policies could improve the attitude of young people towards working in agriculture and improve its image. In contrast, the education level of household heads has a significant and positive impact on household income and the probability of a household being food secure. This could suggest that the government encourages farmers to participate in higher levels of education. Although the Ministry of Education (MOE) provided the 15-year free education policy in 2009 which covers from pre-elementary level (3 – 5 years old) to upper secondary level (16 – 18 years old) (MOE, 2009)[35], more than 80% of household heads of rice-farming households only complete their education at the primary level. Thus, the MOE should put more effort into changing the attitude of farmers and low-income households to increasing their level of education and provide the education system in rural areas to make it equally accessible for all households.

We also find that the estimated elasticity of the value of farm output with respect to the number of family labourers in the households that consume more than the level of energy intake of 2,100 kcal/day is significant and positive and the government should provide information on access to nutritious food for rice farmers to meet their daily consumption requirements. In addition, family labour should be encouraged to work on the farm rather than off the farm. Also, fertiliser consumption is significantly and positively associated with the value of farm output and household food security, implying that farmers can increase their productivity by using more fertiliser and increase the probability of household food security. However, the price of fertiliser is relatively high and this constrains its use especially by low-income farm households. This suggests an input subsidy policy particularly for fertiliser but possibly for other inputs. This would help farm households to increase productivity, generate local employment and reduce farm production costs.

[35] The basic system of Thai education is called a 6-3-3 system, consisting of six years of primary education, three years of lower secondary, and three years of upper secondary education. Plus, three years of pre-elementary level are subsidised by the government in 2009.

From the analysis of household food security, the odds ratio (OR) for both the dependency ratio and household size are significant and negative. These findings have implications for policies that could address family planning and child day-care services. Usually in Thai society, females or grandparents are responsible for childcare at home which contributes to lower household income since at least one family member has to stay home instead of entering the labour market. Thus, additional child day-care services could be made available to farm households. However, the price of childcare is high and the government could also develop a national programme of subsidised day-care services. Our suggestions support the policy of MOE about free basic education by subsidising the 3 years of pre-elementary level. The child day-care services or nurseries are currently rare and not commonly used. Thus, the government could also run educational campaigns to inform the public about the advantages of such services and attempt to change perceptions about them.

The OR of household income has a significant and positive impact on household food security, but total household expenditure has a negative relationship with household food security. The government could provide information on managing farm household budgets since income and expenditure are important determinants of the probability of households being food secure. This could be a useful tool for households to manage their incomes to enhance nutritious food consumption since the household expenditure on food is significant and positively associated with the probability of households being food secure.

The estimated elasticities of household income and the value of farm output with respect to farm size are significant and positive. Also, an increase in farm size can improve the probability of household food security. Our results support the food production and security strategies (2012 – 2016) of NFC which focus on managing land reform and agricultural area production. This policy could encourage farm households to allocate their lands for agricultural cultivation to increase farm productivity. However, the land allocation in terms of farm size might be diminished by land fragmentation because a family's land is divided for all members of the household. This contributes to the problem of land protection, loss of working hours, the problem of transporting farm machines and products, reduction of farm productivity, and an increase in labour cost (Webster and Wilson, 1980; Bizimana *et al.*, 2004; Demetriou, 2014, pp. 13 – 14; Latruffe and Peit, 2014). Thus, the government should provide information on re-allocating larger land holdings for farmers in order to reduce the scattered distribution of land.

In addition, livestock, and production for household consumption have significant and positive effects on household food security, farm households should be trained in the concept of integrated farming (or "Rai Na Suan Pasom"). This is mixed farming where landowners divide their land proportionally into farming, water supply, livestock and living zones and could promote self-sufficiency even with less cash-in-hand. This can support the MOAC's policy about improving the quality of life of farmers and sustainability of food supply. Also, the government should encourage farm households to produce for their own consumption to meet their dietary requirement.

8.4 Contributions, Limitations and Future Research

This study contributes to the understanding and knowledge about the relationship between nutrition, labour productivity, and food security in Thai rice-farming households. Two limitations of the study relate to data availability and our econometric methodology.

On data availability, the nutrition-labour productivity link is estimated only at the household level because individual data are not available in the SES, and we cannot explore the effects of nutritional intake on labour productivity for all household members. Nevertheless, we calculate nutritional intakes per adult equivalent to measure nutrients that are consumed at the household level. This may avoid differences between nutritional consumption of gender/age groups among household members. In addition, some other studies include anthropometric variables such as, height, BMI, weight for height to model the effect of cumulative consumption or energy stock on labour productivity. We only estimate the effect of current nutritional intake on labour productivity due to the lack of data on anthropometric variables. Moreover, labour productivity is measured in terms of wages received per working hour and farm output. Here, we use average household income and the value of farm output because the SES does not contain wages per working hour, and there are no data on the quantity of farm output. More importantly, effective labour as an input in the production function is widely measured as working hours, but we use the number of effective household labourers that attain an energy requirement level of 2,100 kcal/day. Additionally, the dataset does not separate information between family labour and hired labour, so we cannot distinguish between the effects of family and hired labour on labour productivity.

Further analysis can be developed as follows. First, if reliable data are available at the individual level, future studies could estimate the link for all members in the farm households. Second, the anthropometric variables should be added to empirical models to examine the impact of long-term nutritional variables on labour productivity. Third, if data on wages per working hour and on information between on-farm labour and on- and off-farm labour are available, empirical models of future studies should be estimated using another econometric approaches. Fourth, the production function could be re-estimated with data on working hours of effective workers. Also, a production frontier could be estimated. Fifth, the measure of food security here only focuses on food accessibility due to data availability. Further research should capture all dimensions of food security: availability, accessibility, utilisation, and stability. Next, the wage equation and production function should be jointly estimated. This may be appropriate to enhance statistical credentials for further research. Finally, it is hoped that the approaches developed here could be used for analysis of the relationship between nutrition, labour productivity and food security of a wider-range of Thai population groups and other micronutrients such as iodine.

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