CHAPTER 1: INTRODUCTION

1.1 Background

The world is confronted with a climate change crisis due to pollution. Climate change affects average global temperatures and precipitation, and, consequently, the size of polar ice-caps, the rate at which glaciers melt, sea levels and the frequency of extreme weather events. There are many dire situations around the world that are being linked to the effects of climate change. For example, in 2003, Europe experienced the hottest summer in over 500 years, at 3-5 °C above average temperatures (Patz, Campbell-Lendrum, Holloway, & Foley, 2005). The hot summer caused water shortages around the Mediterranean and in the south of Russia (Bindi & Olesen, 2010). There were also extreme weather events, including storms, droughts and heat in all areas of Europe. Climate change is linked to changes in cultivars, crop species, sowing dates, irrigation, fertilization, farming systems and land allocation to farming(Bindi & Olesen, 2010).

Another region which is being affected by climate change is Africa, where it represents a significant threat to African infrastructure, markets, agricultural production and, consequently, to farmers' living standards. By 2020, agricultural yields from rain-fed areas in some countries of Africa could decrease by up to 50 per cent (Müller, Cramer, Hare, & Lotze-Campen, 2011). The predicted influence of climate change on global agriculture is alarming. On a regional level, the predicted fall in agricultural production is pronounced for Canada, North Africa, South-East Asia, the Middle East and the US (Calzadilla, Rehdanz, & Tol, 2011). As a result, the negative impact on total agricultural income may be in the order of US$18 billion by 2020 and US$ 283 billion by 2050 (Calzadilla et al., 2011).

Predictions of the effects of climate change for Australia and New Zealand for 2050 are that average temperature will increase by 3.4 °C (in south-west Australia there is likely to be an increase in average temperatures of between 1.25 and 1.75 ºC) and precipitation will decrease by 6.4 mm per month, resulting in a decrease in rainfall of 20-60 mm (Turner, Li, Xiong, & Siddique, 2011). This has been calculated to reduce Gross Cell Product[1] (GCP) by

[1]The concept of GCP is the same as that of Gross Domestic Productand Gross Regional Product. It is widely used in the national income and product accounts of major countries. It represents the gross value added in a specific region (the total production of market goods and services in a region) less purchases from other businesses. The main difference betweenGCP and GDP is that the former is defined by a geographic unit of

approximately US$622 million per cell due to anticipated falls in productivity (Seo, 2011). Moreover, climate change may also affect the health and well-being of Australian and New Zealand people through conditions such as cardiovascular disease, obesity and type-two diabetes, which result from impacts on the production and distribution of agricultural products (Tapsell et al., 2011).

1.1.1 Effects of climate change on Thailand

Thailand has been affected by several natural disasters in recent years. For example, during the period 1991-2000, damage to agricultural areas was caused by drought, floods and storms, with damage costs of about 50 billion baht or US$1.67 million (IPCC, 2012).

In May 2006, five Northern provinces suffered from flash-floods and mud-slides due to the heavy rain. The damage impacted 983 transportation routes, 181 bridges, 226 temples, schools and government offices, 269 sewage pipelines and 3,567 households (Srithawatchai, 2006). Thirty-two Thai national parks and wildlife sanctuaries are situated in climate change hot-spots and are expected to be affected by climate change (Boonprakrob and Hattirat, 2006). Moreover, Thailand will lose its biodiversity more rapidly and severely, particularly of those species living in wetlands. There has been a decline of at least 42 per cent in the population of amphibious animals, and 33 per cent of freshwater fish in Thailand are now threatened (Henry, 2010).

Coral bleaching, due to increases in sea temperature, are also evident (Brown & Cossins, 2011). The average temperature of the oceans in Thailand and other tropical countries has increased by around 0.7 °C from a long run of average sea temperature of 28-29 °C (Bindoff et al., 2007). In 2011, the average temperature of Thailand's sea was more than 31 °C.[2] The effects of increased ocean temperatures on coral is expected to influence the Indian Ocean, and include the Maldives, Sri Lanka, Myanmar, Malaysia and Indonesia (Vassanasong, 2011). Already there are thousands km^2 of coral bleaching around the world due to climate change (Hoegh-Guldberg, 2011). The Thai Ministry of Natural Resources and Environment has implemented regulations to control some activities in the areas of coral bleaching, both in the Gulf of Thailand and the Andaman sea (Sukhsangchan & Kulanujalee, 2011), closing seven Thai marine parks.

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one latitudeby one longitude grid cell, whereas the latter is defined by political boundariessuch as countries or provinces (Nordhaus, 2006).

[2]Coral bleaching is the breakdown of the symbiosis between zooxanthellae and corals, which is related to a pronounced loss of colour due to the photo pigment-rich zooxanthellae expulsion (Wild et al., 2011, p 205).

The forecast future climate scenario for 2010-2039 and 2051-2089 is that wind speeds and wave heights will also increase considerably, resulting in more severe storm surges, which will lead to increased coastal erosion (Chalermpong et al., 2009a). Moreover, annual average temperatures are predicted to increase throughout all regions of Thailand, by up to 1 °C by 2050-2059 and up to 2°C by 2080-2089. This means that the total number of warm days per year (days with average temperature exceeding 33 °C) will continually increase in all regions, while the total number of cold days per year (days with average temperature below 15 °C) will continually decrease.

Climate change creates risks and impacts in various sectors of the economy, including in agriculture, where it is estimated that rice productivity will decrease by 5-10 per cent per rai[3], given a 2 °C increase in temperature (Chalermpong et al., 2009b). Indeed, climate change appears already to be having a negative effect on the Thai agricultural sector: there has been a statistically significant decrease of 30-40 per cent of rice production in Sisaket, Petchaboon, Nakornsawan, Chainat, Nakornnayok and Petchaburi (Buddhaboon et al, 2008; Felkner, Tazhibayeva, & Townsend, 2009). Poor rice harvests will directly affect poor people, especially in rural areas, since 90 per cent of the poor live in the countryside. Rising food prices will pose a threat to the overall situation of poverty in Thailand (Jitsuchon & Siamwalla, 2009).

1.1.2 The Thai government response to climate change

Thailand is the seventh biggest producer of CO_2 in Asia and has emissions per capita higher than India and China (Mallilkamarl, 2009). Thailand imports fossil fuel at approximately 820,000 barrels per day (Bell, Silalertruksa, Gheewala, & Kamens, 2010), of which 40 per cent is used in the transportation sector, followed by the industrial sector (35%), the commercial and residential sectors (22%) and the agricultural sector (18%) (Sriroth, Piyachomkwan, Wanlapatit, & Nivitchanyong, 2010). Thailand has been contributing to the widespread global impacts associated with climate change and, on 28 December 1994, committed itself to being a party to the United Nations Framework Convention on Climate Change (UNFCCC). It also ratified the Kyoto Protocol on 28 August 2002. As a party to the Convention, the Thai government and Ministry of Natural Resources and Environment (MNRE) has promoted the use of bio-fuels with the aim of reducing the country's

[3] Thai measurements for land area are recorded in "rai". The following conversions to hectares (ha) and acres apply: 1 rai = 0.16 ha, 1 ha = 6.25 rai, 1 rai = 0.395 acres and 1 acre = 2.53 rai.

dependence on fossil fuel, reducing pollution and enhancing the quality of life of the people (Gonsalves, 2006). Moreover, the Ministry of Energy has developed two significant alternative energy plans for Thailand: the first National Alternative Energy Development Plan applied to the period 2004–2011, and the second plan applies to the period 2008–2022 (Preechajarn & Prasertsri, 2010).

His Majesty King Bhumibol has also shown concern about global warming. He has given the royal imprimatur to an approach for solving this problem by balancing the process of development and conserving natural resources. Royal projects have focused on natural resources and environmental management, especially forest and water resources management and rehabilitation of the soil quality (Chalermpong et al., 2009a). One of the King's concepts, which influenced the National Economic and Social Development Plan, is economic self-sufficiencywhich includes the use of bio-fuels.

1.1.3 Thailand's alternative energy plan

In the first four months of 2011, E20 gasohol consumption in Thailand increased to 0.641 million litres per day, up nearly 50 per cent from an average 0.348 million litres per day in the previous year. Also, E85 consumption nearly doubled from the previous year to 0.017 million litres per day. The increase reflects the government price subsidy for E20 and E85 gasohol from the State Oil Fund, causing E20 and E85 to be cheaper than premium gasoline by 28 per cent and 53 per cent, respectively (Department of Business Energy, 2011).

In 2012, ethanol consumption continued its upward trend to 1.3 million litres per day. The growth of E20 and E85 consumption growth is anticipated to continue due to the increase in the number of E20 and flex-fuel vehicles and gasohol stations. However, the anticipated increase in ethanol consumption is lower than the government's medium-term goal of 6.2 million litres per day in the 2012-2016 period. The deficit may be due to the government's reversal of its initial decision to permit the use of gasohol. In addition, LPG (Liquid Petroleum Gas)[4] and NGV (Natural Gas Vehicles)[5] consumption have trended upwards at the

[4]These are the light hydrocarbons fraction of the paraffin series, derived from refinery processes, crude oil stabilisation plants and natural gas processing plants comprising propane and butane or a combination of the two. They are normally liquefied under pressure for transportation and storage (OECD, 2006).

[5]Natural Gas for Vehicles (NGV) is a compound of hydrocarbons with methane as its primary component, making it "lighter than air". NGV is more suited for use as a vehicular fuel than gasoline or liquefied petroleum gas (LPG) because it is clean-burning and safe. The octane number of NGV is around 130. It is colourless and odourless except for that of the aromatic substance added to make it easy to detect any natural gas leakage (Energy Policy and Planning Office, 2013a).

expense of gasohol because they are 60–70 per cent cheaper than gasohol. NGV consumption has increased to 6.1 million kg per day, increasing by 22 per cent from 2010 (Preechajarn & Prasertsri, 2011).

1.2 Research problem

The climate change policy of Thailand has been set up to make certain that the country's commitments and obligations under the Kyoto Protocol and the UNFCCC are fulfilled and are compatible with the national interest. As indicated in the initial national agreement in the Kyoto Protocol, Thailand has put the problems of climate change into the national development planning process since the Seventh Plan (1992-1996) (Kyoto Protocol, 1997).

Thailand has implemented an ambitious policy framework to promote bio-fuels production and use. The Thai policy framework for bio-fuels is underpinned by the Alternative Energy Development Plan (AEDP) which covers the 15-year period from 2008 to 2022. The plan includes targets for a wide range of alternative energy sources, including bio-fuels such as ethanol. Under the plan ethanol production is to expand from 770 million litres per year in 2010 to 3,285 million litres per year in 2022 (Department of Alternative Energy Development and Efficiency, 2011).

Cassava is the main feedstock for bio-ethanol in Thailand, because the crop requires minimal inputs for planting, has high productivity and is capable of being planted and harvested all year round (Zhang, Han, Jing, Pu, & Wang, 2003; Sriroth and Piyachomkwan, 2008). Additionally, the total cost of ethanol from cassava is low compared to that of sugar cane and molasses, with respective prices of 14.68, 18.43 and 27.23 baht per litre (Pingmuang & Luengsumrit, 2009).

The price of cassava feedstock is the most important factor influencing the price of ethanol, accounting for 60 per cent of the costs of ethanol production (Nguyen, Gheewala, & Bonnet, 2008; Seumpakdee 2009; Bell, Silalertruksa, Gheewala, & Kamens, 2010). Consequently, the schedule of cassava production has become the main factor behind variability in raw material supplies. Problems arise because most Thai farmers are not accustomed to following a fixed schedule of farming with, for example, chemical input application, irrigation system and planting times. Furthermore, farmers apply inappropriate techniques for pre- and post-harvesting. Thus, the quality of raw materials is variable (Nualvatna, 2003). There are also shortages of labour in the cassava production system (Office of Agricultural Economics,

2007) and cassava cultivation has been threatened by aphid infestations, which have caused significant drops in production (Department of Export Promotion, 2010). In addition, the efficiency of the marketing information system is poor (Nishimura, 2003; Nualvatna, 2003).

To succeed in reducing the problems associated with climate change, it is necessary to better understand how to develop and implement policies for sustainable, alternative energy sources, such as ethanol. An important factor in the implementation of increased production of ethanol is to reduce the cost of ethanol production by controlling the pricing of cassava.

To decrease the cost of cassava feedstock for ethanol production but not decrease the wellbeing, such as the incomes and gross margins of cassava farmers, contract farming arrangements have been mooted as a solution. The contract farming approach can reduce the cost for all parties,farmers ethanol processors, marketing of the farm products, farm suppliers and storage operatorsinvolved in the production flow by providing credit and information about how to increase efficiencies at each stage and in transactions between stages.

The Thai government has created a plan to develop Thailand's agriculture and agro-industry, and to support contract farming operations that involve farmers, agricultural industrial firms and government agencies. The aim of the plan is to improve production efficiency and the provision of technological information. However, most private contract farming schemes have, thus far, failed (Baumann, 2000), among them palm oil and cashew nuts (Glover & Ghee 1992; Baumann, 2000). However, there are also examples of successful contract farming initiatives, such as baby corn, potato, sweet corn, maize seed and vegetable seed.

The main issue in this study is to consider the role of contract farming of cassava production for ethanol as an alternative energy solution of the climate change problem in Thailand. Thus we consider three problems:

i) What factors influence contract farming by cassava farmers?
ii) Whether contract farming can be used by smallholders to reduce the cost of cassava for being the raw material of ethanol production due to the policy response of the Thai government to the climate change problem?
iii) Whether contract farming can be used to improve the living standard of cassava farmers?

1.3 Objectives and Hypotheses

In this study, there are four main objectives. The first objective is to examine the agri-business systems of cassava production for producing ethanol as an alternative energy source and to identify the types of smallholders who might decide to become involved in using a contract farming system in their cassava production process.

The second objective is to evaluate the factors affecting contract farming; this objective requires examining factors influencing contract participation. One hypothesis to be examined, in the light of transaction cost theory, is that human capital, physical assets, farm expenses and accessibility influence smallholders' participation in contract farming.

The third objective is to evaluate the effects of contract participation on total cost of cassava production, cassava incomes and farm gross margins. Based on the transaction cost approach, the hypothesis is that when markets are imperfect, the smallholders' choice of farm enterprise may reduce transaction costs resulting in increased income and farm gross margins.

The fourth objective is to evaluate the effects of contract participation on employment. By reducing high transaction costs associated with labour market imperfectionsthrough contract participationthe smallholders' ability to choose an appropriate form of farm enterprise may improve utilization of family labour on family farms. Again, human capital, physical assets, farm expenses and accessibility are factors that may influence the allocation of family labour to farm, off-farm and non-farm activities.

1.4 Organization of the Study

The remainder of this study is organized as follows. Chapter Two reviews Thai government policy on climate change, including climate change as a global problem, climate change problems in Thailand and Thai government responses to climate change. Chapter Three describes the bio-ethanol policy response in Thailand, which includes the Thai fuel market, bio-ethanol processing, and links in the value chain for bio-ethanol. Chapter Four focuses on cassava cultivation and production in Thailand, and related industries, including the native starch industry, modified starch industry and ethanol. Chapter Five presents the theory of contract farming and transaction costs, motivation of smallholders entering contract farming, reasons for success in contract farming, benefits to smallholders and agribusiness firms from contract farming, Thai government policy and implications and effectiveness of the contract farming scheme. Chapter Six discusses the smallholders' responses and the agribusiness system, including farmer attributes and key variables for socio-economic characteristics in surveyed households. Chapter Seven examines the proposed methodology: binary choice models, instrumental variables, two-stage least square and propensity score matching.

Results from the estimated models for contract participation are presented in Chapter Eight including types of smallholders based on ownership of land and assets, factors influencing contract participation, and effects of contract participation on outcomes, including cassava incomes, farm gross margins, total costs and employment of cassava production. The results of the study, with general conclusions and suggestions for further research are summarised in Chapter Nine.

CHAPTER 2: THAI GOVERNMENT POLICY ON CLIMATE CHANGE

2.1 Introduction

Global warming and climate change are the results of human activities, which have emitted large amount of greenhouse gas (GHG) into the atmosphere. The concentrations of gases, such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), have significantly increased in the atmosphere since the period of the industrial revolution because of the use of fossil fuels. The greenhouse effect caused by these GHGs has an important role in global warming because they trap heat around the earth, preventing heat reflection back into space. The principle is similar to that occurring in a greenhouse for plants where glass traps heat inside.

This chapter is organized as follows. Climate change as a global problem is discussed inSection 2.2. Climate change in Thailand and the Thai government's responses to climate change are discussed in Section 2.3 and 2.4. These sections are followed by a summary in Section 2.5.

2.2 Climate change as a global problem

As already noted, global warming is implicated in the significant changes to earth's climate currently being experienced. Agriculture is one of the most important sectors being affected by climate change. Whether agricultural productivity with increase or decrease, however, is not yet certain (Stern, 2007), but Cline (2007) reports that climate change has decreased the agricultural productivity of many regions, especially in developing countries such as Thailand, Vietnam and Africa.

On a regional level, the fall in agricultural production is pronounced in Canada, North Africa, South-East Asia and the Middle East, as well as in the US. The prediction for the Loess Plateau, which covers seven provinces in China, is that the average temperature will rise by 2.5-3.75 °C by 2050, resulting in a higher frequency of droughts and reduced rainfall (Turner, Li, Xiong & Siddique, 2011; Turner, Molyneux, Yang, Xiong, & Siddique, 2011). The increase in the frequency of dry spells and heat waves is likely to result in decreased crop yields and a greater risk of crop collapse due to extreme temperatures. Such climatic effects have impacted populations all over the world. Calzadilla et al (2011) estimates that global welfare has decreased by US$283 billion (0.29% of GDP) as a result of climate change. This is in spite of findings that climate change has had positive effects on the productivity of agriculture in some countries, such as Australia, New Zealand, China, Japan, South Korea and Western Europe.

The productivity of the main agricultural crops such as rice wassignificantlydecreased when they faced short episodes of high temperatures during the period of reproduction. A high risk of yield damage was found for continental lands at high latitudes, mostly in the Northern Hemisphere (40-60°N). Central North America, Eastern and Central Asia and the Northern area of the Indian subcontinent have large suitable cropping areas under heat-stress risk. Globally, this ranged from less than 5 Mha of suitable lands for maize for the baseline climate (1971–2000) to more than 120 Mha for wetland rice for a future climate change condition (2071–2100) (Teixeira, Fischer, van Velthuizen, Walter, & Ewert, 2013). Consequently, Liu et al. (2013) showed significant spatial variations in the impacts of climate change on crop production across regions and among climate change scenarios, climate change was likely to lead to a higher total amount of crop production by the 2030s in the western and northeast areas of the USA and a large area of Europe, as well as in western and southern coastal areas of South America, southern Africa and northern China. However, in the North-Central, Midwest, East-Central, Central and Southeast areas of the USA, parts of South America (a large area of the Amazon and Parana River Basins),the southern area of the cropland belt in Canada, the central area of Africa and the southern edge of Sub-Saharan Africa climate change would likely lead to lower production.

It is very possible that climate change will rise in significance as a driver for changes in biodiversity over the next few decades, even though, for most ecosystems, it is not presently the biggest driver of change. Climate change is already affecting American biodiversity and ecosystems, including changing species diversity and distribution, phenology and growing seasons. There is some evidence to show that net primary productivity and growing season length has increased significantly in the higher latitudes of North America. Nearly 60 per cent of the 1,598 species examined show shifts in their phenologies and distributions over the 20- and 140-year time-frame studied(Compass Resource Management, 2007).

The world’s poorest people live in Africa. The African population is growing rapidly with resultant losses in natural resources. The poverty in Africa is being made worse by increases in temperature and sea-level rises, variable seasons and weather extremes. Drought and decreased rainfall are also problematic (Parry, Canziani, Palutikof, van der Linden, &Hanson,

2007). Since the end of the 1960s, mean yearly rainfall has been decreasing in the western part Africa. Other regions, especially in the eastern and southern parts of Africa, have seen rises in heavy rainfall events, as well as widespread and extreme droughts. Approximately 35 per cent of Africans live in drought-prone areas, mainly in the Sahel, in Southern Africa and around the Horn of Africa (Collier, Conway, & Venables, 2008).

The effects of climate of change on Africa are deeply concerning. In one study, Candida et al. (2011) investigated the impact of climate change on biodiversity and community livelihoods in the Katavi ecosystem, and showed that climate change and variability are affecting both large mammals and community livelihood in that ecosystem. In recent years, the amount and distribution of rainfall have become more unpredictable, causing significant impacts on all production sectors, including biodiversity conservation. Late rains, little rain, floods and unpredictable rainfall distribution, as well as high temperatures seem to be becoming more common.

Sub-Saharan Africa contains the most significant area of rain-fed agriculture in Africa, accounting for 97 per cent of total cropland (Arnell et al., 2002). The agricultural sector is critically important to Africa in terms of both economic and social development. However, if the effects of climate change continue, by 2020 agricultural yields, such as cereal crops from rain-fed areas in some countries of Africa, will decrease by up to 50 per cent (Arnell et al., 2002) and by 2100, regions of semi-arid and arid land are estimated to increase by 90 million hectares, resulting in critical losses in agricultural production (Parry et al., 2007). Climate change also represents an important threat to current African infrastructures and markets. The impacts on African agriculture are of serious concern, not only to African farmers but also to regional decision-makers, national governments and international organizations (Müller, Cramer, Hare, & Lotze-Campen, 2011).

IPCC’s Special Report on Emission Scenarios (Nakicenovic et al., 2000) predicts the average temperature in Australia will increase by 1-5 °C by 2070 (CSIRO, 2007). As already noted, if predictions for Australia’s climate change are correct, GCP will likely fall, and there will be an increased incidence of disease and pests. Moreover the prediction of temperature of the south-western part of Australia indicates it will increase by 1.25 °C to 1.75 °C, and rainfall will decrease by 20-60 mm by 2050 (Turner, Li, et al, 2011). If predictions are correct, GCP would fall by approximately US $622 million per cell (34%) (Seo, 2011).

Climate change will also affect the health and well-being of people in Australia and New Zealand, such as through cardiovascular disease, obesity and diabetes type two, because of climate change's impact on production and distribution of agricultural products (Tapsell et al., 2011). Changes in temperatures are also predicted to alter the occurrence and incidence of diseases and pests. For instance, the Queensland fruit fly will spread southwards in response to higher temperatures, dropping yields and raising costs to the Australian agricultural sector (Preston & Jones, 2006).

Tropical areas in the Pacific are also being impacted by climate change. Donner et al. (2007) found, in 2005, that the Caribbean reefs are becoming bleached, causing significant decreases in coral cover across the whole Caribbean basin. Extensive bleaching of coral in the past 20 years has been related to El Nino events, which have increased in duration and frequency. Increases in water temperatures in 2005 had also been partially attributed to climate change.

In Europe, throughout the 20th century, annual mean value of surface air temperature in Europe has risen by approximately 0.95°C (European Environment Agency (EEA), 2005). Europe is warming at a faster rate than the world average. Central and northern Europe seem to be wetter (Europe Acacia Project European Commission Directorate General for Research, 2000; EEA, 2005). Extreme cold events have decreased, while floods, heat waves and droughts have increased (EEA, 2005).

According to the findings of the ACACIA (A Concerted Action towards a Comprehensive Climate Impacts and Adaptations assessment for the European Union), annual temperatures in Europe are increasing at a rate of 0.1 °C to 0.4 °C per decade (Europe Acacia Project European Commission Directorate General for Research, 2000). The warming is expected to be the greatest over northeast Europe, Finland, western Russia and southern Europe, Spain, Italy and Greece,and least along the Atlantic coastline of the continent.

Kerr (2008) has found that the process of ice-sheet melting around the Arctic is non-linear. Melting of ice sheets such as the Greenland ice-sheet, is occurring at a faster rate than it did many years ago. Based on measurements by satellites, Murray (2006) found that, over the past four years, the Greenland ice-sheet has been contributing to sea-level rise at an accelerating rate. The melting of the Antarctic ice-sheet and Greenland ice-sheet could trigger sea-level increases of several metres by the year 2100 (Overpeck et al., 2006). Moreover, Sommer et al. (2013) concluded that in Central Asia, the impact of climate change on river water was uncertain and assumed that total glacier ice mass in the Pamir Mountains in

Central Asia is shrinking at a fast rate and climate change might affect the seasonality of stream flow (Siegfried et al., 2012). Meanwhile, Jacob et al. (2012) showed that the previous projections of glacier melting were too high.

The Stern Review (Stern, 2007) estimated the climate change affect would be economically significant at a global level. In fact, over the next two centuries, there could be an average reduction in global per capita consumption by at least five per cent. If a larger range of effects (unequal climate burden, amplifying climate system feedbacks and non-market impacts) and risks are taken into account, the estimated damage could increase to 20 per cent of GDP (Stern, 2007). Link and Tol (2004) believe that, as a result of a slow-down or a complete collapse of the thermohaline,[6] there will significant economic impacts on, especially, Western Europe, Canada and the US.

2.3 Climate change and Thailand

Based on the IPCC's AR4 report, Southeast Asia will likely experience an increase in mean temperature of 1–2 °C, similar to the predicted rise in the global mean temperature, as well as an increase in rainfall variability in the southern part of the region (Manton et al., 2001; Pachauri & Reisinger, 2008). These changes will be relatively small compared to that affecting other parts of Asia (Central Asia, Eastern Asia and South Asia) and other regions in higher and lower latitudes (North America, Africa and Europe) (Christensen, Hewitson, & Busuioc, 2007). However, because Southeast Asia has complex physiographical features and altitude differences, the impact of the changes (temperature and precipitation) is likely to vary across both space and time (McCarthy, Canziani, Leary, Dokken, & White, 2001).

Thailand is a Southeast Asian tropical country covering approximately 51 million hectares of land. It shares borders with Myanmar, Laos, Cambodia and Malaysia. The country extends from 6° to 20° north (latitude) and 97° to 106° east (longitude) and can be divided into five physiographic regions: northern, north-eastern, western, central, southern (including east coast) and west coast peninsulas (Economic Intelligence Unit, 2005). Climate conditions over Thailand are affected by two major air streams: the northeast monsoon and the southwest monsoon. The climate components dominating the distribution of temperature and

[6] Thermohaline circulation is the part of the ocean circulation which is driven by density differences and depends on temperature and salinity, thus it is named thermo-haline. The salinity and temperature differences arise from heating or cooling at the sea surface and from the surface freshwater fluxes (evaporation and sea ice formation enhance salinity; precipitation, runoff and ice-melt decrease salinity) (Rahmstorf, 2006, 10).

precipitation over Thailand are the monsoons and the movement of the Inter Tropical Convergence Zone (ITCZ) (Kripalani, Singh , Panchawagh, & Brikshavana, 1995).

Generally, the average temperature in Thailand varies from 24.4–29.3 °C with annual precipitation ranging from 998–4,603 mm. Except for the lower southern part of Thailand, the northeast monsoon brings cool and dry air from the Siberian anti-cyclone and the South China Sea to all parts of Thailand. The southwest monsoon, the main source of precipitation in Thailand, brings humidity from the Indian Ocean to the eastern region in the rainy season, which occurs from May to October (Sangpenchan, 2009). The Office of Natural Resources and Environmental Policy and Planning (ONEP), through the Office of Climate Change Coordination (OCCC), has accepted the overall predictions for climate change for Thailand, reporting that the annual average temperature will increase throughout all regions of Thailand by up to 1 °C in the period 2050-2059, and by a further degree in the period 2080-2089. In addition, the total number of warm days per year (days with average temperature exceeding 33 °C) will continually increase in all regions, whereas the total number of cold days per year (days with average temperature below 15 °C) will continually decrease (Chalermpong et al., 2009a).

Climate change is a particularly important risk factor for the agricultural sector of Thailand, because agriculture is extremely dependent on water, temperature and the land's nutrients. Currently, the agricultural sector uses 96 per cent of the country's natural water supply. Recent severe weather events, presumed to have resulted from climate changeincluding flooding and occasional (non-seasonal) rainfallhas had negative effects on agricultural production (Thavornyutikarn & Sirasoontorn, 2010). Rice growing, long established as an important economic activity in Thailand, dominates the agriculture sector. Rapid growth of agricultural products, especially rice, began in 1855 (Phongpaichit & Baker, 2005). Modern agricultural methods and techniques are being rapidly adopted in Thailand. In 2006, Thailand was one of the world largest agricultural producers (Fischer, Shah, Tubiello, & Velhuizen, 2005) including of meats, fruits, vegetables and cereals, accounting for 0.15 per cent of world food production in 1979 and 1.51 per cent of world production in 2004 (FAO, 2006), particularly of rice, sugarcane and rubber. Thus, the impact of climate change on Thailand poses a risk not only for Thailand but also for agricultural production globally, especially of rice production (Thanasupsin, 2011). There is evidence that climate change is already affecting single grain crops, such as rice, wheat, corn and soybean (McCarthy et al., 2001; Edmonds and Rosenberg 2005; Motha and Baier, 2005). There is also evidence that climate change is influencing monsoon patterns, altering the intensity of both temperature and precipitation in various areas (Kripalani et al, 1995; Mitchell & Hulme, 1999; Pachauri & Reisinger, 2008).

Rising temperatures by themselves have been found to have only a small impact on yields of rice, cassava, maize, sugarcane and palm oil in Thailand (Southeast Asia START Regional Centre (SEA START RC), 2006) but yields of crops might be affected by other factors, such as changes to soil nutrients, cropland management and plant switching. Sussangkarn (1997) found that if there is a temperature increase of 1-2°C, in-season rice yields over the next 20 years will drop by only one per cent compared to average yields in the previous decade. This is in cycle with past statistics about the relationship between temperature and major crop yields over the past ten years, which had a correlation of only about 30 per cent (Vassanasong, 2011).

Fischer et al. (2005) argue that an increase in CO_2 concentration will increase the productivity of the agricultural sector because of increased photosynthesis. The rising CO_2 "fertilization effect" which is associated with higher temperature is known to stimulate photosynthetic systems. Plants respond to increased CO_2 concentration by reducing stomata conductance and transpiration (Thornton, van de Steeg, Notenbaert, & Herrero, 2009). Hence, they conserve water and decrease water stress with subsequent crop productivity increases (Thomson et al, 2005). There is evidence that, under optimum climate conditions, crops including rice, wheat and sorghum, benefit from the CO_2 fertilization effect (Parry et al., 2004; Motha & Baier, 2005).

However Chalermpong et al. (2009b) predicted that rice productivity in Thailand will decrease by 5-10 per cent per rai, given a 2°C increase in temperature because of other factors apart from CO_2. In the areas of Petchaboon, Nakornsawan and Chainat Province, the potential of rice production would fall by around 31-40 per cent because of a significant reduction of irrigated rice yields (Buddhaboon et al, 2008). Rice yields under rain-fed conditions in the Lower Mekong River Basin are already low when compared to the irrigated rice yields because of many factors, including droughts, floods, coastal salinity and tidal flows (Hossain & Fischer, 1995; Hoanh et al., 2003).

Unusual drought conditions during the past three years have resulted in the depletion of water in major reservoirs throughout Thailand by approximately three per cent per year. More than 10 million rai of land were damaged in flood and drought, reducing yields of major crops by two per cent per year over that period. Floods at the end of 2010 damaged total croplands of more than 10 million rai or almost 10 per cent of total cropland areas; these floods were among the most severe floods in the past decade (Vassanasong, 2011) resulting in rising prices of both food and energy crops. In May 2006, there were five Northern provinces, Sukhothai, Uttraradit, Phrae, Nan and Lampang, which suffered from flash-floods and mud-slides due to the heavy rain. There were 87 casualties, 33 missing persons and 300,000 people who suffered from the disaster (Srithawatchai, 2006). The damage to the infrastructure included 1,709 groundwater wells, 314 pipeline groundwater systems, 31 dams and reservoirs, 39 pipeline water systems and over 240 village water resources. The damage extended to 983 transportation routes, 181 bridges, 226 temples/schools/government offices, 51 dams/check dams, 269 sewage pipelines and 3,567 households (Srithawatchai, 2006).

A report from the Food and Agriculture Organization of the United Nations (FAO, 2006) reveals that demand for cereals from consumers in developing countries during the next two decades is likely to exceed supply by more than 16 per cent. This is partly due to lower yields caused by climate variability in major food-producing countries, as well as the switching of growing areas from producing food crops to producing energy crops. This situation could eventually lead to food price shocks, and could raise cereal prices by around 30 per cent from normal levels during 1997-2006. Energy crops will increase by around 40 per cent from the current level due to the rising popularity of alternative energy sources to reduce fossil fuel (oil) dependency. This is evident from the current extensive commercialized production and distribution of biodiesel. There is, especially, a rising demand for palm oil in Central America, South America, Africa, Indonesia, Malaysia, and Thailand. Demand for alternative energy is estimated to double in the next 20 years. This will result in encroachment on land producing food of land for producing crops, especially sugarcane, palm oil, cassava, corn and soybean, for energy purposes. One obvious example is the increase in palm oil price of around 10 per cent per year over the past decade, which resulted in eight per cent growth in palm oil farming areas (Colgan, 2009).

The coastline of Thailand is around 2,600 kilometres long. The ecosystems in these areas are very important for social and economic development in the eastern and southern regions of the country. Several studies have attempted to estimate the potential effects of sea-level rise due to global warming for Thailand’s coastline. A study in Krabi province showed that the sea level along the coast of Krabi could increase by 11 to 22 centimetres in 30 years due to global warming with the result that 350 kilometres of the coastline would be inundated

(Pongponrat, Calgaro, & Naruchaikusol, 2009). Chalermpong et al. (2009b) estimated for the future climate scenario 2010-2039 and 2051-2089 that wind speed and wave height will increase considerably, resulting in more severe storm surges which will lead to further coastal erosion.

According to the latest (2011) Climate Change Vulnerability Index (CCVI), Thailand was ranked among the 14th country (out of 170 countries) at extreme risk from climate change. Maplecroft (2011) notes that the main reasons behind Thailand's vulnerability are:

1. A highly agriculture-dependent economy. Although the agricultural sector in Thailand accounts for only about 17 per cent of GDP, over 40 per cent of labour is employed in this sector.
2. The poverty situation. Even though the poverty headcount in Thailand has improved recently, many people are still poor by World Bank standards, and they are the group most vulnerable to energy and food crises.
3. The low adaptive capacity of the government with respect to climate change due to a lack of proactive policies and measures to prevent and deal with the impacts of climate change in a systematic manner.

The Bangkok Metropolitan Administration (BMA) calculated that, in 2005, Bangkok released about 43 million tonnes of CO_2 compared with 44 million tonnes in London, while Bangkok's economy is only about one-tenth that of London's. Moreover, CO_2 emissions in Bangkok were also about 70 per cent of those in New York, one of the most densely populated cities in the world. Nearly 40 per cent total CO_2 emissions in Bangkok are from the transportation sector, compared to London's emissions where this sector accounted for only about 20 per cent. The majority of Londoners commute using public transport (Kusumastuti & Weesakul, 2012).

The impact of climate change might increase the discharge of the watershed at Khlong Krabi Yai in Krabi province (Sangmanee et al., 2011). Sangmanee et al. (2011) reported that the effects of climate change on the Mekong Basin were: i) decreasing water supply in both upper and lower basin; ii) increasing intensity and frequency of rainfall which produces more sedimentation and pollution; iii) increasing vulnerability due to floods, especially in September and October; and iv) increase in the metabolic rates of microbes and invertebrates.

Changes in the seasonality of climate variables could have a marked impact on forests (Melillo et al., 1990). Based on the assessment of the Land Development Department, in 2008, the areas of swamp and marsh wetlands were reduced by 42 per cent or almost half of the wetlands that existed in 1999, with the result that at least 42 per cent of the population of amphibious animals have declined, and 33 per cent of freshwater fish in the world are now threatened (Henry, 2010). Areas of subtropical wet forest and subtropical moist forest in Thailand have declined from five per cent and 48 per cent of the total area, respectively. Additionally, the areas of tropical moist forest and tropical dry forest rose from 15 per cent to 44 per cent of the total area; the subtropical moist forest was almost completely replaced by tropical dry forest which declined from 48 per cent to two per cent, but the area of tropical dry forest rose from 32 per cent to 70 per cent and tropical moist forest mostly replaced subtropical wet forest (Boonpragob & Santisirisomboon, 1996). The Millennium Ecosystem Assessment Project noted that climate change is one of the main factors threatening biodiversity and could be a catalyst of more rapid and severe biodiversity loss, particularly for the species living in wetlands.

It is estimated that the total area of mountainous rainforests and dry forests in the north of Thailand will decrease considerably while the total area for mixed deciduous forests and dry dipterocarp forests will increase. In particular, mixed deciduous forests will cover most of the forested areas, accounting for 72 per cent of the forested land in the north of Thailand. Such change has important implications for the forest ecosystems and biodiversity, which will in turn impact on the country's national parks and wildlife habitats (Chalermpong et al., 2009b).

In 2006, there were 32 Thai national parks and wildlife sanctuaries situated in climate change hot spots expected to be affected by climate change (from the UK 89 Model) (Boonprakrob & Hattirat, 2006)

2.4 Thai Government responses to climate change

Since 1961, Thailand's National Economic and Social Development Plans have provided a framework for sustainable development. Over the past four decades, Thailand has gradually improved its processes of sustainable development. Development priorities as well as the planning process and implementation have been adjusted to national and regional circumstances, and global development dynamics. At present, Thailand is implementing the Eleventh Plan (2012-2016).

Due to increasing deterioration of natural resources and the environment, Thailand has promulgated the Enhancement and Promotion of the National Environmental Quality Act (B.E. 2535). Under the Act, a five-year action plan for environmental quality management is prepared on a regular basis. At present, Thailand is implementing the Environmental Quality Management Plan for 2007- 2011. It is noted that the planning periods for economic and social development and environmental management are in parallel. This is to ensure that the country's economic and environmental development process occur simultaneously (Khunkitti, 2010). The committees working on the Plans are composed of stakeholders. The planning processes for the two Plans are similar. A bottom-up approach through stakeholder consultation is used. The planning process is coordinated and integrated to ensure full consideration of natural resource and environmental conservation in the economic and social development path, leading to the country's sustainable development. Thus, Thailand's economic and social development plan is consistent with the sustainable development concept. Through a process of parallel planning, natural resource conservation and environmental protection are integrated into the economic and social development of the country.

At the 16th Conference of the Contracting Parties (COP16) to the UNFCCC held at Cancun, Mexico, 29th November to 10th December 2010, the Thai delegation, comprising representatives from government agencies, business and NGOs, stated its position on climate change, which was, coincidentally, the same as that of other developing countries, particularly with regard to compliance with the convention and the Kyoto Protocol. That is, on reducing GHG emission, developed countries should support developing countries in terms of finance, funding and technological transfer (Irene & Caballero Anthony, 2011). Most of all, Thailand sympathized with the G77[7] on the proposal to reduce global temperature by 2°C. Thailand, however, will receive little from the COP16 Agreement because it has a low priority status for support from the Green Climate Fund (GCF).[8] Nevertheless, Thailand agreed to comply with the Kyoto Protocol by conducting and presenting National Communications every four years and National Inventories of GHG emission every two years. To do this, Thailand is seeking financial support from UNFCCC.

[7] G77 is the group of 132 developing countries which funded in 1964 to discuss the most relevant issues concerning the development agenda at the United Nations and its specialized agencies. The G77 strives to promote peace and prosperity for humankind through a strong and effective multilateral system FAO, 2013).

[8] The Green Climate Fund (GCF) was established at the 16th Conference of the Contracting Parties as an operating entity of the financial mechanism of the Convention under Article 11. The GCF will support projects, programmes, policies and other activities in developing country Parties. The Fund will be governed by the GCF Board (UNFCC, 2013).

Since there is no commitment to provide these two reports within a certain timeframe, Thailand will deliver them depending on its capabilities. The Office of Natural Resources and Environment Policy and Planning (ONEP) is the national focal point for UNFCCC, making policy in cooperation with implementing agencies, such as the Ministry of Energy, Ministry of Agricultural and Cooperatives and Ministry of Foreign Affairs. Lately, ONEP has proposed three principles to the National Committee on Climate Change Policies. Cabinet approved these policies on 22 March 2011 (Kositraratana, 2011):

1. Develop effectiveness of implementation on global warming by hierarchical planning from policy frameworks and directions as well as research on climate change in Thailand; feasibility study on potential for GHG emission reduction project; feasibility study on GHG emission reduction from deforestation; and forest degradation and strategic planning on climate change adaptation.
2. Promotion of the potential and strengthening of the organization by establishment of the office of cooperation on climate change according to the Prime Minister's Office regulation.
3. Encourage the use of international mechanisms such as ASEAN, which has established a working group on climate change in the ASEAN group.

2.4.1 Political

From the late 13th to 18th century, Thailand was an absolute monarchy. Then, in the late 19th century, during the reign of King Rama V (1868-1910), Thailand adopted a Constitutional monarchy system (see Figure 2.1), aiming to create a more efficient organization of government similar to that found in developed countries. The original Organization of State Administration Act was implemented in 1932 and was replaced by the Act of 1991. The civil service administration of Thailand used a combined centralized, de-concentrated and decentralized system consisting of central administration, provincial administration and local administration, which included i) provinces, municipalities and sanitary districts, and ii)

Bangkok Metropolis and Pattaya City (Aim-on Aramkul, 1997).

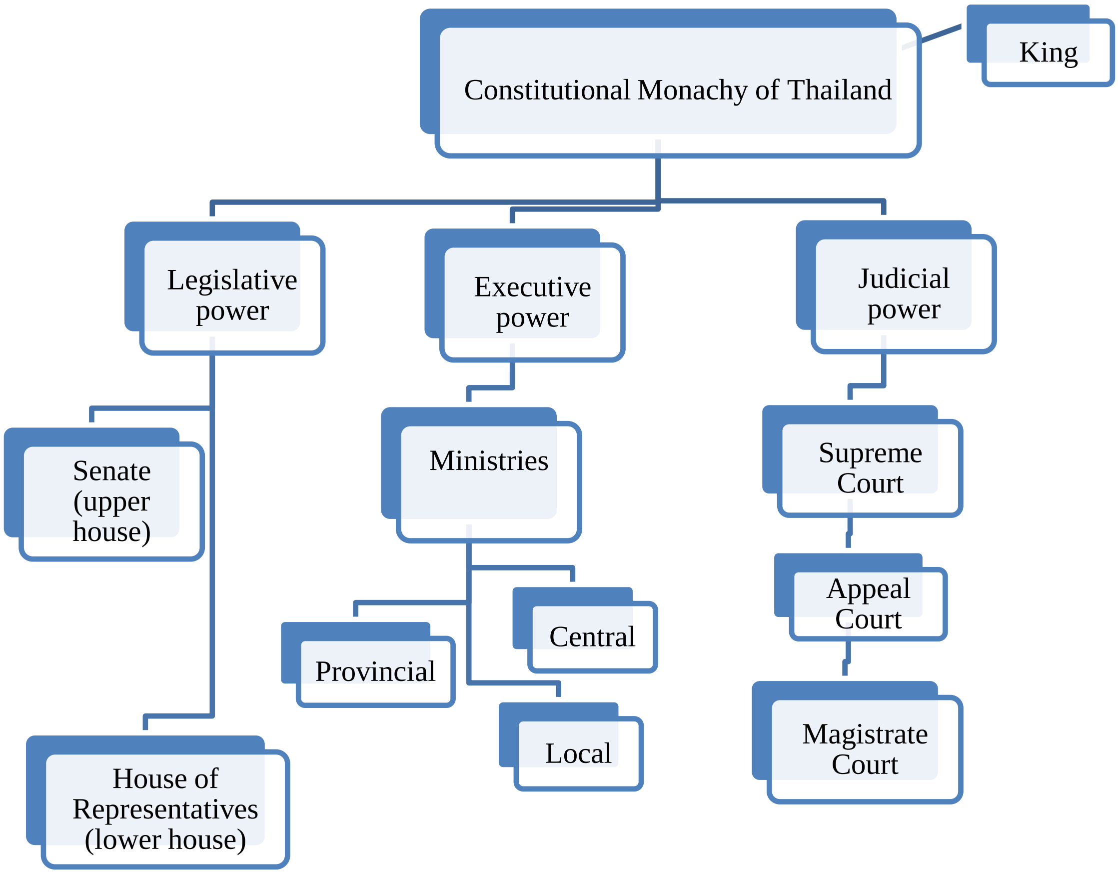

Figure 2.1: Thailand's constitutional monarchy system
(**Source:** Aim-on Aramkul, 1997)

On 4 December 1989, to influence the Thai people to appreciate the problems caused by human activities involving over-usage of natural resources and causing changes in the world's atmosphere and land, and impacting on human beings, His Royal Thai Majesty made this speech:

> The environment has changed. They say there is too much carbon dioxide which acts like a green house. Accordingly, the world is becoming warmer, icebergs will melt into the sea, and the sea water-level will be increased. Increase in the amount of carbon dioxide in the atmosphere is occurring from fuel combustion in the soil and burning.

As in previous royal speeches, His Majesty King Bhumibol was concerned about global warming. He offered his ideas as an approach to solving this problem, requiring a balancing of economic development and conservation of natural resources. It is evident that the royal intention was to become involved in projects concerned with natural resource and environmental management, especially of forest and water resources management, and rehabilitation of the soil quality.

The problems of natural resource destruction, which includeforests, water and soil, are mainly caused by human activities leading to changes in the balance of nature. His Majesty the King believed problems could be solved through integrated natural resource management (Mongsawad, 2010). An example of a success story of integrated natural resource management is the Huay Hong Krai Royal Development Study Centre, Chiangmai, which has been shown to relieve global warming conditions. The noticeable results were as follows (Senanarong & Councilor 2004; Isarangkun and Pootrakool 2007; Chalermpong et al., 2009a):

1. Rivers and water sources were able to provide more moisture.
2. Enhanced rainfall, evaporation rate, temperature and relative humidity: The meteorological centre in Chiangmai reported that,there was more rainfall in the development study centre than in Chiangmai province. The incidence of rainfall quantity in Huay Hong Krai Royal Development Centre has been increasing nearly every year. In 2006, average rainfall was 1,314 millimetres and average evaporation rate was 1,142 millimetres, with 26.7 °C for average temperature. Moreover, the average relative humidity in 2006 was 88 per cent, compared with only 74 per cent in 1984.
3. Forest type, forest species, and forest density have been changed positively: the number of mixed deciduous forest areas was 16.55 per cent, but this has increased up to 45 per cent. As a result of the rehabilitation, there have been many changes in forest species and forest density. The number of species increased from 35 to 80, and tree density increased from 100 trees per rai to 200-240 trees per rai.
4. The overall environment has improved: there was a forest fire within Huay Hong Krai Royal Development Study Centre areas in 1983. Fires destroyed about 2,000 rai each year between 1973 and 1983. Since the humidity has increased, there have been no forest fires within the area in the past 10 years. A diversity of plants and natural foods has been established that a community can utilize and gain additional revenue from. The community was able to live without causing impacts on the natural resources and the environment of the watershed area.

2.4.2 Legislature

The Kingdom of Thailand is a civil law kingdom with strong regular law powers. Modern Thai law was inaugurated by the King, known as Chulalongkorn King Rama V, between 1868 and 1910. He also started the process of codifying Thai law and the Thai Penal Code was reformed in 1908. Many of the improvements were supervised by Prince Rapee Pattanasak (the 14^{th} son of King Rama V), who is the father of the modern Thai legal system. The modernization and codification of Thai law were continued under the reigns of King Rama VI between 1910 and 1925 and King Rama VII between 1925 and 1935 (Leeds, 2008).

In Thailand's constitutional monarchy system, the King is the head of state and exercises his supreme powers through the Council of Ministers, the National Assembly and the Courts (Leeds, 2008). After the death of King Ananda Mahidol (King Rama VIII) in 1946, King Bhumibol Adulyadej came to the throne at 18 years of age. He has been responsible for developing the role of the monarchy under a constitutional government (Ockey, 2005). There are three branches to the government: the legislative branch, the executive branch and the judicial branch (Leeds, 2008).

Legislative power is exercised by the National Assembly, including the Senate and the House of Representatives (the Lower House). The Senate or the Upper House include members appointed by the King on the suggestion of the Council of Ministers and the House of Representatives, including popularly voted members. The King's agreement is necessary to promulgate any law; however, if the King does not agree to a law, a law may be promulgated with the votes of at least two-thirds of the National Assembly members.

Executive power is exercised through a Cabinet headed by a Prime Minister. The Council of Ministers and Prime Minister are responsible for establishing government policies and the administration of state affairs. The Council of Ministers may advise legislation for consideration by the National Assembly. The support of the Prime Minister is necessary for the introduction of money bills. Moreover, the Prime Minister has to be a member of the House of Representatives and has to have the endorsement of a majority of the House of Representatives' members.

Judicial power is exercised through the courts, which adjudicate cases according to law in the name of the King. The courts have responsibility for adjudicating and trying cases. The Constitution particularly provides for four categories of courts: i) The Constitutional Court:

this has eight members, who are selected by the King on the recommendation of the Senate, and they serve one nine-year term. There are three judges in the members of the Constitutional Court: a) the judge of the Supreme Court of Justice, b) two judges from the Supreme Administrative Court and c) four individuals consisting of two experts in a social science and two experts in law. ii) The Courts of Justice include three levels: a) Courts of First Instance, b) Courts of Appeal and c) the Supreme Court of Justice. iii) The Administrative Courts, and iv) the Military Courts (Leeds 2008).

2.4.3 Planning

Thailand instituted a national subcommittee on climate change under the National Environment Board after Thailand signed on to the agreement of the UNFCCC in 1994. The subcommittee provided a climate change plan to guide Thailand’s strategy. In 2006, the subcommittee on climate change was changed to become the National Climate Change Committee, chaired by the Prime Minister, and three sub-committees were formed to take charge of the technical, public relations and negotiation aspects of climate change (Khunkitti, 2010) as shown in Figure 2.2.

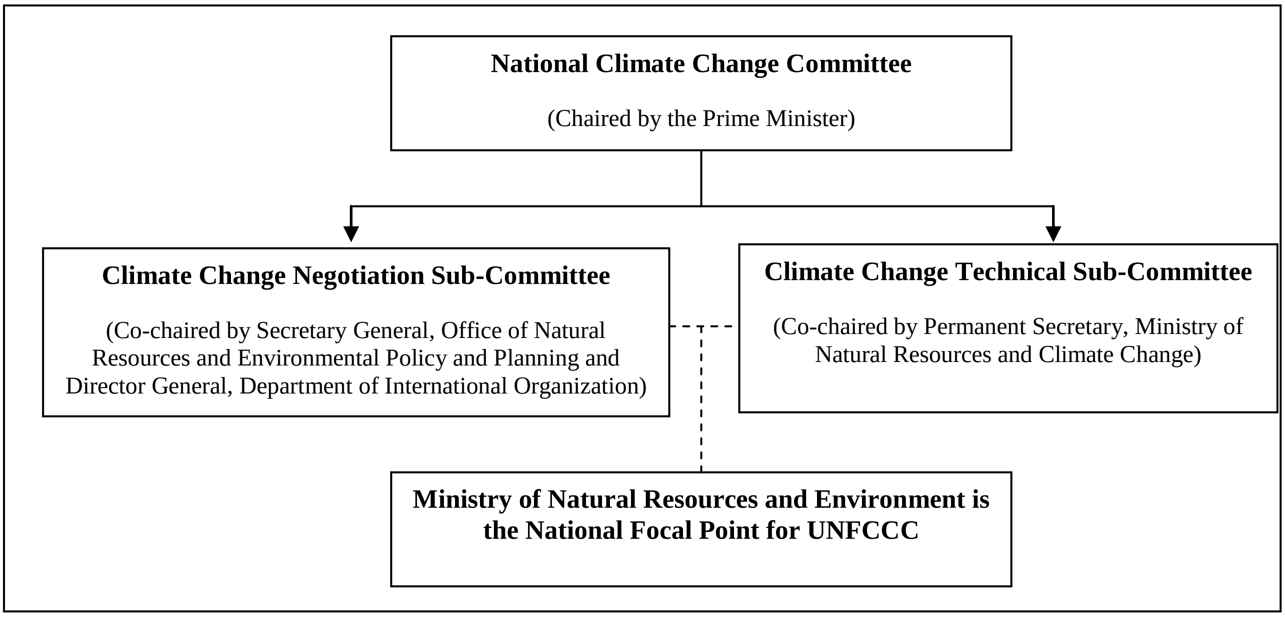

Figure 2.2: Policy making concerning climate change in Thailand
(Source: Khunkitti, 2010)

The climate change policy of Thailand was set up to make certain that the country's commitments and obligations to the Kyoto Protocol and the UNFCCC were fulfilled and were compatible with the national interest. As indicated in the initial national agreement in the Kyoto Protocol, Thailand has put the problems of climate change into the national development planning process since the Seventh Plan (1992-1996) (Kyoto Protocol, 1997).

Under the Eighth Plan (1997-2001), the core development objective was to focus on the welfare of people. A holistic development program was used to reach a balance of environment, economic and social sectors. Unfortunately, at some stage in the Eighth Plan, the economic crisis caused the Thai government to put on hold the original plan and to implement a range of crisis measures to save the Thai economy, particularly those affecting economic stability and income. As a result, this plan became ineffective. However, the plan set the stage for further developments. Public participation was broadly accepted, inspiring the preparation of the national organization, which laid the main social institution that served as a key mechanism for national development (National Economic and Social Development Board, 1996).

In the Ninth Plan (2002-2006), “sufficiency economy”[9] was approved as a direction for direct national development. An important part of the Plan was a continued focus on the Thai people. The result of the Ninth Plan was satisfied because, economic growth continued with more social stability and a decrease in poverty. The people’s quality of life was improved, including better provision of public health and sanitation services. However, Thailand’s economy continued to be vulnerable to external issues, with the main problems being quality of education, public safety, income distribution, good governance and transparency (National Economic and Social Development Board, 2001).

The common policy on climate change under the Eighth and Ninth Plans was a win-win policy. Under these policies, Thailand created national policies on water resources, forests, energy and so on, in order to decrease GHG emissions, both indirectly and directly, and also to improve agriculture. Some indicators showed that the changing structure of the global economy during the period influenced Thailand’s social development and economy. Particularly, differences in the production efficiency of agriculture and industry became evident, depending on exports, and there was an imbalance between the international and domestic economy (National Economic and Social Development Board, 2001).

Under the Tenth Plan (2007-2011), the sufficiency economy philosophy has continued to guide national economic and social development. Thus, the people’s interests have continued to ensure a balance among the economic, social and environmental aspects of development, alongside the strengthening of self-reliance among the Thai people. Guided by a vision of sustainable happiness for Thai society, the Tenth Plan emphasizes the development of economic, social and environmental natural and resources capital. These aspects of national capital are very important for enhancing and strengthening the advantages of the Thai people. Five strategies are promoted: i) development based on sustainable utilization of diversified environmental resources, ii) improvement of good governance in national management and administration, iii) adjustment of the economic structure and sustainability, iv) strengthening the community, and v) development of the quality of the people (National Economic and Social Development Board, 2001). Additionally, Thailand had also defined precise approaches related to its main environmental and natural resources. Among these strategies

[9]Sufficiency Economy is a philosophy that guides the livelihood and behaviour of people at all levels, from the family to the community to the country, on matters concerning national development and administration. It calls for a ‘middle way’ to be observed, especially in pursuing economic development in keeping with the world of globalization 9Krongkaew, 20030

were the first national strategic plan for organic agriculture development (2008-2011) and the national action plan for organic agriculture development (2009-2011).

Thailand had begun the preparation of the Eleventh Plan with the introduction of its idea for the period starting 2012. The idea of the importance of the environment to the patterns of production and consumption remains important, as noted in the following statement (National Economic and Social Development Board, 2001):

> Maintain the environment in good condition and be mutually supportive of each other, adopt environment-friendly production systems, ensure energy and food security, observe self-reliance in a competitive world and live with pride in the regional and global communities.

An important assignment is to assist in the management of biodiversity and natural resources to ensure their wealth. Therefore, the people will recognize the value of the environment and natural resources. With regard to the global environmental policy and vision for the next two decades, Thailandrecognized the association between obligations and conditions affecting technological development and the global environment. Future development would be based on innovation and knowledge, particularly regarding energy security, biotechnology information technology and nanotechnology (National Economic and Social Development Board, 2011). It could be said that Thailand had become increasingly concerned about climate change and global warming as serious issues affecting sustainable development.

2.4.4 Bio-fuels Policy

The International Energy Agency (IEA) project's global energy demand will increase by 1.2 per cent per year over the next 20 years, which will cause oil prices to increase to almost US$200 per barrel or almost three times the price in 2010 (US $80 per barrel) (Ministry of Energy, 2009). This projection is based on the new policy scenario, which specifies the concentration of GHG at over 650 parts per million of CO_2-equivalent, resulting in the rise of global surface temperatures of more than 3.5°C. This is compared to the previous scenario known as the 450 Scenario, which limits the concentration of GHG to 450 parts per million of CO_2-equivalent, and predicted rise in temperature limited to not more than 2°C by 2030 (Parry et al., 2007).

Since fossil fuel prices were very high in 2004, the Thai government modified Thai programs and policies to encourage major increases in bio-fuels production and consumption. The

Alternative Energy Plan 2008-2022 is the base of the current 15-year bio-fuels plan and includes biodiesel and ethanol. There are three stages of ethanol production targets between 2008 and 2022: i) In the short term between 2008 and 2011, focus on encouraging commercial alternative energy technology and produce ethanol at 3.0 million litres per day, ii) In the medium term between 2012 and 2016, focus on development of alternative energy technology industry, research and development of technological methods and sources, and introduce the concept of "Green City" for sustainable development. In this period, the government targets ethanol production for 6.2 million litres per day; and iii) In the long term between 2017 and 2022, enhance utilization of new available alternative energy technology, with a target to produce ethanol at9.0 million litres per day. Gasohol production, despite increasing from 0.92 million litres per day in 2008 to 1.17 million litres in 2010, has been far below the 3.0 million litres target, with current consumption at 1.45 million litres per day.

Table 2.1: The demand for E20, E85 and all types of gasohol in Thailand between 2009 and 2001 (million litres)

Year	2008			2009			2010			2011		
Month/Type of Gasohol	E20	E85	All Type	E20	E85	All Type	E20	E85	All Type	E20	E85	All Type
Jan	0.009	0	227.27	0.154	0	388.04	0.298	0.002	362.00	0.503	0.013	382.10
Feb	0.016	0	227.61	0.151	0	352.41	0.337	0.003	342.99	0.569	0.014	360.20
Mar	0.029	0	235.30	0.167	0	391.17	0.320	0.004	358.17	0.567	0.017	370.26
Apr	0.05	0	253.55	0.184	0	371.91	0.348	0.004	358.60	0.641	0.017	386.50
May	0.066	0	253.84	0.213	0	383.82	0.337	0.004	353.90	0.631	0.024	383.40
Jun	0.089	0	252.90	0.224	0	363.14	0.376	0.005	365.50	0.647	0.026	-
Jul	0.093	0	267.09	0.24	0	369.73	0.381	0.006	379.26	-	-	-
Aug	0.108	0	312.07	0.254	0.001	376.10	0.383	0.006	370.30	-	-	-
Sep	0.117	0	300.56	0.267	0.001	350.55	0.388	0.007	359.10	-	-	-
Oct	0.107	0	333.02	0.278	0.001	367.83	0.411	0.008	364.60	-	-	-
Nov	0.124	0	340.99	0.286	0.002	354.28	0.436	0.009	371.10	-	-	-
Dec	0.142	0	389.80	0.317	0.002	387.45	0.498	0.011	396.82	-	-	-
Average	**0.079**	**0.001**	**282.833**	**0.228**	**0.001**	**371.369**	**0.376**	**0.006**	**365.195**	**0.593**	**0.019**	**376.492**
Total	**0.950**	**-**	**3,394.000**	**2.735**	**0.007**	**4,456.430**	**4.513**	**0.069**	**4,382.340**	**3.558**	**0.111**	**1,882.460**

(**Source:** Department of Business Energy, 2011)

Moreover, Thai consumers have expressed preferences for gasoline and NGV over bio-fuels. In the former case, the price differential between gasohol and gasoline has not encouraged consumers to prefer gasohol. Consumers have also substituted both gasoline and gasohol consumption for the highly-subsidized LPG and NGV. Ethanol production is estimated at 528 million litres in 2011, while consumption is limited to 439 million litres.

Thailand's ethanol exports were estimated to increase from 49 million litres in 2010 to 70 million litres in 2011. The outlook for ethanol production is on an upward trend. In 2012 another five new ethanol plants, with a capacity of 1.8-1.9 million litres per day in total, were to be added to the 19 existing plants (Department of Alternative Energy 2008; Preechajarn & Prasertsri 2010; Preechajarn & Prasertsri, 2011).

In the first four months of the 2011, E20 gasohol consumption increased to 0.641 million litres per day, up nearly 50 per cent from an average 0.348 million litres per day in the previous year. Also, E85 consumption nearly doubled from the previous year to 0.017 million litres per day. The increase reflects the government price subsidy for E20 and E85 gasohol from the State Oil Fund, causing E20 and E85 to be cheaper than premium gasoline by 28 per cent and 53 per cent respectively, as shown in Table 2.1 above (Department of Business Energy, 2011).

In 2012, ethanol consumption will continue its upward trend to 1.3 million litres per day in anticipation of growing E20 and E85 consumption due to the increase in the number of E20 and flex-fuel vehicles and E20 and E85 gasohol stations. However, this anticipated increase in ethanol consumption of 1.3 million litres per day is still far below the medium term goal of government of 6.2 million litres per day in 2012-2016. This difference can be recognized as reflecting an incoherent government policy that reversed its decision to permit necessary use of gasohol when it first enacted its gasohol plan. Additionally, NGV and LPG consumption have trended upward at the expense of gasohol as these fuel sources are 60-70 per cent cheaper than gasohol. Presently, NGV consumption has increased to 6.1 million kg per day, up 22 per cent from 2010 (Preechajarn & Prasertsri, 2011).

2.5 Summary

Climate change is a problem that will become more critical as time goes by. It will have important effects on every country in the world. Rising climate-correlated disaster such as floods, drought, heat waves, wild fires and storm surges are being increasingly experienced by many countries. Examples from the last few years include very heavy snow in North

America, the extreme cold across Europe, the serious flooding in Australia, extraordinary snowing in the north of Myanmar and flooding in Thailand.

The UNFCCC was initiated with the aim to stabilize GHG concentration in the atmosphere, sufficient to allow ecosystems to adapt naturally, to ensure food production and to enable economic development to proceed in a sustainable manner. However, this commitment is the obligation set by Annex I for developed countries. Thailand belongs to the Non-Annex countries, which include developing countries, and Thailand ratified the UNFCCC without a commitment to reducing GHG emissions. However, as a Party to the Convention, Thailand has made policy adjustments on climate change following the outcomes of the negotiation. Thailand has continued to modify its government policies to lead to increases in bio-fuels production and consumption, and has also created the Alternative Energy Plan 2008-2022 which includes biodiesel and ethanol production.

CHAPTER 3: BIO-ETHANOL AS A POSSIBLE POLICY RESPONSE IN THAILAND

3.1 Introduction

As noted in Chapter 1, cassava is used as a raw material in ethanol production. There are many advantages to the use of cassava, such as: small inputs for planting; ability to plant and harvest all year round; high starch content, which is a huge benefit for ethanol processing; and competitive bio-ethanol production cost compared to other feedstock (Zhang et al., 2003; Sriroth & Piyachomkwan, 2008). Sections 3.2 and 3.3 of this chapter describe the Thai fuel market and bio-ethanol processing. Section 3.5 discusses the links in the value chain for bio-ethanol, including inputs, providers, farmers and users 3.5. A summary in Section 3.6 concludes the chapter.

3.2 The Thai fuel market

Thailand has moderate amounts of fossil fuel reserves, the most important of which is natural gas. Domestic energy needs are partially served by domestic energy supplies, however, and the bulk of energy needs -more than 60 per cent- are from imported supplies. Production and consumption has increased steadily as a result of the continued expansion of the economy, particularly since 2009.The steady increase has occurred in spite of the devastation caused by severe floods to several regions of Thailand in the latter half of 2011. The overall consumption of primary commercial energy for2011 rose by about four per cent from 2010 levels to average about 1.85 million barrels of crude oil equivalent; 80 per cent of the consumption is of petroleum (44% natural gas and 36% crude oil), 17 per cent coal and three per cent hydropower.

3.2.1 The fuel situation

The Office of the National Economic and Social Development Board (2011) in Thailand produced the 11th plan (2012-2016) in 2011. It aims to steer economic development by utilising human resources by promoting the involvement of all sectors of society and integrating national development in a comprehensively balanced way. Energy policy formulation is part of the national development direction framework under the policy of the Cabinet. As a unit of the Ministry of Energy, with a core role of securing energy supply from indigenous mineral fuels for national energy security, the Ministry of Energy has devised four strategies in line with the national energy policy and the Ministry of Energy's strategies.

There are 63 concessions and 79 blocks (202,722.68 km^2) of exploration, and 17,418.419 km^2 of production of petroleum concessions in Thailand as of 1[t] January 2012, including 29 concessions and 36 blocks, which comprises: 83,432.14 km^2 of exploration and 16,089.33 km^2 of production, in the gulf of Thailand; 33 concessions 40 blocks, which is 74,768.88 km^2 of exploration and 1,329.090 km^2 of production in onshore areas; and concessions three blocks, which is 44,521.660 km^2 of exploration, in the Andaman Sea (Department of Mineral Fuels, 2012).

Two major energy companies operate in Thailand: PTTEP[10] and Chevron. They produce and supply gas and oil (World Bank, 2008). The companies own two pipelines which transport refined oil products from refineries to oil terminals in Bangkok and the surrounding area. However, both pipelines are underutilized since other means of transporting the fuel, such as trucking, is more economical.

Oil depots are located all over the country. They have a total storage capacity of 7,240 million litres. More than 80 per cent of the storage capacity is located in the Bangkok area and in the eastern part of Thailand. The storage capacity of existing oil depots is sufficient to serve demand and no expansion is expected in the near future (World Bank 2008; Alternative Energy and Efficiency Information Centre, 2011).

The Ministry of Energy (2011) created a 20-year Energy Efficiency Development Plan (EEDP) that aims to reduce 25 per cent of energy intensity by 2030 compared to 2005, or to reduce approximately 30 million tonnes of crude oil equivalent (toe)[11] or 20 per cent of final energy consumption by 2030. The transportation sector and the industrial sector are two priority economic sectors targeted to achieve energy conservation. The EEDP is also aiming to reduce energy elasticity (the percentage change in energy consumption to achieve one per cent change in national GDP). Achieving EEDP's aims will result in increasing energy savings of an average of 14,500 kilo toe per year, reducing CO_2 emission by 49 million tonnes per year on average and valued at 272 billion baht per year.

[10]PTTEP or PTT Exploration and Production Public Company Limited is the local Thai company for exploration and production on petroleum for Thailand and investing countries. PTTEP has invested in 45 E&P activities and5 investments in Thailand, Myanmar, Vietnam,Cambodia,Oman,Indonesia,Algeria,New Zealand,Australia,Canada,Mozambique andKenya.

[11]A tonne of oil equivalent (toe) is a unit of energy, a conventional value, based on the amount of energy released by burning one tonne of crude oil, of 41.868 GJ, 11.63 MWh, 1.28 TCE, 39.68 million BTU, or 6.6 - 8.0 actual barrels of oil Shin, Park, Kim, & Shin, 2005).

3.2.2 Thai energy consumption

Between 2010 and 2011, Thailand’s petroleum products consumption rose at an average rate of 3.9 per cent, from 697,537 barrels to 724,539 barrels per day. The net import of petroleum products and crude oil rose by 0.8 per cent (Alternative Energy and Efficiency Information Centre, 2011; Energy Policy and Planning Office 2012; Department of Enegy Business, 2013). Thailand obtains petroleum from both domestic and imported sources as follows.

Crude oil: Thailand produced total crude oil at approximately 139,841 barrels per day, which accounted for 8,115 million litres in 2011,a decrease of 8.7 per cent compared to 2010. The most important onshore oil producer was the Sirikit Field, which accounted for 16.4 per cent of total oil provided. The Fang Field produced 0.7 per cent, and other fields combined produced 3.5 per cent. Crude oil production from the Gulf of Thailand, including the Benchamas Field, Plamuk Field and Jasmine Field produced approximately 19.4 per cent, 10.1 per cent and 9.1 per cent respectively. Thus, domestically, Thailand produced a total of 40.8 per cent of its crude oil needs from the combined 14 crude oil fields (Alternative Energy and Efficiency Information Centre, 2011) in 2011, amounting to 57,912 million litres of crude oil and condensate. This was a decrease of 3.1 per cent from 2010 supplies. The total production from refineries comprised diesel (41.7%), LPG (21.1%), gasoline (15.0%), jet fuel (11.4%), fuel oil (10.5%t) and kerosene (0.3%).

In 2011, Thailand also exported approximately 1,900 million litres of crude oil of, an increase of 11.2 per cent from 2010, valued at 39,055 million baht.

In 2011, 5,399 million litres of LPG and 984 million litres of natural gasoline,an increase of 21.6 per cent and an increase of 21.5 per cent from 2010 respectively, were used in Thailand (Alternative Energy and Efficiency Information Centre, 2011).

Thailand also imports crude oil. In 2011, 46,090 million litres at a rate of 794,226 barrels per day were imported, a decrease of 2.7 per cent from 2010. The value of the importswas 976,789 million baht,an increase of 29.6 per cent from the previous year. The Middle East supplied 77.5 per cent of the total imported oil, and 8.9 per cent, 8.2 per cent, 3.6 per cent, 1.6 per cent and 0.2 per cent were imported from the European countries, ASEAN countries, Asia-Pacific (excluding ASEAN countries), Africa and South America respectively. Butane and propane were also imported,approximately 2,616 million litres, which accounted for

38,902 million baht for petroleum products production (Alternative Energy and Efficiency Information Centre, 2011).

Thailand has eight refineries with a total capacity of 1,094,500 barrels per day, six natural gas separation plants and one small-sized Liquefied Petroleum Gas (LPG) plant gas processing unit (Alternative Energy and Efficiency Information Centre, 2011).

Gasoline. The average consumption of gasoline in 2011 was 20.1 million litres per day, decreasing by 1.1 per cent compared to 2010. The volume of gasoline consumption during October-November 2011 dropped due to the impact of the domestic flood crisis, along with the switch to NGV by a number of car users. Regular gasoline consumption share was 67 per cent: 42 per cent octane[12] 91 gasoline (ULG 91), and 25 per cent octane 91 gasohol (gasohol 91). Premium gasoline consumption remained at 33 per cent: one per cent octane 95 gasoline (ULG 95) and 32 per cent octane 95 gasohol (Gasohol 95).

Average **diesel** consumption in 2011 was 52.6 million litres per day, increasing by 3.9 per cent from the previous year, because the retail price of diesel was fixed at 29.99 baht per litre by the government from the beginning of 2011. Moreover, the government's relief measure suspending contribution collection to the Oil Fund, effective since 27 August 2011, resulted in a further reduction of retail diesel price by 3.00 baht per litre, which induced greater use of diesel. In addition, during the flood crisis, particularly between November and December 2011, diesel consumption greatly increased, as it was used for pumping water out of critically flooded areas.

Rapidly increasing oil prices in the last few years have stimulated efforts to find alternative energy sources to replace oil. The government has implemented measures and policies to promote the continuous increase of alternative energy consumption, especially alternative energy which can be produced domestically, such as, solar energy, wind energy, hydro energy, biomass, biogas, garbage, bio-fuel (gasohol and biodiesel) and NGV.

In 2011, **gasohol** accounted for 58 per cent of all fuel consumption, decreasing from 12.0 million litres per day in 2010 to 11.5 million litres per day (3.9 per cent decrease) due to the

[12]Octane is a measure of a fuel's tendency to knock or ping when it is mixed with air and burned in the cylinder of an engine. This octane rating is not based on the amount of chemical octane in the gasoline. The rating is called octane because the gasoline's ability to prevent engine knock has been rated against the performance of pure hydrocarbon octane, which has a rating of 100. Gasoline, which is made from a blend of many other hydrocarbons, may have a higher or lower rating, depending on how its anti-knock performance compares to the performance of pure hydrocarbon octane (Minnesota Department of Commerce, 2004, p. 2).

impact of a food crisis and also the suspension of collections by the government of contributions to the Oil Fund; the Fund was originally used to reduce the retail price for octane 95 gasoline by 8.02 baht per litre and octane 91 gasoline by 7.17 baht per litre. Thus, with the price subsidy gone, a large number of consumers turned to using gasoline instead of gasohol; the rates of contribution to and subsidy from the Oil Fund were reviewed and adjusted to increase the price gap between gasoline and gasohol. The new prices were not attractive enough to induce consumers to continue to use gasohol. The demand for octane 95 gasoline was 5.81 million litres per day in 2011, decreasing by 21.2 per cent from 2010 demand. The average price gap between octane 95 gasoline and octane 95 gasohol (E10) was 9.91 baht per litre before August, 2011 and was then adjusted to 4.72 baht per litre after August, 2011. Demand for octane 91 gasohol was 5.10 million litres per day in 2011, increasing by 19.9 per cent from the previous year. The average price gap between octane 91 gasoline and octane 91 gasohol (E10) was 7.12 baht per litre before August, 2011 and 3.02 baht per litre after August, 2011. By the end of 2011, the expansion of the octane 95 gasohol (E20) service-station network reached 830 stations, increasing from 542 stations in 2010 and octane 95 gasohol (E85) service stations increased to 38 stations in 2011 from 10 stations in the previous year.

Biodiesel consumption was 661 tonnes of oil equivalent in 2011 (Department of Alternative Energy Development and Efficiency, 2011). In 2011, the blending ratio of biodiesel (B100) in high-speed diesel was adjusted several times. Early in the year, there was a crude palm oil shortage (used in the production of biodiesel), making it necessary to reduce the ratio of B100 blending in high-speed diesel from the formerly available two grades with three per cent and five per cent of B100 blending to only one grade with two per cent B100 blending. The aim of the policy is cope with the scarcity of palm oil when it is out of season.

The demand for **Liquefied Petroleum Gas(LPG), Propane and Butane** in 2011 was 18.9 thousand tonnes per day, increasing by 15.9 per cent from 2010. Household consumption accounted for the largest share of total demand at 39 per cent; followed by feedstock for the petrochemical industry at 36 per cent, growing by 34.2 per cent; fuel used for vehicles was 13 per cent, increasing 35.3 per cent, resulting from the stabilization of LPG price for the transportation sector at a low level of 11.20 baht per litre; LPG used for the industrial sector was 10 per cent, decreasing by 7.8 per cent, because the government increased the retail LPG price for this sector to reflect the actual costthe increased price which was made every three months at three baht per kg per period.

Natural gas: Exploration and development of natural gas started in 1981 as part of a plan for the country to become less oil-dependent. The Department of Mineral Fuels (DMF) is responsible for granting concessions for exploration and development of oil and gas fields. As a result of exploration and development activities, the country was able to secure both onshore and offshore oil and gas reserves, such as gas fields in the Gulf of Thailand, and an oil field in the central plains (World Bank, 2008).

PTT is the sole operator of an integrated transmission and distribution pipeline system for natural gas. It procures natural gas from both domestic (73 per cent of the overall supply) and overseas sources (mainly Myanmar). PTT is also the largest gas separator in the country. PTT's current natural gas pipelines are approximately 2,700 kilometres long and capable of transporting 3,170 million cubic feet per day (Mcfd) of gas. The network comprises 2,400 kilometres of transmission pipelines, both on and offshore, and 300 kilometres of distribution pipelines. Three major offshore pipelines link the Gulf fields with the Rayong and Pattaya coasts. Their combined capacity is currently 3,350 million cubic feet per day of gas and is expected to increase to 4,500 Million Mcfd when the Arthit pipeline in the Gulf of Thailand has been provided with a compressor unit (World Bank, 2008). Thus,natural gas is based on an average production rate of 3,577 Mcfd. Natural gas production in 2011 totalled 1,305,530 Mcfd, which increased by 2.1 per cent from the previous year. Just over ninety-six per cent of total supply was from the Gulf of Thailand and the Malaysia-Thailand Joint Area (MTJDA). The remaining 3.8 per cent was from the Sin Phu Horm Field, Sirikit Field and Nam Phong Field (Alternative Energy and Efficiency Information Centre, 2011). In addition, natural gas, petroleum products and liquid natural gas were imported at approximately 990 Mcfd, 462 million litres and 98 Mcfd, valued at 93,923, 10,382 and 15,993 million baht respectively (Alternative Energy and Efficiency Information Centre, 2011) and NGV consumption in 2011 totalled 2,036 tonnes of oil equivalent (Department of Alternative Energy Development and Efficiency, 2011).

3.2.3 Trends in fuel prices

Table 3.1 provides a summary of trends in fuel prices between 2007 and 2011. These prices were large a result of various government decisions to encourage or discourage the use of fuels, and to raise revenue.

Table 3.1: Thailand's trend in fuel prices between 2007 and 2011

Type	Baht/Unit	2007	2008	2009	2010	2011
LPG (Cooking)	kg.	16.91	18.13	18.13	18.13	18.13
LPG (Auto)	litre	9.14	9.79	9.79	9.79	9.79
Unleaded Gas Octane No.91	litre	28.32	33.43	31.34	36.10	39.72
Unleaded Gas Octane No.95	litre	29.18	35.33	37.47	41.26	44.64
Gasohol E10 (Octane No.91)	litre	25.76	28.16	26.69	30.85	33.96
Gasohol E10 (Octane No.95)	litre	26.17	28.97	27.50	32.35	36.52
Gasohol E20 (Octane No.95)	litre	-	27.23	25.39	29.96	32.94
Gasohol E85	litre	-	18.29	18.87	19.21	21.75
Kerosene	litre	28.94	38.34	37.21	37.51	38.21
High Speed Diesel	litre	25.66	34.26	24.77	28.69	29.45
High Speed Diesel B5	litre	24.95	30.39	22.71	27.55	29.95
Palm Diesel	litre	24.97	30.52	22.85	22.85	22.85
Low Speed Diesel	litre	25.45	33.20	27.04	27.04	27.04

Source:Alternative Energy and Efficiency Information Centre (2011)

Fuel prices increased quickly in 2004, and then the Thai government started encouraging use of alternative energy sources, including Compressed Natural Gas (CNG). The demand for CNG increased significantly from December 2011 to April 2012, from 6.4 to 7.0 billion cubic feet per day. Prices of LPG as well as regular and premium petrol were also increased to 11.41 baht per litre ($0.37). Additionally, the government announced that the prices of octane 91 and 95 gasoline would also increase (Gordy, 2012).

In December 2012, the National Energy Policy Committee (NEPC) announced that retail CNG prices would also rise by 0.5 baht/kg ($0.02) per month starting in January 2012; the price of CNG increased from 8.5 baht per kg ($0.27) in December to 10.5 baht per kg ($0.34) in April 2012. However, in an effort to help reduce the increased cost of living in Thailand, the NEPC announced a freeze on the cost of CNG at 10.50 baht per kg ($0.34) for three months from 15 May 2012 (Gordy, 2012).

Jantraprap (2012) reported that a government decision to raise the prices of LPG and NGV in 2013 would likely increase the 2013-2014 income for PTT Public Company Limited by 5.1 per cent. In December 2012, the energy Minister, Pongsak Raktapongpaisal, announced a plan to raise the prices of NGV and LPG by 16-37 per cent from the currently capped prices aimed at lowering the country's oil fund deficit due to larger subsidies for LPG and NGV. However, subsidies for diesel remain unchanged with retail prices stable at 30 baht per litre ($0.97) because the government believes that diesel subsidies are essential for controlling price increases in other products. In addition, the price of gasohol has stayed the same. However, Thailand ranked sixth in the world list of countries which suffered from high fuel prices in 2012, with fuel priced at $4.96 per litre in relation to an average daily income of

$16, calculated by the percentage of average daily income needed to buy a gallon of fuel by Bloomberg (Randall, 2012).

The Thai ethanol industry continued to expand in 2013 due to the failure of policy effective 1 January 2013 of gasoline octane No.91. This is expected to increase the adoption of ethanol by at least 400 thousand litres per day or increase ethanol use from 1.30-1.40 million litres per day to 1.70-1.80 million litres per day in 2013. As a result, overall implicit price of ethanol increased due to the increasing cost from feedstock. Moreover, the price for ethanol in 2013 was expected to be slightly higher than 2012 due to feedstock cost from cassava and molasses.

3.3 Bio-ethanol processing

Cassava is the main feedstock for bio-ethanol production in Thailand. This section outlines the cassava feedstock preparation, how it is produced and the capital requirements for production.

3.3.1 Cassava feedstock preparation

Both cassava roots and cassava chips are used as feedstock for the production of bio-ethanol.

Cassava Roots

During the cassava harvest season, fresh roots are plentiful and the price is low. Therefore, it is common to use them to make slurry by grinding and then mixing them with cassava chips. Cassava roots can also be used as a main raw material and cassava chips added to adjust the solids concentration. There are two processes for preparing cassava fresh roots for bio-ethanol production: “with fibre” and “de-fibre” (Sriroth, 2011).

In the “with fibre” process, cassava roots are fed into a root hopper, in which root peelers remove soil and sand from the roots. The roots are then washed, chopped and rasped. The puree of milled roots is then mixed without fibre removal and used for liquefaction. This process requires less equipment and is recommended for batch-type fermentation (Sriroth et al., 2010). However, with the presence of cell wall materials, ground fresh roots develop semi-solid characteristics and need to be mixed with water to reduce viscous behaviour. This causes dilution of the solid loading in a fermenting machine, yielding a low ethanol concentration in the final product. A pre-treatment of ground fresh roots with appropriate cell wall degrading enzymes needs to be introduced to handle such an inferior flow ability

(Martinez-Gutierrez, Destexhe, Losen, & Mischler, 2004; Sriroth, 2011). The use of fresh roots with Very High Gravity (VHG) (high solid loading > 30 per cent) resulting in a higher ethanol concentration (Thomas, Hynes, & Ingledew, 1996). With nearly the same ethanol concentration as beer, the VHG process can not only improve the plant capacity but also minimize the energy consumed during the downstream distillation process.

In the "de-fibre" process, the starch slurry is prepared from fresh roots by modifying a typical cassava starch production process, similar to the wet milling process of cassava chips (see below). After de-sanding and washing, roots are chopped and rasped. The pulp is then removed and starch extracted. The starch slurry is then concentrated by a separator and subjected to a jet cooker for liquefaction. This process causes high starch losses in the pulp and requires higher investment cost. On the other hand, the "de-fibre" process is more controllable and can be readily applied to current well-established technology for ethanol production from other resources. It is also practical for concerning in high solid loading and continuous fermentation process (Sriroth, Piyachomkwan, Wanlapatit, and Nivitchanyong, 2010).

Cassava Chips

There are two processes for preparing cassava chips: "dry milling" and "wet milling" (Kuiper et al., 2007). In the dry milling process, chips are moved to the hopper and a stone and metal detector. Chips are sieved and milled in the hopper to obtain a fine powder. Coarse powders are re-milled. The fine powder, containing all components of the cassavaincluding fibresis mixed with water and proceeds to cooking and enzyme hydrolysis for ethanol production. The heat to cook the slurry is usually from direct steam because of the difficulties of handling particles and contaminants in the slurry. An extra separation unithydro cycloneremoves sand and other impurities from the liquefied chips. The dry milling process is appropriate for batch fermentation. Thailand uses several such plants and most plants in China apply this dry milling process because it uses less investment and equipment (Sriroth, et al., 2010).

The wet milling process had originally been developed to enable separation and extraction of various high-value products from corn, including corn gluten meal with high protein content, corn gluten feed and corn germ for oil extraction. The grains are initially cleaned and soaked in steeping water containing chemicals such as sulphur dioxide, typically, and lactic acid to soften the grains. The softened kernels are then milled to be suitable for a de-germination process. The separated germ is used for oil extraction. The de-germinated ground kernels are then passed through fine mills, enabling the fibres to be readily separated. The protein is further fractionated from the de-fibred starch slurry by centrifugal separators. After fractioning out each component, the remaining starch slurry is further processed to cooking and enzyme hydrolysis for ethanol production.

In the wet milling process of cassava chips, the starch slurry is made from dried chips by transforming the typical cassava starch production process. The chips are milled to fine powder before being mixed with water. The process is sometimes called the “starch milk” process. Starch is extracted from chips by a series of extractors. After de-pulping, the starch slurry is then concentrated by a separator and subjected to a jet cooker for liquefaction.

Wet milling produces high starch losses in the solid waste, but it is more convenient and can be applied with high solid loadings and in continuous fermentation processes (Sriroth et al., 2010). In contrast to the wet milling, the dry-milling process does not fractionate components, yielding a by-product of mixed components. However, although more valuable products are coproduced by the wet milling process, this process is capital and energy intensive and results in a lower yield of ethanol when compared to the dry-milling process (Licht & Agra, 2007). Currently, only a few plants use this process because it requires significant investment (Sriroth et al., 2010).

A modified dry-milling process has been developed for corn which removes both germ and fibre prior to fermentation (Wahjudi et al., 2000; Singh, 2003; Huang, Ramaswamy, Tscirner, & Ramarao, 2008). This combined process is less costly when compared to the wet-milling process while increasing the value added to the dry-milling process. However, do not contain other valuable components in the same way that corn does, so either process, wet-milling or dry-milling is suitable. The less-costly dry-milling process is, therefore, generally used for bio-ethanol production.

When cassava is used for bio-ethanol production, different forms, including fresh roots, chips and starch, can be used. Table 3.5 (see Section 3.3.3) summarizes the advantages and disadvantages of using different forms of cassava feedstock. Types of feedstock used for bio-ethanol plants depend on many factors, including plant production capacity, plant location, nearby cassava growing areas, amount of feedstock available and processing technology. Ethanol plants that are not close to cassava farms prefer to use dried chips to reduce costs of transportation and storage, while those located next to cassava fields use chips and roots.

3.3.2 Ethanol production

There are five main steps for cassava ethanol production (Sriroth, 2011), as illustrated in Figure 3.1:

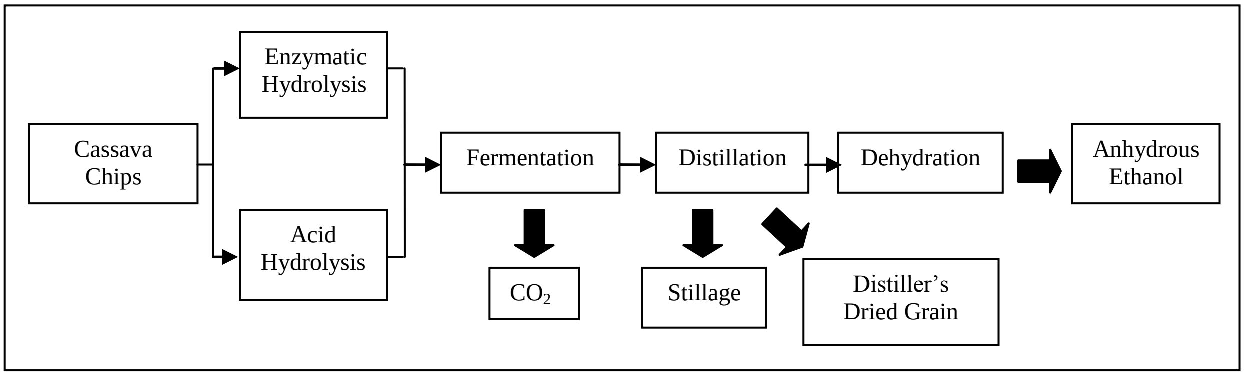

Figure 3.1: The production process of anhydrous ethanol from cassava chips
(**Source**: Yoosin & Sorapipatana (2007); Nguyen et al., (2008); Sorapipatana & Yoosin, (2011))

1. Preparation of feedstock: An important reason for this step is to prepare cassava for cooking, starch hydrolysis, fermentation and distillation, and dehydration. Generally, this step contains steps to purify the cassava: washing and peeling the fresh roots; removing soil, sand and metal by using a hydro cyclone; decreasing the size of the roots by rasping or milling; and separation of fibres.
2. Cooking: The starch is cooked to break down the granular structure and improve its susceptibility to enzyme hydrolysis. For the duration of cooking time, the thickness of the slurry is developed because of starch gelatinization and swelling of some particles. Consequently, liquefying cooked slurry enzymes, such as amylase, are used in the cooking process.
3. Starch hydrolysis: Starch can be changed to glucose by amylase (Gonsalves, 2006) and then, by gluco-amylase. Liquification using amylase is generally performed at high temperatures at which starch gelatinizes. After liquifying by enzymes, the liquified slurry is cooled down to an optimum temperature of about 50-55 °C for hydrolysis, which is dependent on the gluco-amylaseenzyme.
4. Yeast fermentation: The resultant glucose (from the hydrolysis process) is then fermented using yeast. By the end of fermentation, the achieved 'beer' contains approximately 10 per cent ethanol. Actual concentration of ethanol depends on the solids loading during fermentation.

5. Distillation and dehydration: The beer is subjected to distillation to concentrate the ethanol to 95 per cent and then water is removed, yielded anhydrous ethanol with 99.5 per cent ethanol.

Currently, the process of starch bio-ethanol is aimed at significantly decreasing processing time and energy consumption by using a process of simultaneous saccharification fermentation (SSF) processes (Gonsalves, 2006). In this SSF process, the liquified slurry is cooled down to 32 °C, then, gluco-amylase and yeast are added together. Gluco-amylase produces glucose and yeast uses glucose to produce ethanol. No glucose is accumulated during this fermentation process (Ronjnaridpiched et al., 2003).

There are by-products from sugar-based ethanol production: carbon dioxide, stillage and fuel oil. The carbon dioxide by-product produced in the fermentation process can be collected, purified and transformed for use in soft drink, coolant, dry ice, soda and fire extinguisher industries (Nguyen et al., 2008). The cassava waste is dried in the sun for 7-10 days and sold for the manufacture of animal feed at a low price (Kosugi et al., 2009). Moreover, the process of ethanol production will be fermentation utilizing bacteria and preferred technologies are Alfa Laval, Katzen, Maguin, Praj and Shandong, see Table 3.2.

Table 3.2: Thailand ethanol production by technologies

Technology	Cassava	Application
Alfa Laval	- Batch Fermentation (SSF) - a Multi Pressure, Multi Distillation Columns	- Thai Alcohol Plc
Katzen	- Fermentation (SSF) - a Multi Pressure, Two Distillation Columns	- Ratchaburi Ethanol
Maguin	- Cascade Fermented Continuous - Two Distillation Columns	- Thai Agro Energy - Petro Green
Praj	- Continuous Fermentation (SSF) - a Multi Pressure, Two Distillation Columns	- Khonkaen Alcohol - Thai Sugar Ethanol - KI Ethanol
Shandong	- Continuous Fermentation - a Multi Pressure, Two Distillation Columns	- Thai Nguan Ethanol

Source: Department of Alternative Energy Development and Efficiency (2008)

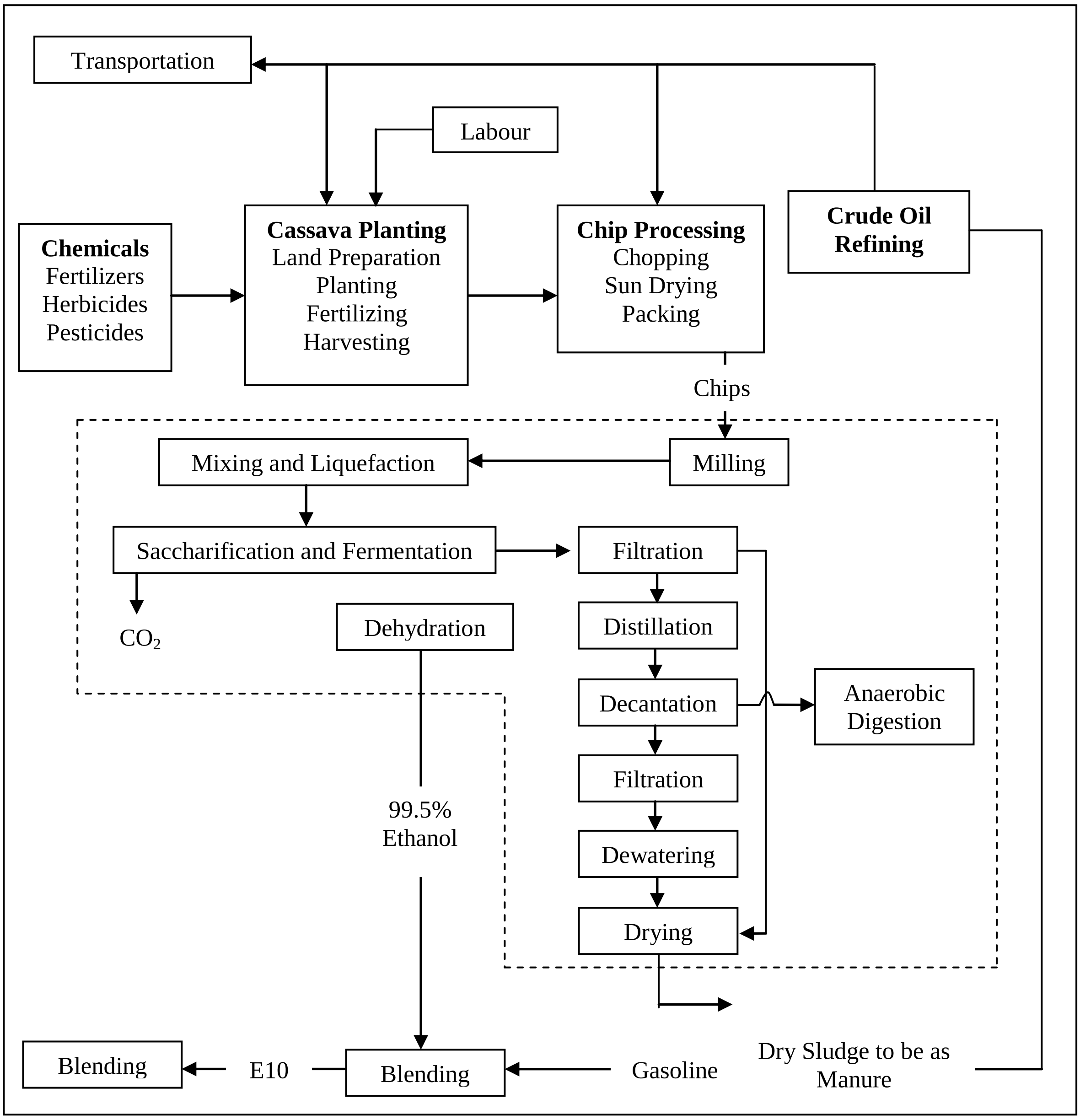

Figure 3.2: Flow chart of the production of cassava-based E10
(Source: Nguyen et al., 2008)

Figure 3.2 shows the process for producing cassava based E10.

1. Cassava production begins at the plantation where land is prepared through ploughing and ridging the soil before planting. The plants are then fertilized, weeded and harvested.
2. Harvested plants are sent for processing. Ethanol plants prefer dried chips for ethanol production rather than fresh root because they store for a longer period (up to eight months). Thus, cassava processing for ethanol production starts with the transport

offresh root cassava to an ethanol plant or to a processing plant, placing the roots into chopping machines, chopping into chips, sun-drying for two or three days until judged as ready for ethanol production.

3. Ethanol conversion which involves the steps described above of mixing and liquefaction, sacchacrification and fermentation, and dehydration or distillation.

Nguyen et al. (2008)calculated the profits for farmers and ethanol plant, and the benefits for rural employment stabilization from ethanol production using the following formulas:

$$retailprice = exrefineryprice + oilfund + taxes + marketingmargin + VAT$$

However,

$$exrefineryprice = exdistilleryprice + transportationordistributioncosts$$

and,

$$exdistilleryprice = cassavafeedstock + energycosts + chemicals + maintainancecosts + insurance + wagesandsalary + depreciation + profitmargin$$

The calculations derived:

1. Farmers receive a profit of approximately 2.2 baht per litre of ethanol produced from cassava.
2. Ethanol plants obtain a profit of between 1.5 and 1.9 baht or 10 per cent of production cost.
3. On average, if the Thai government produced 3.4 million litres per day of ethanol, farmers would benefit by 2,221 million baht and ethanol plants would earn 1,530-1,938 million baht a year.
4. Rural employment: the authors assumed that the production scale could stabilize the workdays of cassava production labourers as 21 million workdays per year.

3.3.3 Capital requirements

Gonsalves (2006) estimated that costs for cassava-based ethanol plants with a capacity of 1-2 million litres per day operated by Thai Oil PCL was $150-$200 million. If the plant capacity was 1.5 million per day, the cost would be $175 million based on the average currency in 2006. For other capacities, the cost is estimated as shown in Table 3.3.

Table 3.3: The estimated cost of ethanol plants sorted by capacity

Capacity (million litres per day)	Estimated cost $million
0.1	34.5
0.2	52.2
0.3	66.6
0.4	79.2
0.5	90.5

(**Source:** Gonsalves, 2006)

The most important cost factor of an ethanol plant is the distillation process, where fermented alcohol (10 per cent ethanol, 90 per cent water) is concentrated to anhydrous ethanol (99 per cent ethanol) (Gonsalves, 2006). In 2008, the Thailand Board of Investment (BOI) approved a project proposed by Petro Green Company Limited with 998 million baht in a 95 per cent ethanol production project with an annual production capacity of 66 million litres per year, 80 per cent of which would be sold to domestic energy companies such as PTT, Bangchak, Shell and Chevron (Investment Services Centre, 2008), and 1,500 million baht for the Impress Technology Company, with a capacity of 71 million litres per year to be sold to PTT and 1,375 million baht to Supthip company which produces 99.5 per cent ethanol with a capacity of 66 million litres annually (The Royal Thai Government, 2008). In addition, in 2010, the BOI invested 4,318 and 6,500 million baht in the Eternal Energy Public company and Suan Industry Energy company with a capacity of 214 and 140 million litres per year from cassava (Investment Services Centre, 2010).

Table 3.4 shows the existing and ongoing process of ethanol production in Thailand in 2012. The total ethanol production capacity was 3.065 million litres per day, produced from 26 operating ethanol plants, which is an increase from 19 plants in 2011. There are seven new cassava-based ethanol plants with 2.22 million litres per day of total production. Moreover, in the first quarter of 2012, ethanol plants operated 1.89 million litres per day on average, an increase of 32.2 per cent from 2011, including cassava-based ethanol plants which operated at 0.14 million litres per day, decreased 50 per cent from the previous year (Pratruangkrai, 2012). As a result, some cassava-based ethanol plants stopped their operation. Additionally, there were 20 ethanol plants existing in Thailand with capacity 3.27 million litres per day and five processing plants using cassava as feedstock with capacity a 1,820,000 litres per day, including: i) TPK Ethanol phase 1,2 and phase 3, ii) Double A Ethanol, iii) Sima Inter Products, iv) Impress Technology and v) Thai Agro Energy (Department of Alternative Energy Development and Efficiency, 2013).

Table 3.4: List of existing ethanol plants in Thailand in 2012

Plant	Capacity (litres/day)	Feedstock	Commencing Date
1. Pawn WiLai Inter Group Trading	25,000	Molasses/Cassava	Oct 03
2. Thai Agro Energy	150,000	Molasses	Jan 05
3. Thai Alcohol	200,000	Molasses	Aug 04
4. Khon Kaen Alcohol	150,000	Molasses	Jan 06
5. ThaiNguan Ethanol	130,000	Fresh and Cassava Chips	Aug 05
6. Thai Sugar Ethanol	100,000	Molasses	Apr 07
7. KI Ethanol	100,000	Molasses	Jun 07
8. Petro Green	230,000	Molasses/Sugarcane Juice	Jan 08
9. Petro Green	230,000	Molasses/Sugarcane Juice	Dec 06
10. Ekrath Pattana	230,000	Molasses	Mar 08
11. Thai Rung Rueng Energy	120,000	Molasses	Mar 08
12. Ratchburi Ethanol	150,000	Cassava Chips	Jan 09
13. ES Power	150,000	Cassava Chips	Jan 09
14. Maesawd Clean Energy	200,000	Sugarcane Juice	May 09
15. Sup Thip	200,000	Cassava Chips	May 10
16. Tai Ping Ethanol	150,000	Fresh and Cassava Chips	Jul 09
17. PSB Starch Production	150,000	Fresh and Cassava Chips	Aug 09
18. Petro Green	200,000	Molasses/Sugarcane Juice	Dec 09
19. Khon Kaen Alcohol	200,000	Molasses/Sugarcane Juice	2011
Total	**3,065,000**		
Processing Plants in 2012			
20. PTK Ethanol -Phase 1	340,000	Cassava Chips	2012
21. PTK Ethanol -Phase 2,3	680,000	Cassava Chips	2012
22. Thai Agro Energy Phase 2	200,000	Cassava Chips	2011
23. Double A Ethanol	250,000	Starch	2012
24. Sima Inter Products	150,000	Fresh Cassava	2012
25. Impress Technology	200,000	Fresh and Cassava Chips	2012
26. Ubon Bio Ethanol	400,000	Fresh and Cassava Chips	2012
Total	**2,220,000**		
Total Production Capacity	**5,285,000**		

(**Source:** Department of Alternative Energy Development and Efficiency, 2013)

Table 3.5: Problems and barriers to ethanol production in Thailand

Type	Problems and barriers
Technical	- Planting areas for energy crops are restrictive - Lack of expert personnel - Insufficient feedstock to produce ethanol, if government promotes using at nine million litres per day in 2022
Economical	- Sometimes, ethanol cost higher than fossil fuel - Oil pricing fluctuation - Unstable feedstock which may be glut and scarce
Policy and regulations	- There are stable and confident government policies for farmers, entrepreneurs and investors

(**Source:** Department of Alternative Energy Development and Efficiency, 2008; Sriroth, 2011)

3.4 Value chain for bio-ethanol production

Cassava chips are used for producing animal feed and bio-ethanol industry. That is, the bi-product of ethanol production is suitable for use as animal food. Unmodified and modified starches are used by many industries, both food industries and non-food industries, as, shown as Figure 3.3.

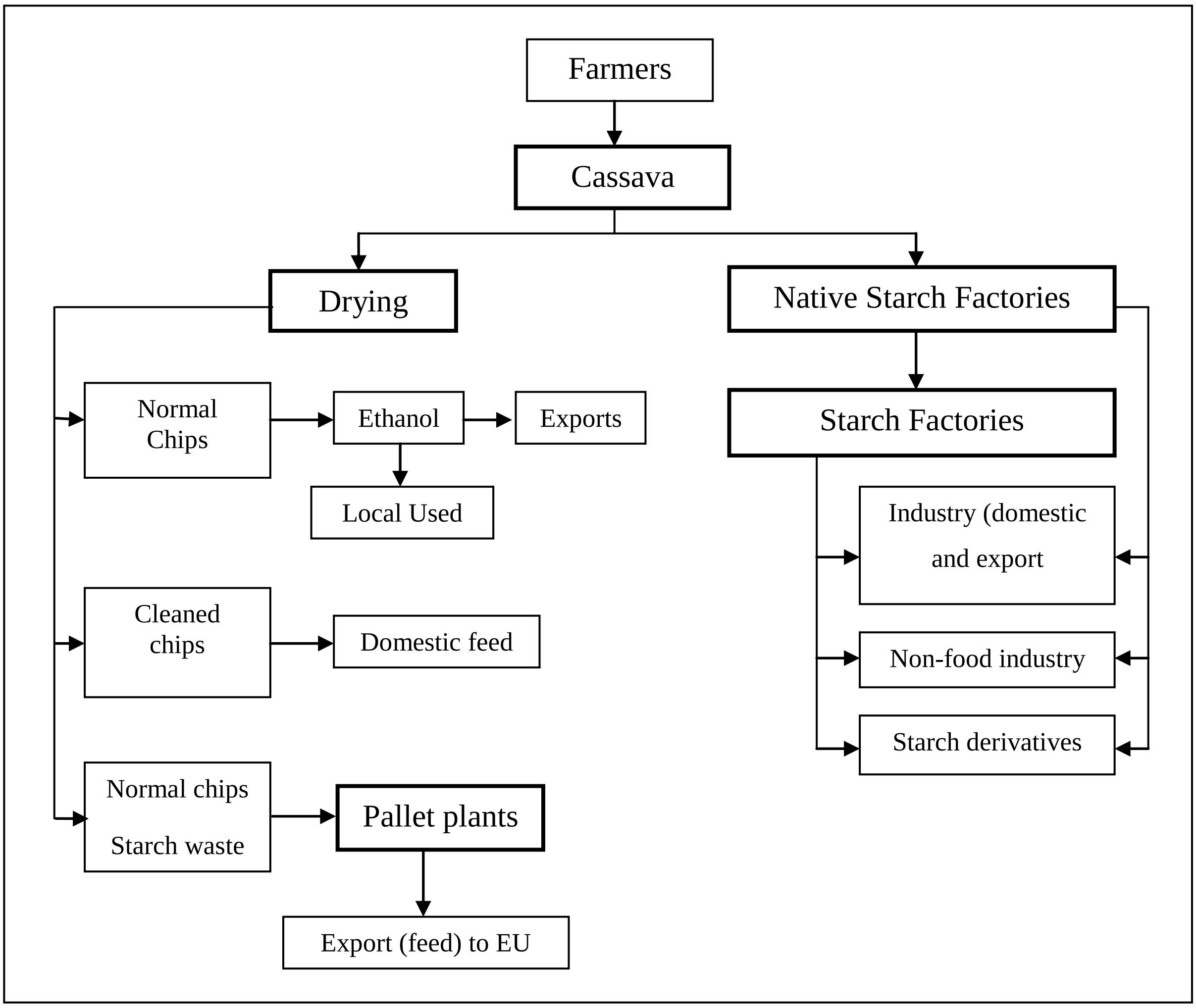

Figure 3.3: Thai cassava value chain
(**Source:**Sriroth, Lamchaiyaphum, & Piyachomkwan, 2007; Kaplinsky, Terheggen, & Tijaja, 2011)

There are many stakeholders involved in the ethanol production process in Thailand: i) farmers, who are directly involved as suppliers of feedstock for ethanol production; ii) middle merchants, primary processing factories, the Ministry of Agriculture and Cooperatives, the Ministry of Commercewho buy, process, transport and support the farmers; iii) the ethanol industry, producers and distributors of ethanol production technology, the Ministry of Industry, the Ministry of Science and Technology and Ministry of Energywho work on the ethanol production; and iv) marketers and distributor of the product to energy users, including oil-trading companies, oil refineries, oil service stations, automobile industry, Excise Department, Customs Department, industrial factories and people who use the bio-ethanol as gasohol for their vehicles (Sriroth et al., 2007; Sriroth, 2011).

Ethanol manufacturers in Thailand are stepping up efforts to find international markets after government policy reversals have left domestic sales at much lower rates than expected, and increased doubts about ambitions to create the country as an Asian hub for the fuel. Thailand can produce 3.26 million litres a day from 20 plants and the government wants to almost triple that in 10 years to nine million. Nevertheless, domestic demand is just 1.2-1.3 million litres a day and plants are running at half capacity because the government has wavered on trying to prod motorists to use more gasohol, a blend of ethanol and gasoline. Producers have also been squeezed by government intervention to help farmers, which has pushed up the price of cassava chips (Phoonphongphiphat, 2012). Additionally, Preechajarn and Prasertsri (2012) reported that producers were targeting traditional ethanol importers such as Singapore, South Korea, Taiwan and Japan which use ethanol in the liquor, chemical and bio-fuel industries. The new cassava ethanol plantswill produce 400,000 litres per day when fully operational, and there are reports that there is an export contract for 100 million litres per year to China (Bangkok Post Business, 2012). The share of starches in China's total cassava imports from Thailand has grown from six per cent in 2002 to 27 per cent in 2008 (Tijaja, 2010) and to 27.8 per cent in 2009 (Kaplinsky et al., 2011). Half of Thailand's ethanol exports are destined to supply the Filipino market where prices are running at about $672 per cubic metre with 26.7 million litres of ethanol exported (The Nation, 2012).

In an effort to create a new energy plan, the Thai Government has developed a planto increase the average yield of cassava to more than five tonnes per rai (31 tonnes per hectare) by 2021, netting a total production about 35 million tonnes of cassava per year. The State Oil Fund of the Thai government will subsidize E20 gasohol by 30 baht per litre for (80 per cent gasoline and 20 per cent ethanol) which is cheaper than gasohol octane number 95. Additionally, the Thai government plans to give a 0.5 baht per litre marketing margin on top of the octane 91 gasoline sales for gasoline stations to increase the E20 gasohol sales. The Government will continue to supportthe manufacture of Eco-cars (E20 vehicles) by dropping the tax for automobile manufacturers by 30,000 baht per vehicle, and flex-fuel vehicles (FFV), which are compatible with E85 gasohol (a blend of 85 per cent ethanol and 15 per cent gasoline), by 50,000 baht for each vehicle (Preechajarn & Prasertsri, 2012).

In 2012, there were 21,065 fuel stations in Thailand, including gasoline, gasohol, biodiesel, 472 NGV gas stations and 1,129 LPG gas stations. PTT is the largest petroleum operation in Thailand (Department of Business Energy, 2013) and has 23.89 per cent of the market share. It is ranked 128 among the top 500 companies in the world (Fortune Magazine, 2011), followed by Bangchak, ESSO Thailand, Shell Thailand and Chevron Thailand which account for 26.11, 11.41, 13.15 and 7.54 per cent market share respectively (excepting others which are the traders who do not use the trade mark of fuel traders under section seven of the Fuel Trade Act, B.E. 2543)(Bureau of Fuel Trade and Stockpile, 2013), as shown in Table 3.7. In total, 4,032.27 million litres of gasohol, including gasohol E10, E20 and E85 was used in Thailand in 2012 (12.08 million litres per day) (Department of Business Energy, 2013).

With regard to gasohol, there are 1,378 gasohol stations including gasohol E20 and E80. PTT is the biggest distributer of gasohol E20 and has 51.15 per cent of the market share, while Bangchak is the largest distributer of gasohol E85 with a market share of 75.00 per cent in 2012 (Department of business Energy, 2013), as shown as Table 3.6.

Table 3.6: Thailand gasohol stations in 2012

	2008		**2009**		**2010**		**2011**		**2012**	
	E20	**E85**	**E20**	**E85**	**E20**	**E85**	**E20**	**E85**	**E20**	**E85**
PTT	103	3	140	3	241	5	370	8	670	16
Bangchak	91	1	131	2	297	5	454	30	574	51
PTT Group	0	0	0	0	4	0	6	0	66	0
Rayong Pure	0	0	0	0	0	0	0	0	0	1
Total	194	4	271	5	542	10	830	38	**1,310**	**68**

(**Source:** Department of Business Energy, 2013)

Table 3.7: Number of petrol stations selling fuels in Thailand (September 2012)

Provinces	Total	PTT	Shell	ESSO	Chevron	Bangchak	Thai Oil	Rayong Pure	Susco	PETRONAS	PTG Energy	IRPC	PTT Groups	P.C.	Saeng Thong	Picnic	World Gas	Unic	Siam Gas	P.A.P	N.S. Gas	Takuni	Others[13]
Bangkok	890	155	117	110	65	106	-	4	12	44	14	-	22	-	13	18	48	2	68	11	9	13	59
BKK Surroundings	693	80	48	67	36	64	-	2	6	18	15	-	30	-	2	26	46	6	42	-	-	6	199
Central Plain	1,276	94	31	29	24	80	-	12	5	8	31	-	18	-	-	2	16	4	19	14	1	-	888
North	4,890	224	84	87	59	246	-	13	31	14	118	-	10	-	-	5	42	37	36	1	-	-	3,883
North-eastern	7,470	336	81	66	72	308	-	22	29	1	192	-	12	-	-	-	33	24	109	1	-	2	6,182
East	1,644	142	64	41	45	97	2	10	10	7	52	1	34	-	-	6	36	4	27	10	1	-	1,055
West	1,899	167	40	66	25	78	-	6	3	5	73	-	20	1	2	39	43	16	27	7	1	5	1,275
South	2,303	191	73	51	49	84	-	-	44	-	32	-	-	10	-	4	8	17	30	-	-	-	1,710
Total	21,065[14]	1,389	538	517	375	1,063	2	69	140	97	527	1	146	11	17	100	272	110	358	44	12	26	15,251

Source: Office of the Council of State (2000) and Bureau of Fuel Trade and Stockpile (2013)

[13] Others are the traders who do not use the trade mark of fuel traders under section 7 of the Fuel Trade Act, B.E. 2543: any person is a fuel trader having a trade volume of each type of fuel or in all types altogether per year from one hundred thousand metric tonnes or upwards, or a fuel trader of only liquefied petroleum gas having trade volume per year from fifty thousand metric tonnes or upwards shall have a license to operate fuel trading granted by the Minister.

[14] Including 472 NGV gas stations and 1,129 LPG gas stations.

3.5 Summary

Cassava is not only a food crop in developing countries, it is also an industrial crop, serving as an important raw material for alternative energy. There are some important cassava products such as starches, modified starches and sweeteners, which are used by several industries, for example, textile, paper, adhesive, pharmaceutical, biomaterial products and building industries. As a result, demand for cassava has been increasing.

Currently, Thailand uses cassava as the feedstock for producing bio-ethanol as a renewable alternative fuel for automobile uses. The fuel is also attractive because it is environmentally friendly. The idea of using cassava for bio-ethanol is supported by many reasons, including low input requirements relative to other commercial crops, distinct plant agronomic traits for high tolerance to drought and soil infertility, and the potential for improvements of root yields. Additionally, cassava roots contain low impurities and are rich in starch, even though fresh cassava roots are perishable and contain high moisture content.

Cassava chips are less costly to store, transport and process. High energy inputs for ethanol production from starch sources are becoming less of a concern because low energy consumption processes are being developed, such as SSF, which can attain higher ethanol concentration which are VHG. With those developments, the use of cassava as an energy crop is becoming an increasingly feasible solution to address fuel and food security.

CHAPTER 4: CASSAVA PRODUCTION AND RELATED INDUSTRIES

4.1 Introduction

Root or tuber crops play a crucial role in the agricultural sectors of many countries. These crops provide an important source of animal feed and a raw material for industrial products. The most important role of root crops is their contribution to the world's food supplies (Office of Agricultural Economics, 2009). Unlike cereal crops, the root that is the edible part of the plant can be kept underground until needed. With this characteristic, root crops may serve as substitute foods when other food or cereal crops are in short supply. Root crops, such as cassava, potato, sweet potato and yam, have provided household-level food security for more than 2,000 years (Rijks, 2003).

Among several root crop varieties, cassava (*Manihot* sp.) is one of the main root crops growing in many developing countries located in a low latitude region (Itharattana, 2003). Cassava was introduced into Thailand via Malaysia sometime between 1786-1840 (Atthasampunna, 1992) for making starch and sago in the south of Thailand. The plants were grown between rows of rubber trees. Later, with the increasing expansion of rubber cultivation in the southern region, cassava growing in the south gradually decreased and the cultivation spread to the east and north-east region (Phruetthithep, Thanomsub, Masari, & Noowisai, 2009). At present, there is no cassava cultivation in the southern region (Parthanadee, Buddhakulsomsiri, Monthatipkul, & Khompatraporn, 2009).

World annual production of cassava is approximately 250 million tonnes, which increased by about 13 per cent in 2006-2009 and fell in 2010 due to a poor harvest in Thailand because of drought and diseases in that country. Africa produces more than half of the world's contribution, with Nigeria the largest contributor. Asia promotes the growth of cassava crops for industrial and alternative energy reasons; it contributes about a third of world production, with 60 per cent from Thailand (approximately 25 million tonnes) and Indonesia (22 million tonnes) (United Nations Conference on Trade and Development, 2012). However, Thailand has long dominated world cassava trade, controlling 70 per cent and 90 per cent of the world's dried cassava and cassava starch exports respectively (Tijaja, 2010).

This chapter is organized as follows. Cassava cultivation in Thailand and Thailand's cassava production are discussed in Sections 3.2 and 3.3, followed by consideration of related industries in Section 3.4 and closing with a summary in Section 3.5.

4.2 Cassava as a 21st century crop

Cassava is a woody perennial shrub growing from 100 to 500 cm in height. It has been cultivated, mostly for its starchy roots, for 9,000 years, making it one of agriculture's oldest crops (Martinez-Gutierrez et al. 2004; Allem, 2002). In pre-Colombian times, it was grown in many areas of the Caribbean islands, Mesoamerica and South America (Allem, 2002). Following the Portuguese and Spanish occupation, cassava was taken from Brazil to the Atlantic coast of Africa. By the 1800s, it was being grown in Southern Asia and along Africa's east coast. Farming of cassava expanded considerably in the 20th century, when it emerged as an important food crop across sub-Saharan Africa, India, the Philippines and Indonesia (Allem, 2002). Because it has a growing season of nearly one year and is sensitive to frost, cassava is cultivated almost completely in tropical and subtropical regions. It is grown today by millions of smallholders in more than 100 countries, from American Samoa to Zambia, Brazil, Honduras, Indonesia, Kenya, Nigeria, Viet Nam to Thailand (Howeler, Lutaladio, & Thomas, 2013). Howeler et al. (2013) point out that the characteristics of cassava make it very attractive to smallholders in rural areas where rainfall is low and soil is poor. Because it is propagated from stem cuttings, planting material is low-cost and readily available. Cassava is highly tolerant to acid soils and has formed a symbiotic association with soil fungi that help its roots absorb phosphorus (P) and micronutrients.

Cassava roots are more than 60 per cent water but their dry material is very rich in carbohydrates at around 300 kg per tonne of fresh roots (Pérez, 1997). The best time to harvest is between eight and ten months after planting if the root is used as food; a longer period of growing creates higher starch content. Nevertheless, harvesting of some varieties can be as needed at any time between 6 and 24 months. Cassava is a rich source of nutritional energy. Its energy yield per hectare is frequently higher than that of cereals (Latham, 1997). In many countries of sub-Saharan Africa, cassava is the cheapest source of calories available. Additionally, Pérez (1997) showed that cassava roots contain major amounts of vitamin C, thiamine, riboflavin and niacin.

However, they may also contain high levels of cyanogenic glycosides,[15] particularly in the outer layers (depending on the variety) (Fukuba, Igarashi, Briones, & Mendoza, 1982). Once harvested for food, cassava roots are peeled then carefully cooked, grated and soaked to make fermentation to release the volatile cyanide gas. The pulp is processed further by boiling, roasting or drying to make it into common flour and other food products.

Cassava leaves are 25 per cent protein (dry weight basis). In some countries, therefore, it is also grown for its leaves (Latham 1997; Chávez et al., 2000). Cooking or sun-drying decreases the hydrogen cyanide of cassava to harmless levels. Both roots and leaves can be feedstock for animals, cassava stems can be used firewood and growing mushrooms. Cassava root starch can be used in many industries, including pharmaceuticals, food manufacturing, plywood, paper, textiles and feedstock for ethanol bio-fuel production.

Cassava farmers in Asia produce 30 per cent of the world cassava crop. Over the past three decades, their cassava production has increased by 66 per cent, from 45.9 million tonnes in 1980 to 76.6 million tonnes in 2011, with average yields increasing from 11.8 tonnes per ha to 19.5 tonnes per ha (Howeler et al., 2013). As in Africa, cassava was mostly a smallholder crop grown as a store in case of shortfalls in the rice harvest and as on-farm animal feed (Kawano, 2003). In the 1990s, the Thai government began to distribute new, higher-yielding varieties of cassava to farmers together with improving farmer's access to mineral fertilizer and extension. This strategy caused a two-thirds increase in yields of cassava in Thailand in the period 1990-2009, increasing average yields of cassava and boosting smallholders' incomes by an estimated US$650 million, lifting many cassava farmers out of poverty (Abdulai, Diao, & Johnson, 2005).

In general, in Asia, cassava production has much increased by 55 per cent, as many countries seek to join in the profitable export markets and supply important consumers such as those in China; in 2000-2009, China's annual imports of dried cassava increased from 0.26 million tonnes to more than six million tonnes and imports of cassava starch increased to 1.2 million tonnes, a doubling from the previous year.

[15]Cyanide is among the most potent and deadly poisons, existing in gaseous, solid and liquid forms.Cyanide is used in many industries. Humans can be exposed to cyanide by eating cyanogenic foods, such as the tropical root cassava, that contain cyanogenic glycosides that liberate cyanide when metabolized in the body. Additional sources of cyanide exposure include metabolites of the antihypertensive drug nitroprusside, suicide attempts and malicious acts such as murder attempts or terrorist attacks. Cyanide is a potential chemical weapon for use by terrorists because it can be easily obtained and dispersed and may be rapidly incapacitating or even lethal(Geller, et al, 2006)

In 2010, Thailand dominated the world export trade for cassava, shipping six million tonnes of dried cassava chips and starch worth US$1.5 billion (Thai Tapioca Starch Association (TTSA), 2012). However, Thailand faces increasing competition from Vietnam, Indonesia, Cambodia, Lao PDR and the Philippines. Vietnamincreased its cassava production from two to nine million tonnes between 2000 and 2010, and exported one million tonnes of dried cassava in 2010. As well, in Indonesia, cassava exportsincreased from 0.15 million tonnes in 2000 to 1.4 million tonnes in 2010 (Poramacom, 2012). Many Asian countries which are seeking to decrease reliance on imported fuels and reduce greenhouse gas emissions, such as the Republic of Korea, Japan and China, are using cassava feedstock as an alternative energy source (Howeler et al., 2013).

Cassava's new status in agriculture was an important step forward in the formation of a global cassava development strategy, which was adopted in 2001 after four years of consultation between the International Fund for Agricultural Development (IFAD), the Food and Agriculture Organization (FAO), 22 cassava-producing countries, and private and public sector partners (Plucknett, Phillips, and Kagbo, 2000). The policy recognizes the potential of cassava to not only meet food security needs but also provide a source of higher incomes for traders, processors and farmers, and an engine for rural industrial development (Plucknett et al., 2000).

An important driver of increasing production rates is the high prices of cereals on world markets, whichsparked global food price increases in 2008. In Africa, persistent urban poverty has boosted the use of cassava food products as consumers seek cheaper sources of energy (Sanni et al., 2009). Among the recommendations by FAO to governments for holding down food prices was processing cassava into products that were profitable as instant foods with a long shelf life (FAO, 2011). At present, cassava suppliesonly a small part of production but demand from China is growing quickly following its decision to decrease using cereals to make bio-fuels. Howeler et al. (2013) reported that 50 per cent of China's ethanol is derived from cassava roots and sweet potatoes, and in 2012 it was expected to use six million tonnes of dried cassava for producing 780 million litres of ethanol.

Ceballos et al. (2007) reported thatbetween 2000 to 2007, Thailandearned approximately US$4 billion from starch exports, Thai scientists have been developing a variety with root starch which provides premium starch. A new cassava mutation offers smaller root starch granules that decrease significantly the time and energy required for the production of cassava-based ethanol.

An additional attractive factor driving increased cassava production is the potential of cassava to adapt well to climate change.

Policymakers, industry and farmers are looking for ways to increase the yield of cassava (Hershey et al., 2012). Smallholder farmers in Thailand, India and Brazil have been extremely successful in commercial production with between 25 and 40 tonnes per ha of cassava yields. African cassava yields are less than half the global potential yield, although root harvests of up to 40 tonnes have been produced in on-farm experiments (Marijke, 2009). Howeler et al. (2013) concluded that the future of cassava is likely to see an increase in mono-cropping on larger cassava planting areas, the widespread adoption of higher yielding genotypes that are more suited to industrialization, and higher rates of use of irrigation and agrochemicals.

Mono-cropping, however, can threaten good cassava yields. In northeast Thailand, multiple years of cassava production in upland areas have seen decreases of yield due to the failure of farmers to incorporate residues in the soil, employing tillage practices that removed soil cover and also soil fertility because of erosion (Polthanee, Wanapat, Wanapat, &Wachirapokorn, 2001). In Colombia, with the problem of soil degradation over nine years not addressed, the yields of mono-cropped cassava production decreased from 37 tonnes to 12 tonnes per ha. Nigeria as well is facing the same problem because of increasing soil erosion when traditional mixed cropping is replaced by mono-cropping (Odemerho & Avwunudiogba, 1993). Traditional poly-culture practices have been found to be highly successful for decreasing the soil erosion problem (Odemerho and Avwunudiogba, 1993). In Vietnam, mono-cropping of cassava produced 19 tonnes of yields but resulted in severe, unsustainable soil losses to erosion of more than 100 tonnes per hectare (Howeler, 2000).

In 2011 the Thai Commerce Ministry consideredbringing back the pledging scheme for cassava production to shore up prices. However, the pledging project for cassava was cancelled in 2008. Although the Abhisit Vejjajiva administration later launched an income guarantee for cassava, farmers did not participate in the project as the market price was higher than the guaranteed price due to a shortage of cassava following drought and pest infestation (Pratruankrai, 2011). Since the Thai government launched the cassava pledging program in 2012, there have been more than 600 tapioca processing plants, with approximately 700,000 tonnes of cassava joining in the project. However, the government conceded that Thai exports of tapioca have suffered some setbacks.

Concerning the pledging scheme, the Commerce Minister expected around 6 million tons likely to be pledged with the government. He went on to say that the government has instructed all related state offices to clamp down on all irregularities related to the cassava pledging program(Chaichalearmmongkol, 2012).

Theparat, C. (2013) reported that the Thai government has allocated 44 billion baht to subsidise cassava root for the 2012-2013 crop in 2013. Under the new pledging scheme, which ran from Oct 1, 2012 to March 31, 2013, the state initially paid 2.50 baht per kg for cassava root, raising the amount by five satang each month until it reached 2.75 baht this month. The purchasing goal was at 15 million tonnes of cassava root for this season. The state pledged 10 million tonnes of cassava root out of a total production of 24 million tonnes in the previous season, with 27 billion baht paid. Moreover, the government's tapioca pledging scheme has drawn relatively lukewarm interest from farmers, as the drought that threatens to lower production this year has led buyers to offer better prices. Thus, the government had pledged 5.41 million tonnes of fresh cassava root for the 2012-13 crop, while the Bank for Agriculture and Agricultural Cooperatives has paid farmers 7.61 billion baht (Theparat, C., 2013).

From this evidence, the Thai government would carefully consider whether to adopt the pledging scheme for cassava, as it would entail additional budgetary funding to subsidize crops over and above the cost of the rice pledging scheme.

4.3 Cassava cultivation in Thailand

Cassava is used in many industrial sectors for humans and animals, especially in the form of starch. Cassava can grow with good resistance to pests, diseases and drought and produce a good yield. There are two major types of cassava, depending upon their hydrocyanic acid content: bitter cassava or industrial cassava. Bitter cassava is for making starch and other derivatives, and sweet cassava is for direct use of the tuber. The demand for cassava chips, starch and derivatives is growing due to longer preserving and more competitive prices compared with other staple food crops.

Cassava is a main animal feed for export in the form of dry chips and pellets. Approximately 80 per cent of cassava is transformed into starch for domestic use and export. The most important market is the European Union (EU) (Ratanawaraha, Senanarong, & Suriyapan, 2000). The cassava plant is a starch-accumulating crop which is classified into two types: bitter and sweet cassava. Bitter cassava has a higher level of hydrocyanic acid than sweet cassava, thus bitter cassava is not suitable for directly eating. However, bitter cassava contains a high level of starch which can make fermentable sugar using acid or enzymes. As a result, bitter cassava is called industrial cassava and is grown on a large scale in Thailand (Sorapipatana & Yoosin, 2011). Sweet cassava is planted only on a small scale and on single household farms (Gheewala, 2012). The most popular variety of industrial cassava is a local variety. A selection from this local variety was named “Rayong 1”, released in 1975, and used as a source of industrial raw material (Ratanawaraha, Senanarong, and Suriyapan, 2000). There are five other important varieties of cassava in cultivation in Thailand: (Sriroth, 2007; Senadee, Aksornneum, Khemdaeng, & Boonpeomrasi, 2008; Sangpenchan, 2009):

1. Rayong 60: the hybrid varieties between “Mcol 1684” and “Rayong 1” at Rayong Field Crops Research Centre was grown in 1982 and named " Rayong 60" to celebrate the 60th year of His Majesty King Bhumibhol.
2. Kasetsart 50: the hybrid of “Rayong 1” and “Rayong 90”, was developed by Kasetsart University, the Department of Agriculture and the Centro International de Agricultural Tropical (CIAT) at Sri Racha Agricultural Research Station and was grown in 1984. It was named "Kasetsart 50" to celebrate the 50th anniversary of the establishment of Kasetsart University in 1992.
3. Rayong 5: a combination of “Rayong 3” and “27-77-10” developed at the Agronomy Research Centre, Rayong province in 1982.
4. Huay Bong 60: developed by Thailand Tapioca Development Institute and the Department of Agronomy, Faculty of Agriculture, Kasetsart University. This variety is a hybrid of “Kasetsart 50” and “Rayong 5.” Named "Huay Bong 60" to celebrate the 60th anniversary of the establishment of Kasetsart University of Agriculture in 2003.
5. Huay Bong 80: developed by Thailand Tapioca Development Institute and the Department of Agronomy, Faculty of Agriculture, Kasetsart University between “Rayong 5” and “Kasetsart 50” at the Sri Racha Agricultural Research Centre in 1991. Named "Huay Bong 80" to celebrate the 80th birthday of His Majesty King Bhumibhol.

Three important institutes are involved in cassava research in Thailand, with objectives to increase cassava root starch content and higher yields:

1. Rayong Field Crops Research Centre (RAY-FCR), Department of Agricultural (DOA),
2. Sriracha Research Centre of Kasetsart University (KU), and
3. Research and Training Centre of the Thai Tapioca Development Institute (TTDI).

In addition, there are four official trade associations:

1. North-eastern Tapioca Trade Association (NETTA),
2. Thai Tapioca Products Factory Association (TTPFA), which are regionally based,
3. Thai Tapioca Starch Association (TTSA), which represents the starch value chain, and
4. Thai Tapioca Trade Association (TTTA), which is the oldest and largest association and is dominated by the larger dried cassava producers and exporters.

There are four steps to the cassava planting process in Thailand as follows (Nguyen et al., 2008):

1. Land preparation: Cassava is a tropical root crop which grows in a broad area of rainfall (approximately 1,000-2,000 mm per annum) in Africa, Asia and Latin America, and is traditionally produced by smallholder farmers (Howeler, Oates, & Allem, 2000). In Thailand, most of the cassava is grown as a sole crop (Onwueme, 2002). Occasionally, it is intercropped with maize, groundnut and rubber or coconut. Normal spacing in sole cropped cassava is 1 x 1 m^2. Land preparation is less if soil is sandy; however, the soil should be ploughed twice with three-disc and seven-disc ploughs to loosen the soil for easier survival and growth of cassava roots, and to kill weeds in the planting area (Hershey et al., 2001; Sriroth et al., 2010). Additionally, farmers should plough within three days after rainfall to ensure moisture is kept in the soil for cassava growth over the dry season.

2. Weed control is important in the early growth stages of cassava because the crop is slow to establish and cover the ground. Weeding is often the most labour-intensive aspect of cassava production (Cock, 1985). Weeding can be done by hand between the ridges, and then by spraying with weedicide such as Paraquat[16] and Grammoxone[17]. However, when chemicals are used, farmers have to check very carefully that these chemicals do not cause any damage to the cassava (Sriroth et al., 2010). On sloping land, ridges should be constructed against

[16] Paraquat is a quarternary nitrogen herbicide with highly toxic compound for animals and humans (Suntres, 2002).
[17] Grammoxone is a non-residual contact herbicide which is not absorbed by bark, used for growing forestry nursery stock and also for weed control in orchards, forestry and bulb production with the active ingredient named “Paraquat” (Smith, Heath, & Fishman, 1976).

the water flow. This is important for increasing cassava yield and reducing soil erosion (TTSA, 2012).

3. Planting: Cassava can be planted any time of year. However cassava requires high moisture content in the soil during its early growth stage. The plant's physical characteristics dictate a different agricultural practice to those used for cereal crops. Cassava root is developed underground, thus, the flowering and seed production periods are less important than those of cereal crops. The most important cropping periods for cassava production are the planting period and the harvesting period (Rijks, 2003). In Thailand, for instance, the suitable planting period generally starts in the early rainy season and harvest begins at the late rainy season (Sriroth et al., 2010). The reason for this is that the average amount of rainfall in the early planting period determines the quality of starch content as well as the development of fresh roots. Excess rainfall during the planting period could rot cassava roots. The topography in the cassava producing areas is generally undulating and the soils are mostly Ultisols of loamy sand or sandy loam texture and pH 5.0 to 6.5. Some of these soils are erosion-prone and most are degraded because of erosion and long-term intensive cropping. Mean temperature in the cassava regions is about 27°C and the annual rainfall is 1,100-1,500 mm in the central plain and 900-1,400 mm in the North-east. The rainy season commences in April (Onwueme, 2002).

   Thai farmers normally plant cassava based on natural rainfall or they plant before the rainy season (February, March and April) and at the end of the rainy season (November, December and January) (Hershey et al., 2001; Sriroth et al., 2010). It takes eight months under suitable climate conditions and 18 months if grown in adverse conditions to mature. Cassava grows best in direct sunlight and in soil with of pH between 4.0 and 8.0 (Kuiper et al., 2007). Thai farmers normally plant 11-12 months crop using cleaned stems, the most suitable length of stakes being 15-20 centimetres (Tongglum, Suriyapan, & Howeler, 2000). The stems of mature plants could be at least eight months old and the stakes can be planted immediately or stored for up to six months (Cock, 1985). Planting is done on the flat or on ridges, with the cutting placed in a vertical position (Onwueme, 2002) in a depth of 5-15 centimetres (Leihner, 2002). From 7,000 to 20,000 stem pieces are planted per hectare. High populations are used if the soil fertility is low, if cassava is being grown in monoculture or if erect, low-branching varieties are being planted. The most common population is about 10,000 plants per hectare (Cock, 1985).

4. Harvesting: Unlike crops such as rice and wheat, cassava can be harvested more or less whenever it is needed. The harvest may begin as soon as seven months after planting or later. Long growth periods are common in areas that have cool winters and in highland areas where average temperatures are low. Since the root's starch content is greatest when temperatures are low, cassava is commonly harvested during the cooler months. When the rains begin after a long dry season, the starch content drops sharply and harvesting tapers off (Cock, 1985). Thus, in Thailand, harvesting occurs from January to March or in October and very little harvesting is done in the rainy months from May to September. The problems of harvesting in the rainy months include the low starch content of the tubers at that time, low prices, reduced demand from buyers and increased difficulty of sun drying, which is the main method for producing the chips (Tongglum et al., 2000; Onwueme, 2002). However, harvesting can be advanced or delayed depending on the prices (Srirothet al., 2010). During the harvesting period, optimum rainfall and moisture are also required. Too little moisture in the soil will impede the harvesting process because the soil is too hard to dig into, whereas high moisture in the soil will reduce the percentage of starch content in fresh roots, leading to a decline in market price (Office of Agricultural Economics, 2009)

As already noted, the importance of cassava lies in its diverse uses as food and fibre, and as an energy source. The cassava root can be transformed into several end products by food industries (e.g., pellets, chips, flour, sweetener etc.) and non-food industries (e.g., bio-ethanol) (Ratanawaraha et al., 2000; Sriroth, 2007). Its many applications in Thailand and other tropical countries have increased demand for cassava production (Office of Agricultural Economic-Thailand, 2006). Rising demand has precipitated research and development in agricultural technologies that may lead to increased yields.

Another factor that makes cassava different from cereal crops is how post-harvest constraints affect production. Because cassava roots have no natural dormancy, they are highly susceptible to physiological deterioration, such as discoloration, smell alteration and microbial contamination. This results in short storage life (less than four days) of fresh roots (Wenham, 1995). After harvesting, sunny days and open dry areas are needed to expose the cassava roots to natural drying on the ground. In case of unsuitable climate conditions, cassava can be left in the ground without serious damage to the roots until conditions are more favourable. Thus, the harvesting time of root crops is more flexible than that of cereal crops (Ratanawaraha et al., 2000; Rijks, 2003). The link among climate condition, growth period and crop yield of root crops are noted in agricultural reports from the Office of Agricultural Economics in Thailand, but quantitative analysis of climate impacts on cassava has not been attempted.

4.4 Thailand's cassava production

Today, Thailand ranks first among world cassava exporters and third among world cassava producers. Thailand's exports of cassava products account for approximately 90 per cent of total cassava exports on the world market. The principal markets for cassava products (in the form of chips, pellets, and flour) are EU, Japan, China and Taiwan (The FAO's Global Information and Early Warning Service, 2007). Most of Thailand's cassava production occurs in the north-eastern part of Thailand, particularly in Nakhon Ratchasrima province where it is planted by a large number of Thai farmers, some 538,440 families (Statistical Forecasting Bureau and National Statistical Office, 2011) who own small plots of land of about 3-12 rai (Sriroth, Lamchaiyaphum, and Piyachomkhwan, 2006). Very little production takes place in the north and the south regions of Thailand.

In 2010, around 7.56 million rai of land were given over to cassava production in Thailand, a decrease of about one million rai from the previous year. The north-eastern region accounted for 4.04 million rai. However, the areaslost because of drought and floods accounted for 2.6 million rai in 2010.

Due to rising prices and high demand, cassava acreages were expanded from marginal areas to areas intended for other crops. This expansion led to decline in soil infertility, soil erosion and the loss of the genetic diversity of the crop nationwide (Ratanawaraha et al., 2000). As a result, the number of areas used for cassava planting in Thailand decreased continuously during 1993–2002. The Office of Agricultural Economics in Thailand recorded, in 2007, that about 660,000 hectares (7%) of the total cropped area in the northeast was dedicated to cassava. In 2010, the planted area of cassava in the same area was nearly 650,000 hectares (50%) of the total cassava planted area in Thailand. Nakhon Ratchasima Province is the largest area for cassava planting. The 14 million tonnes of cassava harvested in the north east region make up approximately 50 per cent of cassava production in the entire country.

4.5 Food for direct consumption and animal feed

In several African countries, young cassava leaves are frequently picked and cooked as African food. The amino acid content of cassava leaf is the same as protein in egg. Thus, the value of cassava leaves in areas where they are consumed is normally higher than the roots; their sale contributes importantly to farmers' revenue (Lutaladio & Ezumah, 1981). Before eating the cassava leaves, consumers remove the hard petioles, pounding the young petioles and blades using mortar and pestle and then boil the leaf. Then, pulp is sundried for 30-60 minutes to destroy cyanogens (Nweke, 2004). Cassava roots deteriorate rapidly thus, it must be processed as quickly as possible after harvesting. In Indonesia, a popular snack is prepared by washing peeled roots and thinly slicing them; they are put in cold water and drained, then for a few minutes deep-fried and covered with a mixture of sweet or hot spices (Nweke, 2004).

High quality cassava flour (HQCF) can be used instead of wheat flour and other starches in bread and confectionery. These types of cassava products are emerging in sub-Saharan Africa. The value chain is relatively well established in Ghana and Nigeria, with artificial dryers capable of processing one to three tonnes of HQCF per day (Westby, 2012).

Both leaves and roots of the cassava can be used as animal feed, but only in very small amounts. Dry cassava leaf meal for animal consumption is generally obtained by cutting the plant tops at 2.5-3 months after planting. After harvesting, the foliage is chopped and sun-dried until the moisture content is reduced to 12-14 per cent; then the foliage can be milled and stored (Howeler et al., 2013). For non-ruminants, dry cassava foliage meal is best limited to six to eight per cent of the feed for growing pigs and less than six per cent of that for broilers (Ravindran, 1993).

In the case of cassava roots, they are sliced or chipped, while leaves are chopped into small pieces. Before feeding to animals, the chips of cassava are spread out on a floor overnight in order to reduce some of the cyanide. The leaf pieces and root chips can also be sun-dried to be 12-14 per cent moisture content and stored (TTTSA, 2012). On the other hand, the chopped pieces of leaves and roots can be fermented to make silage. To release most of the cyanide, both sun-drying and ensiling should be done before feeding animals such as pigs, cattle, buffaloes and chickens (Westby& Adebado, 2012). Moreover, Thi and Ly (2007) concluded that, under anaerobic conditions for 90 days, leaf silagewhich is made by mixing chopped leaves with 0.5 per cent salt and 5-10 per cent cassava root mealresulted in a sharp drop in pH and cyanide content. Such silage is usually fed to animals such as cattle and pigs.

4.6 Related industries

Cassava contributes considerably to the livelihood and nutrition of up to 500 million people, households of processors, traders and other stakeholders around the world (Balagopalan, 2002). Figure 4.4.provides a summary of cassava related industries.

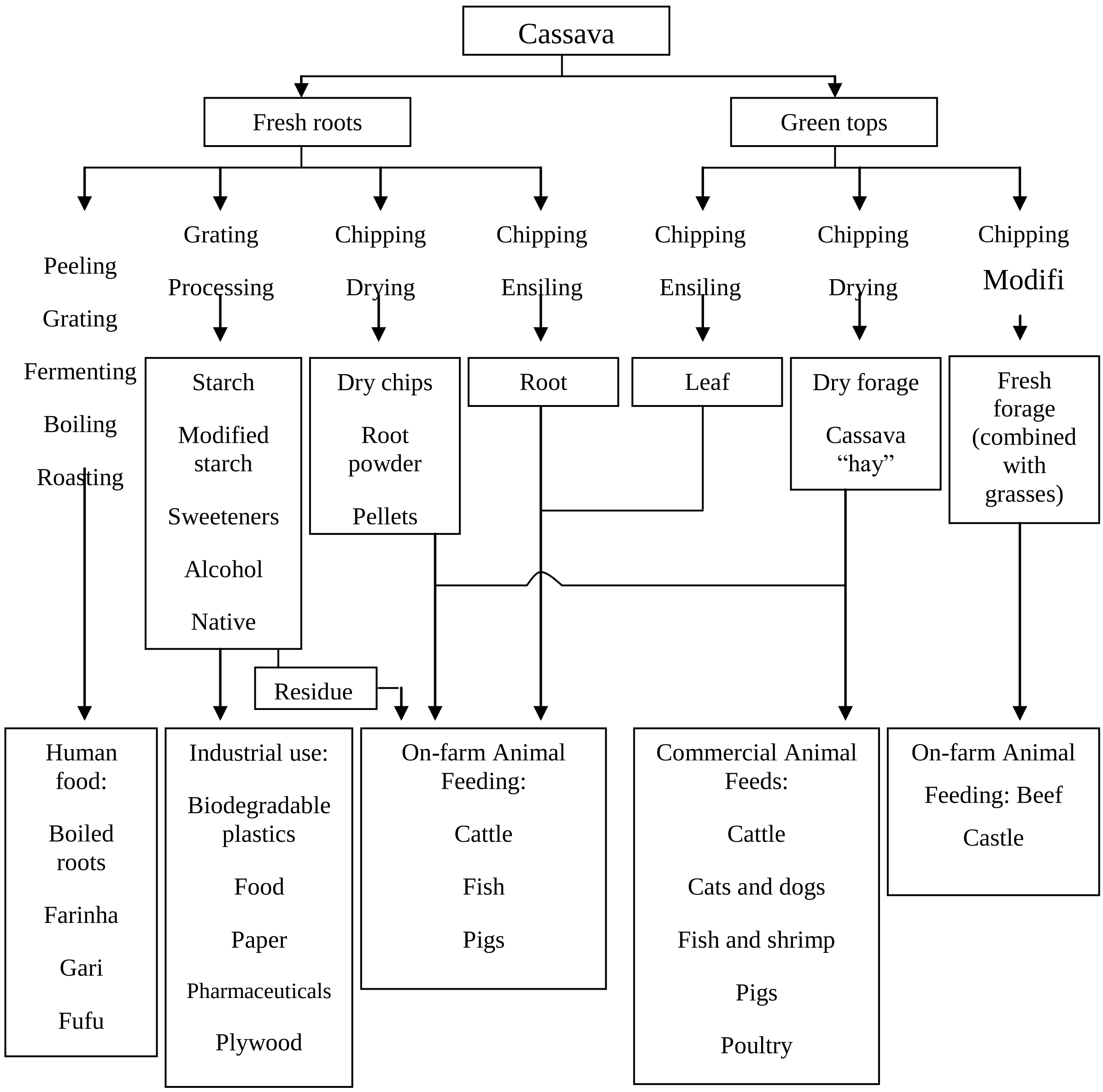

Figure 4.1: Thailand's cassava related industries
(Source: Ratanawaraha et al.,2000); Tongchure, Poramacom, & Kao-ian. 2008)

Cassava's many potential uses can make it a catalyst for rural industrial development and raise the incomes of producers, processors and traders. It can also improve the food security status of producing and consuming households.

In Thailand, much of the native cassava starch is produced to make many kinds of modified starches for integration in food products such as alcohol, fructose, mono-sodium glutamate (MSG) and sweeteners. Modified starch is also used in paper, textiles and plywood industries. Cassava is also being used for alternative energy in the production of ethanol fuel.

4.6.1 Native starch industry

Native starch is the un-modified starch extracted from fresh cassava roots. Native starch can be used for direct consumption and as a raw material in manufacturing and processing of other products. It has been used for decades to meet the demand of the global food market. Obtained from sources like corn, wheat, rice, cassava and potato, native starches are generally used in food texturization and thickening. The relative proportion and structural differences between amylase and amylopectin contribute towards the significant differences in the proportions of starch and functionalities of the applications. Many starch firms in Thailand are owned by Thai people; however, a high share of modified starch firms is under joint ventures with Japan (Tijaja, 2010).

Figure 4.2 shows the production process of the cassava chips (tapioca chips) in Thailand. Cassava chips are made from cleaned and freshly harvested cassava roots which have been loaded into a hopper or a chopping machine by tractor, cut into small pieces and dripped to be sun-dried for two to three days on a cement floor. If sun-drying, farmers use a vehicle with a rake attached for turning over the cassava chips several times a day. One kg of cassava chips is made from 2-2.5 kg of fresh roots. At the end of the drying process, the cassava chips must have less than 14 per cent of moisture and less than three per cent of sand, silica, and other substances. Thus, the cyanogenic glucocide levels are reduced (Sriroth et al., 2006; Kuiper et al., 2007; The Agricultural Futures Exchange of Thailand, 2009).

Generally, farmers sell cassava roots to cassava chip manufacturers for processing. Approximately 10 per cent of processed cassava chips is used in local industry, such as the animal feed industry, and 90 per cent is exported (Nitayavardhana et al., 2010), especially to the EU, for use as animal feed (Westby, 2002). Chips are frequently sold directly to be made into flour that can be mixed with bean, fish, soy or other protein sources to make a nutritious animal feed that is frequently mixed with minerals and vitamins. In terms of protein and energy, the performance of pigs fed a well-balanced cassava diet is similar to that obtained with a diet based on broken rice or maize. Cassava meal is naturally combined with yeast and lactic acid bacteria that improve the micro-flora in the animals’ digestive systems. Moreover, at low levels of hydrogen cyanide,cassava feed can increase enzyme efficiency, acting as a natural antibiotic to destroy mycotoxins in milk and animal's bodies. Animals on cassava diets usually have a low mortality rate, good disease resistance and thus good health (Howeler et al., 2013). Cassava chips are also used in Korea, Brazil and China for making alcohol as a substitute for sweet potato and molasses.

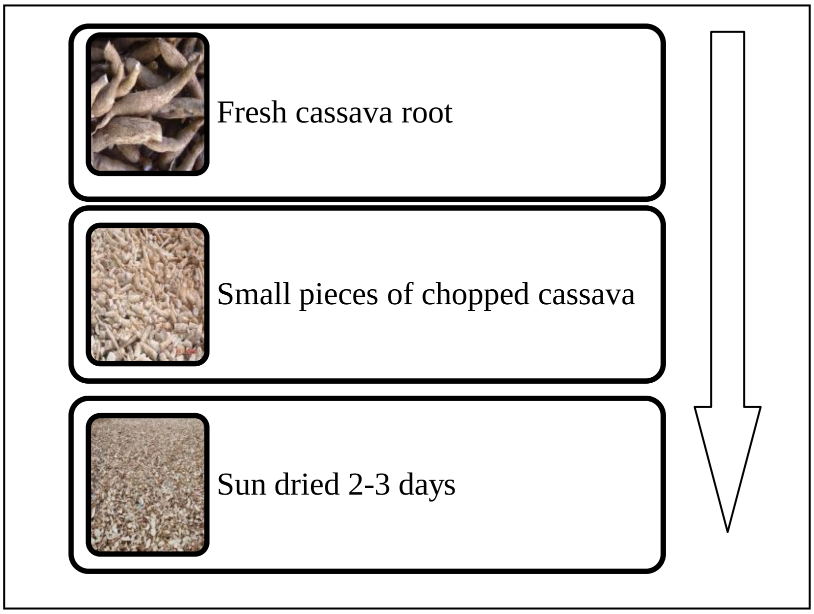

Figure 4.2: Cassava chip production process
(**Source:** The Agricultural Futures Exchange of Thailand, 2009)

Cassava pellets are made and exported in massive volumes for use as an animal feed ingredient, mostly to the EU countries (Nitayavardhana et al., 2010), under the control of the Thai Industrial Standards Institute of the Ministry of Industry. Cassava pellets are produced from dried cassava chips. The small dried chips are preheated with steam then passed through a die having several hundred 78 mm diameter holes. At this stage, the pellets are soft and warm. They are then air-cooled to harden them. The traditional pellets, called native pellets, are no longer produced due to the dust pollution on handling these pellets at the port of destination. Dust-free hard pellets are now produced using improved machinery. The standard specifications for hard pellets are starch 65 per cent minimum, moisture 14 per cent maximum, meal, eight per cent maximum, raw fibre, five per cent maximum, and sand, three per cent maximum, and foreign matter, nil (Westby, 2002; United Nations Conference on Trade and Development, 2012). Cassava pellets are exported as animal feed as an energy source for animals mixed with soy meal at the ratio of 85 per cent cassava hard pellet and 15 per cent soy meal, resulting in an equivalent nutritive value of corn (TTTA, 2012). The price of cassava pellets is more stable when compared to other high-energy feedstuffs, such as corn and wheat, and pellets are available all-year round.

4.6.2 Modified Starch Industry

Native starches have some limitations in the food industry owing to their properties, such as easily lost viscosity, texture limitation and susceptibility to severe processes (high temperature, high shear and acidity). Thus, there exists the need to modify some starches to enhance or repress their inherent properties as appropriate for a specific application. There are three common methods of modifying food starches: hybridization, physical modification and chemical modification (Light, 1990).

Hybridization is a process to yield products with different percentages of amylose and amylopectin content, since both polymer ratios affect starch properties (Light, 1990). Thus, the modified starch is used in a snack process to achieve various textural attributes (Huang, 2011). It consists of waxy starch and high amylase starch. With their fine starch granule size, waxy based starches are the most suitable for the baked snack products because of easy sheeting and good binding which results in minimal breakage (Huang, 2011).

Pregelatinized starch or pregeled starch is the most popular physical modification of starch, also referred to as instant slurries, and are those that have been simply precooked and drum dried to give products that rapidly disperse in cold water to form moderately stable suspensions (Anastasiades, Thanou, Loulis, Stapatoris, & Karapansios, 2002).

Chemical modification: this method can be classified into two types: conversion and diversification. Conversion is a process that is used to reduce the viscosity of raw starches. Its main purposes are to allow the use of starches at higher percentages, increase the water solubility, control gel strength or modify the stability of the starch. Moreover, the method of conversion includes acid hydrolysis, oxidation, dextrinization and enzyme conversion. However, the diversification method includes stabilization and cross-linking (Steeneken, 1993).

However, most forms of cassava processing generate large amountsof waste and environmental pollution such as organic matter after washing; cyanide diffuses into ponds, back-waters and rivers when retting; there is a high content of cyanide and organic matter in peeling and squeezing; there is fibrous waste, starch residue and waste water. Also, the strong and unpleasant odour and the visual display of waste products are produced. On the other hand, although there was no documented evidence that cassava production has had a significant impacton the biodiversity,it has led to deforestation such as has occurred in Thailand (Howeler, et al., 2001).

4.6.3 Ethanol (ethyl alcohol)

Cassava is a raw material for non-food industries, too, including bio-ethanol (Itharattana 2003; The FAO's Global Information and Early Warning Service, 2007). Due to its high starch content, cassava is a high-yielding ethanol source. There is a notable difference, however, between yields from fresh cassava roots and dried cassava chips. Around two kg of fresh cassava roots would make one kg of cassava chips. Moreover, four to six kg of fresh roots (containing 30 per cent starch) or three kg of cassava chips (14 per cent moisture content) can produce one litre of ethanol. As a result, one tonne of fresh cassava roots creates 150 litres of ethanol, but one tonne of dried cassava chips creates 333 litres of ethanol (Kuiper et al., 2007).

4.7 Summary

This chapter has presented general information on cassava production and related industries in Thailand. Cassava was introduced into Thailand in about 1850 and, since 1956, the crop has spread to all parts of the country, particularly the north east, which is now the main producing area; very little production takes place in the north and the south of Thailand. The cassava plant is grown by planting a cutting taken from the woody part of the stem into soil which is, preferably, mostly of a sandy loam texture. After the cutting is planted, one or more of the axillaries buds sprout and roots grow principally from the base of the cutting. Early in the growth cycle, the plants stores small amounts of starch in their roots.

In Thailand, most cassava is grown as a mono-crop and planting is from May to November, with most of the planting being done in May to June. Land preparation is with tractors or by bullocks. Planting is done on the flat or on ridges with the cutting placed in a vertical position by hand. Harvesting by tractors occurs January to March or in October. Most cassava is harvested atabout one-year old using special machinery. Very little harvesting is done in the rainy months from May to September due to the low starch content, low prices, reduced demand from buyers and increased difficulty of sun-drying.

The starch from cassava is used domestically as well as for exports, especially in the form of cassava chips and pellets for animal feed in the EU. Related industries, such as the modified starch industry and ethanol, are also important to Thailand both for domestic use and for export. The cassava industry has witnessed a very rapid and successful expansion.

CHAPTER 5: THEORY OF FARM CONTRACTING AND TRANSACTION COSTS

5.1 Introduction

Market liberalization influences agriculture production in both developing and developed countries. Market liberalization deregulates local food markets and international markets by changing agricultural production patterns in terms of mixed livestock and on-farm crops, changing the types of food which enter global markets and increasing total physical volumes and values of production (Goodman & Watts, 1997). Rapid economic growth leads to decreases in demand for staple foods and increases demand for high value products, such as vegetables, livestock, fruits and processing foods. In developing countries, rural household diversification, including contract farming, is an important strategy for farmers to earn income in this changed economic situation (Simmons, 2003).

Agricultural smallholders can use contracts to manage inputs, organize farm services and invest in new activities. Agricultural products can be transferred directly from farms to markets. Farmers can also transfer their products under contract to intermediaries, such as produce packers and processors and livestock integrators who organize and combine agricultural products for shipment to a different place.

Contract farming is likely to be an important factor in rural development in countries such as Thailand for a number of reasons, including:

1. Economic liberalization has increased demand for high value foods especially for export, often resulting in a higher income risk from market price variability and production failure.
2. Agricultural market requirements have changed since economic liberalization became more important in global trade. This has resulted in many small farms and small agribusiness firms participating in contracts (Eaton & Shepherd, 2001; MacDonald et al., 2005).
3. In the world market, competitive pressures have led to more specialized farm enterprises along with increased demand for large-scale farming to obtain economies of scale. From the perspective of farmers, contract farming can reduce the impact of competition from overseas enterprises that have good financial capacity and access to markets (Baumann, 2000).

This chapter is organized as follows. The concept of contract farming including agricultural contracts is discussed in Section 5.2. The transaction costs approach is reviewed in Section 5.3

including theory and structure. Motivation of smallholders to participate in contract farming is discussed in Section 5.4. Reasons for success in contract farming are discussed in Section 5.5. The benefits to small holders and agribusiness firms from contract farming, Thai government policy and implication, effectiveness of contract farming schemes, and the case of cassava are considered in Sections 5.6-5.9. Section 5.10 provides a summary of the chapter.

5.2 Contract farming

Contracts and vertical coordination are acknowledged as an important characteristic of post-industrial agriculture (Bonnen & Schweikhardt, 1998). Contract farming is a hybrid measure of vertical coordination between a fully vertically integrated firm and atomistic competition in spot markets (Williamson, 1981; Peterson, Wysockib, & Harsh, 2001). Contracting is one of five hybrid forms of organization (cooperative bargaining, contracting, franchising, joint venture arrangement and strategic alliances) defined by Sporleder (1992). There are three contract types: i) resource providing contracts, ii) production management contracts, and iii) market specification contracts (Key & Runsten, 1999).

Contract farming (CF) can be understood as firms providing inputs such as seed, fertilizer, credit, information and technology in exchange for exclusive purchase rights over the crop. In CF arrangements a firm has greater control over the production process and final product. Contract farming is attracting considerable policy and academic attention. It has expanded to become a significant and growing form of agricultural food industry in developed countries (Martinez & Reed, 1996). For example, CF accounted for 39 per cent of the total value of US agricultural production in 2001, a substantial increase over the 31 per cent estimated for 1997 (Young & Hobbs, 2002). Similarly in Germany, CF accounts for 38 per cent of the production from the dairy and poultry sectors; and contracts cover 75 per cent and 23 per cent of broiler production in Japan and South Korea, respectively (Young & Hobbs, 2002). In Southeast and South Asia, CF has also increased in recent decades (Swinnen & Maertens, 2007). For example, CF is prevalent in Malaysia, mainly based on state-promoted out-grower arrangements (Morrison, Murray, & Ngidang, 2006). In East Asia, CF is also extensively practised; for example, in China, the government has supported CF since 1990 with dramatic results; in 2001, over 18 billion hectares were planted under CF arrangements an increase of around 40 per cent from the previous year (Guo, Jolly, & Zhu, 2009).

Agricultural contracts refer to organizing and transferring agricultural products from farms to consumers where there are agreements between farmers and farmers, or farmers and processors, including agreements on conditions such as inputs, production, purchase, marketing and harvesting. MacDonald et al. (2005) suggested that farmers have broadly four methods of management in agricultural transactions (processors, wholesalers, retailers, brokers, shipper and final consumers): spot markets, production contracts, marketing contracts and vertical integration. Based on this classification, CF in this study is mainly about marketing contracts as shown in Table 5.1.

Table 5.1: Four ways of managing the sale of agricultural products to consumers

Governance forms	Who controls assets and production decisions?	How is the farm operator paid?
Spot market	Agricultural operators	Farm operator receives price for farm output, negotiated at time of sale just prior to delivery.
Production contract	Contractors have control over some assets and production decisions. Contracts specify products, quantities and delivery timing.	Farm operator is paid a fee for farming services rendered in agricultural production.
Marketing contract	Agricultural operators control assets and production. Contracts may specify output, quantities and delivery timing.	Farm operator receives price for farm output and is negotiated before or during production of agricultural products.
Vertical integration	Single firm controls assets and production decisions in adjacent farming and processing stages.	Farm operator-manager is compensated for skills and time.

(**Source:** MacDonald et al., 2005)

Physical Spot markets or cash markets are defined as those markets “in which goods are tendered for immediate delivery.”(Heilbron, Roberts,& Rural Industries Research and Development Corporation (Australia), 1995, p. 48). Spot markets have been subject to perhaps the most extensive investigations of pricing systems and performance analysis of any co-ordination mechanism. In these markets, there is no shared control between seller and buyer, and there is significant price uncertainly and risk (Frank & Henderson, 1992). Additionally, the spot market system may suffer from dynamic instability with significant price and production variability within and across market periods, and a lack of information on product quality characteristics (Heilbron et al., 1995). However, modern spot markets for agricultural products reflect previous marketing improvements, including standards of individual agricultural products, payment systems and accounting, and weighing and grading technologies (Netz, 1995).

A **marketing contract** is an agreement on a price formula or price for products to be delivered at a later time (Harwood, Heifner, Coble, Perry, & Somwaru, 1999). The purposes of farmers entering into a marketing contract are possible price enhancement and to reduce price risk (Musser, Patrick, & Eckman, 1996). Moreover, such a contract can improve access to credit and reduce income risk, especially when used together with crop insurance (Katchova & Miranda, 2004). Often, marketing contracts are for grain. This type of contract sets the price formula or price range for products before or at planting. Farmers continue to bear production risk and make the best management decisions they can. However, some management protocols may be stated in the contract. The marketing contract may shift price risk to the processors or contracted prices may be linked to spot prices (Sriroth, 2007).

A **production contract** is an agreement between a farmer or producer and a contractor or processor. It is common in the poultry and livestock industries (Sriroth, 2007). This type of contract is much more specific about management practices compared to marketing contracts. Additionally, in this contract, the farmer may agree to care for and feed poultry and livestock owned by the contractor until the animals are ready to sell (Kunkel, Peterson, & Mitchell, 2009) in exchange for advances on expenses based on a formula normally tied to production performance. In this situation, the contractor provides specific quality and quantities of inputs and expertise, and a specific feeding schedule to be used by the farmer. There are at least four types of production contracts, including the simplest type of contract, the production management contract, resource-providing contracts and vertical integration (Kelley, 1994). There are several possible advantages for production contracted farmers, including: i) guaranteed market, ii) contracts reduce traditional marketing risks, thus farmers get more stable income, iii) increasing the volume of the farm's business with limited funds, and iv) benefits of managerial expertise and access to technological advances (Kunkel et al., 2009). There may also be advantages in management of diseases, which can be managed from "above" by contractors.

Vertical integration occurs when a single firm undertakes successive stages in the chain of production and these stages are under general control and ownership (Black, Hashimzade, & Myles, 2012). According to transaction cost theory, ownership internalizes the exchange or transaction process. The scope of vertical integration is influenced by the appropriateness of alternative exchange mechanisms external to the firm (Kilmer, 1986). These incidences of vertical integration are seen as a mechanism to both lower procurement costs and reduce the risk of supply (Sporleder, 1992). That is, through vertical integration, the opportunity of one independent party obtaining excessive profits in the short-term through exploiting an advantage in a contractual relationship with another party is minimized where the two parties are owned by the same firm (Heilbron et al., 1995). As with contracting, vertical integration is more prevalent in bigger agribusiness firms. Non-farm firms which venture into farming are more likely to do it on a large scale. In markets where there are vertically integrated firms, their activities could be to the disadvantage of non-integrated competitors. Also, vertical integration may deter further market entrants and raise barriers to entry (Casson, 2012). Schroder and Mavondo (2006) summarized a number of costs or dangers associated with vertical integration including:

1. Vertical integration is likely to be more risky than backward integration, given that firms are generally more familiar with input supply than marketing and distribution;
2. There may be production flow balancing problems due to different stages having different production capacities and scale economies;
3. Risk of cross-subsidization; and
4. The reduction in the number of external suppliers may reduce the scope and range of organizational and technological information available to management.

5.3 Transaction costs and contract farming

The theory of transaction cost economics goes back to the era of Coase in 1937 when he answered the question: "Why does a firm emerge at all in a specialized exchange economy?"his answer was that transaction costs are a reason. He defined transaction cost as "a cost of using the price mechanism" (Howeler, 2007, p.4). The costs of organizing production through the price mechanism are those stemming from the discovery of what the relevant prices are, from negotiating and concluding a contract, from a lack of flexibility associated with long-term contracts and from a sales tax on market transactions (Howeler, 2007). Apart from these factors, Watananonta et al., (2005) note that Williamson (1981) identified market uncertainty and asset specificity as the environmental factors which increase the costs of market exchange. However, Jaffee and Morton (1995) define transaction costs as search and information costs, decision and bargaining costs, and enforcement costs. If attention is restricted to firms, rather than final consumers, these factors can be recast in terms of organization costs associated with enforcement and construction of contracts. This allows transaction costs to be viewed as production costs and analysed accordingly.

Following Williamson's contribution in 1975, the term "transaction costs" has replaced Coase's early "marketing costs" (Pitelis, 1993). The contribution of Williamson (1981) was to use transaction cost analysis to distinguish organizations, in particular market failures and the appearance of hierarchies in firms, from failed markets as explanations related to the ability to economize in market transaction costs.

Dietrich (2002) showed that Williamson follows Arrow' (1975) definition of transaction costs. Agribusiness firms may include the following costs:

1. The cost of drafting, negotiating and safeguarding contracts,
2. The maladaption costs incurred when transaction costs drift out of alignment with requirements), the negotiating costs (incurred bilateral efforts are created to correct ex post misalignments),
3. The set up and running costs associated with governance, and
4. The bonding costs of effecting secure commitments.

Table 5.2 shows the structure of transaction costs which were explained by Alston and Gillespie, (1989). They explained that:

> The types of transaction costs encountered in organizing production vary across the factors of transaction and over the stages of the production process.

Table 5.2: Structure of transaction costs

Factors of Production	Production Process		
	Pre-production	**Production**	**Post-production**
Physical and financial capital	Asset specificity	Abuse and agency costs	
Human capital	Information constraints and asset specificity	Coordination costs	Measurement of output and contract enforcement
Work intensity		Shirking and contract enforcement	

(**Source:**Alston & Gillespie, 1989)

For this framework, transaction costs can be placed into two categories: factors of production and the production process.

Production costs depend on technology and input used (Milgrom & Roberts, 1992). There are two categories of **factors of production**:

1. Physical and financial capital: consist of machines, equipment and liquid capital of the production process.
2. Human capital: consists of skills, knowledge and labour for the production process which may be acquired through formal schooling or by learning by doing.

Another distinction Alston and Gillespie (1989) make for investigative purposes is **production process,** which is separated into three periods of time including:

1. Pre-production period including: asset specificity which refers to the difficulty that is made by one party in a transaction making an investment in physical or human capital, which may be partly recovered if the transaction is finished (Williamson 1981); and constraints on the availability of labour is one of the transaction sets and the information constraints related to the achievement and use of human capital (knowledge paradox and information transmission).
2. Production period including the negotiation between seller and buyer which takes place.
3. Post-production period is marked by the service agreed to earlier or delivery of the goods. The items pre- and post-production are factors that support production within the firms.

Pre-production transaction costs of using the market are related to:

1. Asset specificity: Asset specificity refers to the difficulty which occurs when one party in a transaction cannot fully recover investment in human or physical capital when the transaction stops or the business is terminated (Karaan, 2002).
2. Constraints on the availability of labour: An inelastic labour supply creates the potential for shortages in labourers at critical times in the process of production if there is only a limited number of labourers available (Alston & Gillespie, 1989).
3. Information constraints related to human capital, information transmission and knowledge paradoxes. Information constraints reflect the way in which contracts are negotiated within and between firms. **Production costs,** including negotiation, production, processing and marketing transaction costs (Alston & Gillespie, 1989). These costs are related to agency costs, coordination costs and contract enforcement. **Post-production transaction costs** measure the quantity and quality of output. However, the measuring quality of output is difficult, thus measuring is understood in term of inputs. Contract enforcement is included because contractual disagreements regularly occur after production has been made (Alston & Gillespie, 1989) and also contract enforcement is needed for efficient investment in

economic movements (Gow, 2001). There are examples of ineffective situations in enforcing contracts as in Croatia, where processors ended up cancelling the programme of input pre-financed and supported investment for farmers because they sold their products to other processors for a higher price (Gow, 2001).

5.4 Smallholders motivation in contract farming

CF begins with agreements made between agricultural firms and farmers. Firms create contracts to reduce profit uncertainty by diversifying supplies or to increase profits by expanding their organization. If contracts are to work, potential contractors must be interested in participating. Agribusiness firms can use a diversity of agreements to achieve their supplies of inputs for their processing and marketing. They can select to contract for different reasons and their motivations will be reflected in the types of contracts they select.

Adoption of new enterprises. There are three factors which may substantially change the way an activity is pursued: cost implications, profit implications and exposure to risk that might ensue from a new enterprise. For cost implications, input costs and opportunity costs are two types of farm costs relevant to adoption. Farm input costs include seeds, hired labour and machinery, fertilizers, chemicals, and marketing. A new venture has to raise total farm income if it is to be a candidate for adoption by farmers. The second type of cost is opportunity cost, which occurs with a new enterprise because other off-farm or on-farm activities may need to be restricted. The second factor is revenue implications. If income losses are more than fully offset by cost savings, a contract does not need to raise income to be attractive. The third factor is farm risks; how farm risks effect new enterprises may be captured in safety-first theory where farmers will not expose themselves to the risk of profits falling below some level (Anderson & Dillon, 1992).

Access to Markets. The value chains of agricultural products in developing countries have undergone a period of considerable reorganization since the 1970s. There are important reasons for this reorganization on both the demand and supply sides. On the supply side, the liberalization of national and international markets, greater concentration within agricultural supply chains, improvement in logistics and transportation, developments in communication and information technology and increasing importance of standards and the traceability of products have all contributed to the greater prevalence of contracts. Larger populations, greater urbanisation, higher incomes and changing food preferences have all played a role in changing demand for agricultural products on the demand side. Thus, agricultural commodity chains have become more integrated, globalised and consumer-driven. This is referred to as global agricultural industrialization (Prowse & Thirion, 2012). Barrett et al. (2012) summarize how this process occurred first in wholesaling, then in processing and, more recently, in retailing. Agricultural production has evolved from supplying an array of generic, standardized commodities to a much broader series of highly-differentiated food products fulfilling different niche requirements (Kirsten & Sartorius, 2002). Agricultural business firms are influential in opening markets for smallholders. These firms have advantages over farmers. They have market experience and knowledge, transportation resources, economies of scale for efficient processing, and may have strong relationships with financial and international trade organisations (Simmons, 2003).

Access to credit may be important in CF because the production costs per hectare of non-traditional crops or high value food (HVF) are higher than traditional crops and credit, and finance requirements for farm production are often relatively high (Key & Runsten, 1999). This is because non-traditional crops require special inputs, labour, chemicals and technology. Thus, smallholders may need credit to engage in production. However, traditional crops can often be planted using households' financial resources and inputs. For example, in Mexico in 1993, the average per hectare out-of-pocket expenses due to production costs in traditional crops such as (rain-fed) maize and rice were US$258 and US$481 respectively; the average out-of-pocket expenses for non-traditional crops such as sugar were US$661 per hectare and US$10,379 per hectare (Key & Runsten, 1999). Many smallholders face credit constraints or have no access to credit at all (Glover & Kusterer, 1990; Hayami & Otsuka, 1993). However, smallholders face much higher interest rates (three or four times the commercial bank rate) from local moneylenders if the access to credit is available. These high costs are approved for smallholders in the form of high interest rates (Simmons, 2003).

Managing risk. There are three basic approaches to the management of risk in developed countries: i) diversification over off-farm and on-farm activities, ii) adjusting savings and borrowings to smooth income over time to offset high and low income years, and iii) reducing risk by using forward or future markets or crop insurance policies to cover yield and price variability (Simmons, 2003). Smallholders in developing countries have limitations in managing risk. A means of managing risk for such farmers may be to balance the risk between farmers and contracting firms. It may also be possible to distribute credit risk between farmers and contracting firms. A price surcharge can be explicitly linked to it when default is low and contracted prices go up.

Access to information. Most developing countries, such as Thailand, provide government extension services to distribute new information and technologies about both traditional and non-traditional crops. However, private agricultural business firms may offer new information better than agricultural extension services from the government because they have a direct economic interest in improving smallholders' production (Eaton & Shepherd, 2001). Most of the larger contracting firms prefer to offer their own extension services rather than rely on government services. Additionally, larger scale farmers are better informed regarding new information about production technologies, chemical regulations and consumer preferences, and they have advantages over smaller scale farmers because they can deduct the costs related to gaining information from their larger income base (Bivings & Runsten, 1992). Small-scale farmers are often reluctant to adopt new technologies because of the possible risks and costs involved; they are more likely to accept new practices when they can rely on external resources for material and technological inputs.

The higher costs and greater income risk of using non-traditional crops make them a riskier proposition for farmers than traditional crops. Thus, **access to insurance** is important for CF. Producing non-traditional crops in developing countries are likely to have more variable profits because they have more variable yields (because of greater susceptibility to pests and climate variations) and more variable prices (because of market supply, market infrastructure, price swing and price fluctuation) (Key & Runsten, 1999). However, interest rates from local moneylenders are regularly much higher than those of commercial bank rates, making it too expensive to use for purchasing insurance. Farmers with restricted borrowing ability may try to smooth consumption through the growth and reduction of productive assets, which can increase costs and decrease efficiency of productivity (Rosenzweig & Wolpin, 1993). However, contracting firms may provide period insurance for contractors against yield and price fluctuations because they can diversify their production sources geographically, and they may have access to low borrowing rates and be able to provide low cost insurance for contractors in the production process. Moreover, contracting firms can decrease monitoring costs by requiring farmers to bear a significant share of the production risk. As a result, when yield risk is important and producers must bear a share of this risk, firms will have an incentive to contract with larger farmers (Key & Runsten, 1999). Thus, CF is a way of distributing risk between the farmers and contracting firms. While farmers assume most of the production risks, the contracting firms assume the marketing risk, resulting in total risk reduction relative to a non-contracting situation for the product.

Factors of production and raw materials including:

1. Specialized inputs (machinery and chemicals): In developing countries, markets for services and inputs needed in traditional crops production are missing or thin, especially for the specialized crops where seeds, fertilizer, herbicides and pesticides may be difficult to obtain and harvesting equipment unavailable. Once production begins, agricultural firms may use vertical integration and CF to continue the exert monopoly power over specialized inputs (Key & Runsten, 1999).
2. Factors controlled by households such as households' labour and lands: If household labour is not tradable, larger households prefer producing more labour intensive crops (De Janvry, Fafchamps, & Sadoulet, 1991). Consequently, if markets are imperfect, agricultural firms may contract with farmers with underutilized non-tradable factors such as land and family labour. Household labour may be underutilized land endowments that are low because of land renting, lack of financial access or imperfect markets.

Even though it may be considered that agricultural plantations run on a large-scale do so generally at a lower per unit production cost than small-scale farmers are able to achieve, land production involves both direct and indirect labour costs in terms of supervision, hiring and training. It is frequently required to provide houses and food for labourers. As noted above, land can be difficult to obtain and very expensive, therefore, CF can often be competitive, mainly for crops where large-scale is difficult to achieve. As already noted, experience in some developing countries specifies that crop production can develop effectively into cost-effective smallholder contract farming projects.

Transaction costs related to search, screening and transfer of goods. Transaction cost economics asserts than the managerial structure of firms reflects the costs of doing business (Williamson, 1979). Important costs for firms related to contracts include searching for clients, screening of clients, contract negotiation, goods and services transferring, and enforcement of contract terms (Masten, 2001). High transaction costs related to contracting make a motivation for market utilization of the firms or production process. A firm will select its managerial strategy in part to reduce costs related to its different business transactions. Transaction costs usually do not rely on the size of the agent with whom the firm is contracting. The processor can reduce these types of transaction costs by raising the average scale of the out-growers with whom it contracts or the number of agents with whom it contracts. The presence of fixed contract associated transaction costs is a primary purpose for firms to deal with bigger farmers.

5.5 Reasons for success in contract farming

Successful CF can be measured by considering how contracts work. If there are no barriers and freedom to enter and exit the contract, and both parties, firms and farmers, persist due to their satisfaction with the contract agreements, then the contract would be viewed as successful.

A profitable market and a strong market. The environment of the market is important to success for contracting. A market needs long-term capacity to remain profitable. For example, exported horticultural products to the US, Japan and Western Europe are often very competitive. Firms using CF can lose markets if quality standards and deliveries are below par. Firms considering exported agricultural products need to ensure they can meet quality standards and deal with possible future conditions.

Macro institutional policies which influence contract farming could be i) land ownership rules, especially the prevention of land-holding by foreigners or plantation development from multinational corporations; ii) tax and exchange rates because many farm contracts rely on international markets, thus, the exchange rate leads to problems in income and inputs costs such as chemicals; and iii) food security policy to ensure that local people in developing countries have good quality food for living.

Contracted crops commonly require **sophisticated technology** (Key & Runsten, 1999). These crops require special production technology related to high levels of supervision and intensive use of capital. However, farmers have difficulties in accessing information and credit, thus there are interactions between farmers and contracting firms under CF providing special extension support and capital.

Contractors need to have clear access to **land ownership** from a legal perspective because if land tenure is not clear, land is not useful as a guarantee for loans. With most contracting programs, farmers who are landowners or have customary land rights are directly contracted by firms. Nevertheless, there can be many differences in land certificates, such as formal lease of state land, informal seasonal arrangements with landlords, leases from contracting firms that own estates and freehold title. Porter and Philips-Howard (1997) suggest that short leases in land arrangement method or other types of government land reforms resulting in uncertainty over ownership are likely to favour contracting with its lower start-up costs.

The success of CF requires conditions of the management environment: management quality and types of actions taken by management (Simmons, 2003). Porter and Philips-Howard (1997) showed that the failure of contract management in Africa came from using inappropriate cultural values in management roles of expatriated workers. For this reason, contract failure occurred because issues were misunderstood and miscommunication occurred.

Farm groups may play a significant role in achievement of a contract by lobbying to deal with political change as well as by adjustment to changed market conditions and encouraging adoption of new technology (Coulter, Goodland, Tallontire, & Stringfellow, 1999). Successful farm groups are often built on pre-existing groups, are independent rather than "top down" and have both implicit or explicit protocols and organization (Bingen, 2000). Additionally, for **selection of farmers**, in general, contracting firms select farmers for contracts and the opportunity of self-selection by farmers is referred to only indirectly. This reflects that contracting firms are generally supposed to hold the power in relationships with farmers. The difference between selection by contracting firms and self-selection is important because with self-selection farmers with most to gain would be the ones most likely to participate in contracts. That is, smaller, more constrained enterprises that were not doing well in the spot market system would have strong incentives to negotiate contracts. On the other hand, if the selection is made by firms, the firms would choose larger farmers; less constrained farmers with less risk exposure and lower unit costs are likely to be the most attractive partners (Simmons, 2003).

Profit for the farmer. If either contracted farmers or contracting firms fail to realize attractive and consistent financial benefits, the contracts will fail. A further condition is that the contracting firms need to be sure that contractors will gain higher net incomes from entering into contract farming than from other options with less or the same risk.

An important problem for contract success is **contract default**. This problem exists when contractors divert their provided inputs to produce other crops or sell contracted products to other purchasers. Hence, a direct problem for the agricultural business firm making a contract is to ensure contract default is minimised. From the perspective of agricultural business firms, the main factor in contract agreement is providing the farmers with credible desire and prospects for contract renewal.

A main requirement for agricultural investment in developing countries is the existence of **utilities and communication systems** including transportation and telecommunication services. Water supplies and reliable power are mainly essential for agricultural processing and exporting of fresh products. The accessibility of medical services and education is also important for contract farming smallholders, whether they are directly employed by the contracting firms or the farmers themselves.

5.6 Benefits to smallholders and agribusiness firms from contract farming

The main benefit of contracting **for farmers** is that the contracting firms will generally agree to pay for all products with specified quantity and quality parameters. Contracting can also provide smallholders with access to management, extension and technical services that otherwise may be unavailable. Contractors can use a contract as a guarantee to access credit with a commercial bank so as to pay for inputs. Consequently, the major potential benefits for smallholders are: provision of inputs, accessing extension, access to credit, gaining knowledge and technology, price guaranteed structures, and access to markets.

CF has increased cash crop production, rural employment, social facilities and rural infrastructure (von Braun, Kennedy, & International Food Policy Research Institute, 1994; Baumann, 2000; Singh, 2005) and has also led to better employment opportunities for women workers. Many contractual agreements are related to production support to supply the essential inputs such as seed and chemical fertilizers. Contracting firms may also provide land preparation, cultivation and harvesting, as well as training and extension. The main opportunity from CF is the promise of higher income. But, while important, this is not the sole criterion; for example, both Masakure and Henson (2005) and Guo, Jolly and Zhu (2009) point out that stability and technical knowledge were the most important reasons why farmers join contract-farming initiatives. Contract farming can also provide technical assistance, skill and knowledge. The skills that farmers learn by contract farming may consist of the efficiency of farm inputs, record keeping, developed technique of fertilizers and chemicals application, knowledge of demand and quality of markets. Smallholders can achieve knowledge in carrying out field activities following a strict timetable required by the extension services. Additionally, contract farming also offers numerous opportunities for farmers, including allowing access to a reliable market, providing guaranteed and stable pricing structures and providing access to credit, inputs, production and marketing services (Prowse & Thirion, 2012).

For firms, the opportunities provided by CF include:

1. Increased reliability in supply quantity and quality;
2. The contracting firms take losses related with non-existent or reduced throughput for the processing capability (Eaton & Shepherd, 2001);
3. Greater control over the production process and crop attributes to meet standards and credence factors;
4. Reduction of co-ordination costs, because a more regular and stable supply permits greater co-ordination with wider activities; and
5. Economies of scale in procurement, via the provision and packaging of inputs (Prowse & Thirion, 2012).

Although Swinnen and Maertens (2007) posit that the higher transaction costs and investment constraints would tend to limit smallholder participation in contract farming, a clear rationale for contracting smallholders can be found in the literature on the relative merits of large and small farm production in sub-Saharan Africa (Ellis & Biggs, 2002). In terms of labour (related to transaction costs), small farms have benefits over large farms, especially in supervision and motivation, and they are often the most efficient agricultural producers (Prowse & Thirion, 2012).

In terms of poverty reduction, contracting with farmers can reap large dividends, as small farms are usually operated and owned by the poor, often using local hired labour and frequently spending income within nearby locales, creating multipliers (Hazell, Poulton, Wiggins, & Doward, 2006). A larger scale of agricultural production is commonly more cost effective than small scale (Eaton & Shepherd, 2000) but this is not always the case because agricultural production involves direct and indirect costs of labour and land can be expensive; thus, CF can frequently be competitive, especially for crops for which large-scale economies of scale are not easy to achieve.

5.7 Thai government policy and implications for contract farming

CF in some form had been practised before the government chose it as a policy objective in the Sixth National Economic and Social Development Plan of Thailand (1987–1991); for example, CF was used in producing processed foods such as tomato, pineapple and canned fish targeted for export markets. The Sixth Plan included strategies for expansion of agricultural industries. The goal was to support the export of value-added products and import substitute commodities. Guidelines emphasized improving product quality and management systems, assisting agricultural industrial companies to support farmers in processing products and transferring new technology to farmers. Government improved the guidelines called the “Fourth-sector co-operation plan to develop agriculture and agro-industry” (Fourth-sector plan) in which farmers, agricultural firms and financial organizations, such as the Bank for Agriculture and Agricultural Cooperatives (BAAC), and government agencies worked together. The plan aimed to improve the production system, decrease market uncertainty and price risk, improve smallholders’ technical information, and increase production effectiveness. The government placed 250 million baht w into BAAC to support the plan.

Between 1987 and 1993, 20 private firms proposed 12 projects, which were approved. However, several of these project: integrated hog production and eucalyptus failed, and three projects bamboo, ramie and asparagus ceased operation in 1993 (Office of Agricultural Economics, 1993). The asparagus projects, which contracted with three firms, were successful (Naritoom, 2000). Eight projects continued their operations after 1993; they were: barley, basmati rice, castor bean, cashew nut, hybrid corn, sorghum, sunflower, and wheat production projects (Wiboonpongse, Sriboonchitta, Gypmantasiri, & Thong-Ngam, 1998). The Office of Agricultural Economics of Thailand (OAE) reported that the results of the Fourth-sector Plan were unsatisfactory because some projects essentially depended on the support of government. There were several reasons for failure including: i) the contract terms were too inflexible because it was thought that such terms would be fairer to both farmers and firms; ii) farmers felt they needed time for adaptation of new crops that required new technology; and iii) the extension services did not live up to expectations (Sriboonchitta & Wiboonpongse, 2005).

By the end of the Sixth plan, government agencies noted that “contract farming has proved viable and been shown to need to be more supported in the circumstance that the requirements of contracts are improved to be more beneficial and effective to both farmers and contracting firms and other concerned parties” (Singh, 2003). The Seventh-sector plan started in 1995, aiming to support agricultural industrial firms under the same conditions as the Fourth plan. The subcommittee targeted high export potential products: rice, flowers, fruit and seafood, and industrial crops, maize, sunflower, vegetables and fast-growing trees (Sriboonchitta

&Wiboonpoongse, 2008). The Subcommittee agreed to support projects in agricultural industry started under the Fourth-sector plan if they met three ability circumstances: to identify potential farmers and target areas, to decrease risk of production, and to decrease risk of marketing. Additionally, the Subcommittee also targeted two target groups: i) industrial crops such as fast-growing trees, vegetables, maize and sunflower, and ii) high export potential agricultural outputs such as coastal-swamp fish, high-quality rice, flowers and fruit (Wiboonpongse et al., 1998).

However, in the Ninth-sector plan (between 2002–2006), there was an implicit recognition of CF. In 2004, the Ministry of Agriculture and Cooperatives (MOAC) trained farmers and local officials in contract farming activities, which included training in understanding the CF concept, and the need for coordination between farmers and public private firms (Singh, 2005, 217).

CF his still being promoted by the Thai government. In the Eleventh-sector plan (2012–2016), government aims to create jobs and an income security for farmers using an income insurance system together with crop insurance. The government will encourage CF to promote fairness and better quality of life, enabling small farmers who may be negatively affected by free trade agreements to be strengthened so as to sustain their living situation. To support fairness in the system of CF, government will ensure that raw materials are supplied to the manufacturing sector and also guarantee farmers' incomes. Firms and other agricultural businesses are encouraged to cooperate with each other in the development of information and knowledge-sharing organizations so as to participate in creating equity, transparency and fairness (Office of Prime Minister, 2012).

5.8 Effectiveness of the contract farming scheme

The CF experience in Thailand has been different from that of other countries in the form of management and implementation (Singh, 2000). The Thai government created the Fourth-plan to develop agriculture and agro-industry, and support contract farming in which farmers, agricultural industrial firms, BAAC and government departments worked together. The subjects of the plans were to reduce price risk by improving production efficiency and high technology information. However, in 1990, most private contract farming schemes failed (Baumann, 2000). Several studies of the1990s CF experience showed that most of the CF projects concerning palm oil and cashew nuts had been unsuccessful (Glover & Ghee, 1992; Baumann, 2000). In addition, the contracts for Eucalyptus were not sustained when firms switched from artificially-supported terms (Baumann, 2000). Government, however, continues to support smallholder farmers, and the experiences of the pioneers in this industry provide lessons concerning social equity and flexibility of contracts with farmers (Sriboonchitta & Wiboonpongse, 2005).

There was an unsuccessful program for cashew nut contracts which involved cooperation between the Agricultural Land Reform Office, BAAC and private firms in 1990. They expected to involve more than 31,000 farm households and expand their area of production from 175,000 rai (28,000 ha) to 300,000 rai. The project exceeded the target in the initial phase until the pests of the cashew nut rapidly spread. There had been poor risk analysis and lack of research specification for the project. Moreover, it introduced risks that unfairly accrued to smallholders (Sriboonchitta & Wiboonpoongse, 2008). Research on appropriate technology for productivity improvement and cost reduction pertaining to local specifics seems necessary; this was also requested by frozen-vegetable processing contractors in the north of Thailand.

In a case of black tiger shrimp production, smallholders in the South of Thailand were integral to the ultimate success, although overriding concerns have focused on environmental issues. Through the Fifth and Sixth plans of Thailand, international businesses, such as Cargill, invested in parallel with smallholders and were financed by BAAC and others. At that time, Charoen Pokphand (CP) adopted its vertical integration model from the poultry business. Up to 1995, CP grew to contract some 5,000 ha of shrimp contract farming with smallholders. As a result, the incomes of smallholders rose significantly.

In the North-east of Thailand, the provision of irrigation was the key to the success of horticulture products. Products could be planted in the rainy season and distributed in winter and summer. Furthermore, a technical guidance CF scheme supported non-traditional crops of high marketability, such as, tomatoes. The growth of the tomato CF system in this region also faced disagreements about spoilages of products and other problems, which were later resolved through mutual benefit contracts.

In addition, in the north of Thailand, CF has been successful for horticulture products such as eggplant, baby corn, potato, soybean, sweet corn, tomato, maize seed and vegetable seed. Potato contracts were given the most attention because of technological developments, especially in Chiang Mai, which is a major area for potato growing. In addition the government has promoted contract farming in the part of better arrangement in trading with firms, credit guarantee and scientific support from academic institutions and firms (Sriboonchitta & Wiboonpongse, 2005).

Limsombunchai and Kao-ian (2010) studied the financial cost and return analysis between the contract and non-contract farmer groups and found that the total revenue and the net profits of the contract farmer group were higher than for the non-contract group. They stated that the reason was because the farmers who were under contracts had to follow the regulations and the production guidelines of the purchasing company and, in return, they received a higher price for their products. The coefficient of variation of the net profit showed that baby corn production under the contract farming system was less risky than under the non-contract system.

5.9 The cassava case: Reducing transaction costs through contracting arrangements

As already explained, cassava plays a crucial role in the agricultural products economy of many countries, particularly in Thailand. The most important factors influencing cassava production for bio-ethanol are: the price of cassava feedstock; the difficulties related to the production period because farmers are not accustomed to following a schedule of farming; inappropriate techniques for pre and post-harvesting, including inadequate processing technology; and agricultural marketing problems. As a consequence, farmers often produce high cost and low yield cassava, resulting in low profits which discourage higher farm outputs.

CF may be may be a way to improve efficiency in cassava production by decreasing cassava production costs, reducing transaction costs in markets, lower interest rates, increase risk management, and encourage better information sharing between farmers and processors.

Okoye, Onyenweaku, and Ukoha (2010) studied transaction costs and market participation by smallholder cassava farmers in south-eastern Nigeria and found transaction costs constrains farmers from selling. Their results showed the importance of allowing for non-negligible fixed costs in market participation. Contract participation could reduce transaction costs through the promotion of organizations for marketing, and improved transportation would increase market participation. Moreover, developing rural infrastructure would help farmers to deliver their products to urban consumers and cassava processors faster. Furthermore, provision of rural employment opportunities is necessary to decrease migration to a bigger city. The transaction costs of CF participation could thus be decreased through development of transportation infrastructure, improved information flows and promotion of institutional innovations, such as production and marketing cooperatives.

5.10 Summary

This chapter has presented a general discussion of the theoretical basis of CF. There are many good reasons for CF expansion. Following the liberalization of national markets and the collapse of international commodity agreements, agricultural value chains have become increasingly vertically integrated and buyer-driven. From an environmental perspective, CF proposes the best solution for both large and small farm production systems. Smallholder farmers are frequently the most efficient agricultural producers and they have benefits over large farms in terms of reduced labour costs associated with transaction costs, particularly in terms of motivating and supervising workers. However, smallholders often lack the capacity to adopt technological innovations and suffer from capital constraints. CF can bring advantages, usually related to large-farm production systems, including increased output with reduced input costs. Additionally, agricultural firms have comparative benefits in technical knowledge and in marketing, as well as ensuring product quality and traceability.

Contract decisions are determined by three expectations: revenue, costs and risks. These expectations are likely to be determined by levels and characteristics of transaction costs that might occur with different forms of farm enterprises. CF exists for the purpose of reducing transaction costs for both farmers and agricultural firms, including all the participants in the production, processing and marketing of the farm products, including farm suppliers, farmers, storage operators, processors, and credit and information providers who are involved in the production flow from primary inputs to the end consumer.

CHAPTER 6: SMALLHOLDERS' RESPONSES AND AGRIBUSINESS SYSTEMS

6.1 Introduction

This chapter focuses on the first objective of this study, which is to examine the economics of the production of cassava bio-ethanol in Thailand, including the subsystems of the agribusiness system. Since transactions are costly, physical assets and accessibility are included for consideration as potential factors influencing incomes and contract decisions. This chapter is organized as follows: a survey to obtain information about the factors is discussed in Section 6.2. Types of data collected are discussed in Section 6.3. The description of the survey response is discussed in Section 6.4 and the final Section 6.5 is a summary.

6.2 The survey

6.2.1 Selection of region, district and sample householders

In this study, there are three steps in conducting the household survey. The first step was to select a sample region. In 2010, there were around 7.15 million rai of cassava production in Thailand, a decrease of one million rai compared to production in the previous year. The north-eastern region of Thailand was the largest area for cassava planting accounting for 50 per cent of all plantings and accounting for 4.85 million rai with an output of around 1.20 million tons. The eastern, central plain and the western regions also produced cassava but in less quantity.

The next step was to select the provinces and districts in the region for sampling. Nakhon Ratchasima province has been the largest area of cassava planting in Thailand since 2006, accounting for 1.42 million rai followed by Chaiyaphum, Kamphang Phet and Ubon Ratchathani provinces accounting for 0.66, 0.40, 0.36 and 0.34 million rai respectively in 2010 (Office of Agricultural Economics 2008; Office of Agricultural Economics, 2011).

Based on these details, the north eastern region became a candidate for a sample region for the survey and the Nakhon Ratchasima province was selected as a sample province.

In 2010, the five districts in Nakhon Ratchasima which were the largest areas of cassava production of between 135,089 and 308,290 rai were Dan Khuntod (9,846 farmers), Khon Buri (7,816 farmers), Soeng Sang (6,315 farmers), Nong Bun Nak (6,078 farmers) and Si Kew (5,091 farmers) (Department of Agriculture Extension, 2011). Therefore, Dan Khuntod, Khon Buri and

Soeng Sang were selected as sample districts for the survey as they were the largest areas of cassava production and they had the largest number of cassava farmers.

The final stage was choice of sample households from the 23,977 farmers who grow cassava in Dan Khuntod, Khon Buri and Soeng Sang subdistricts. Using the listof farm households provided by the agricultural cooperative and contracting firms and a stratified random sampling method, 50 cassava farmers from each village were selected. Cassava farmers were separated into two groups: contractors and non-contractors; 257 households with 127 contractors and 130 non-contractors were interviewed.

6.2.2 Data Collection

The group of respondents interviewed were met on the day of interview at the District Agricultural Extension Office, Nakhon Ratchasrima province, and were compensated for their travel and time away from their farms. Enumerators interviewed the respondents in their local language and there was no opportunity for other smallholders to interject during the interview. Enumerators were trained prior to the interview to make them familiar with the survey form. The survey process was a follows:

1. The objectives of the survey were discussed and outlined to enumerators and other participants who would be directly involved in the survey. There was an open discussion where all participants had an opportunity to make an input into the survey process. The form was then adjusted where necessary to remove bias and errors.
2. A trial survey was undertaken by an experienced interviewer or supervisor, while trainees watched and completed the form, then the groups of enumerators undertook two additional trial interviews. After the form was completed in each interview the results and any problems were discussed.
3. Based on trial interviews, enumerators who had the required skills were selected to participate in the survey. During the survey activities, supervisors immediately checked the form after completion and, if there were inconsistencies or incomplete information, the enumerator was responsible for obtaining the missing information as soon as possible.

6.3 Types of Data

Three types of data were collected in this study: quantitative data, qualitative data and supplementary data from primary and secondary sources. Primary data was collected from interviews using open-ended questions because the quality of the data is usually high, with a low sampling frame bias and low response bias (Czaja, Blair, & Blair, 2005). Three hundred Thai cassava farmerscontractors and non-contractorsprovided information about socio-economic characteristics of farmers, agricultural income, non-agricultural income and accessibility to contracts. Primary data also came from Thai cassava bio-ethanol processors and stakeholders of the Thai cassava bio-ethanol industry. Secondary data, from various sources, was used as supplementary data for validating information from the field surveys, calculating specific variables, such as local market price, and explaining statistical results associated with agricultural policies.

6.3.1 Quantitative Data

To examine the hypotheses in this study, a quantitative data set was needed to calculate both exogenous and endogenous variables. Table 6.1 provides an index of the information derived in the survey. More details are contained in Appendix 1.

Table 6.1: Index of the survey form

Index	Types of information
A	Household characteristics
B	Off-farm income
C	Family/household assets (farm and non-farm)
D	Cassava production and inputs
E	Contract
F	Multiple crops and tree crops
G	Labour use for multiple crops and tree crops
H	Livestock
I	Labour use for livestock
J	Credit
K	Membership of farmers groups
L	Community responsibilities

(Source: Tabulated from the survey form – see Appendix 1)

Table 6.2 lists the sources of the quantitative data set from the survey form. This table consists of four blocks of information. The first block is socio-economic characteristics of smallholders recorded in Form A, C and D. These forms mainly cover two types of information. The first type is demographic characteristics of smallholders such as education, age of family members and gender. The second type is economic characteristics of smallholders such as the ownership of land, housing, machines, electricity and source of water supply.

The second block is cassava income indicated by cassava income which is calculated from quantity (kg/rai) x price (baht/kg), wages and rental costs, labour use in cassava production, inputs information and cropping systems for cassava production and contract farming. These were recorded in Form D and E. Information about on-farm income, including multiple crops and tree crops, and livestock income were recorded in Form B, F and H. From these forms, on-farm income is calculated from the following information: price, labour costs including family and non-family labour, and non-labour costs, such as fertilizer, pesticide and machinery costs.

Table 6.2: Sources of quantitative data

Type of information	The survey form	
	index	No. Questions
Socio-economic characteristics of smallholders		
1. Number of household members	A	1
2. Gender of household head	A	3
3. Family labour force	A	1
4. Age of the household head	A	4
5. Years of education completed by household head	A	7
6. Years of education completed by household members	A	7
7. Non-agricultural assets	C	1-17
8. Agricultural assets	C	1-17
9. Worked land	D	3.1
10. Irrigated land	D	3.1
Cassava Income		
1. Wages and rental costs	D	3.1
2. Cassava income	D	3.2
3. Inputs information and cropping system	D	3.4
4. Labour use in cassava production	D	3.5
5. Contract farming	E	1-15
Non-cassava Income		
1. Off-farm income (household members earning income out of agriculture)	B	1-4
2. Multiple crops and tree crops income	F, G	
3. Livestock income	H	
Market Access		
1. Selling price	D	3.2
2. Credit	J	1-9

(**Source:** Tabulated from the survey form – see Appendix 1)

The information about contracting firms was described in part E, as shown in Table 6.3

Table 6.3: General questions with particular reference to cassava contracting firms

Question	Choices	
	index	No. Questions
1. Have you produced cassava before without a contract?	E	1
2. What year did you first grow cassava under contract?	E	2
3. How many years have you not grown cassava under contract?	E	3
4. What were the two major reasons for not growing cassava crops?	E	4
5. What do you usually do with the cassava residue?	E	5
6. What are the potential benefits of contracting this commodity?	E	6
7. What are the potential costs or risks of contracting this commodity?	E	7
8. When do you receive your income?	E	8
9. What is the name of the firm you are under contract to?	E	9
10. When first considering accepting a contract to grow cassava, what were your major concerns?	E	10
11. Would you change the conditions of the contract if you could?	E	11
12. Has the contract changed over the years?	E	12
13. Has the introduction of cassava forced you to change other aspects of your farming operations?	E	13
14. Do you have any other experience with contract farming in the last five years?	E	14
15. Would you enter these types of contract arrangements again if you had the chance?	E	15

(**Source:** Tabulated from the survey form – see Appendix 1)

The third block of information is non-cassava income. This information was recorded in Forms, B, F and H and covered information about income from non-agricultural activities such as home industry, transportation, government, local retailing and non-agricultural subsidies from both government and non-government organization (NGO).

The fourth block of information concerned accessibility to markets and credit. Information about selling price was recorded in Form D through interviews, and supplementary information for calculating accessibility to markets and information about credit was recorded in Form J. These forms also cover information about the financial institutions such as village funds, commercial banks and BAAC.

6.3.2 Qualitative Data

The qualitative data set comprises information about household perceptions of contract farming, financial institutions and community organizations. This information was gathered from Forms E, J, K and L. Some of the main information included: i) small holder motivations for accepting CF, ii) smallholder perceptions about the benefits of contracting, iii) smallholder perceptions about the difficulties in accessing financial institutions, iv) smallholder motivations for getting credit, and v) smallholder perceptions about the benefits of participating in community organizations.

6.3.3 Supplementary Data

A considerable amount of district, regional and national data was also gathered from various secondary data sources (see Table 6.4) on:

1. Government budget allocations and other indicators of regional and national priorities in economic development.
2. Government policies, particularly agricultural development in dealing with poverty allocation.
3. Economic development, particularly poverty, economic structure changes and labour use.

Table 6.4: Sources of supplementary data

District Level			
economic development	**infrastructure**	**climate**	**demographic**
- income per capita growth - poverty indicators - economic structural changes - labour use - local prices of cassava	- local stores - storage - financial institutions - transport	- rainfall - climate hazards - fertility status of soil	- population - density - education - health
Regional and National level			
economic development		**government policies**	
- government budget allocations - labour use - other indicators		- agricultural development - poverty	

Source: Tabulated from the survey form

6.4 Description of survey responses

6.4.1 Human capital

Age of household head and average age of household members

Figure 6.1 shows age and average age of household heads and household members. On average, age of household heads of non-contractors was 49.04 years with 46.92 per cent for females and 53.08 per cent for males. This was slightly higher than contractors who were 48.83 years with only 8.66 per cent males and over 90 per centfemales. The average ages of non-contractors and contractors were 37.86 and 37.62 years respectively, not significantly different.

The responses show that the number of household heads who are female contractors was much higher than non-contractors. This might be because Thai women are more likely to undertake further study in higher education (Office of Women's Affairs and Family Development, 2007). The proportion of females working in local administration and the number of female household heads has increased from 25.7 per cent in 2001 to 28.3 per cent in 2005 (Office of Women's Affairs and Family Development, 2007).

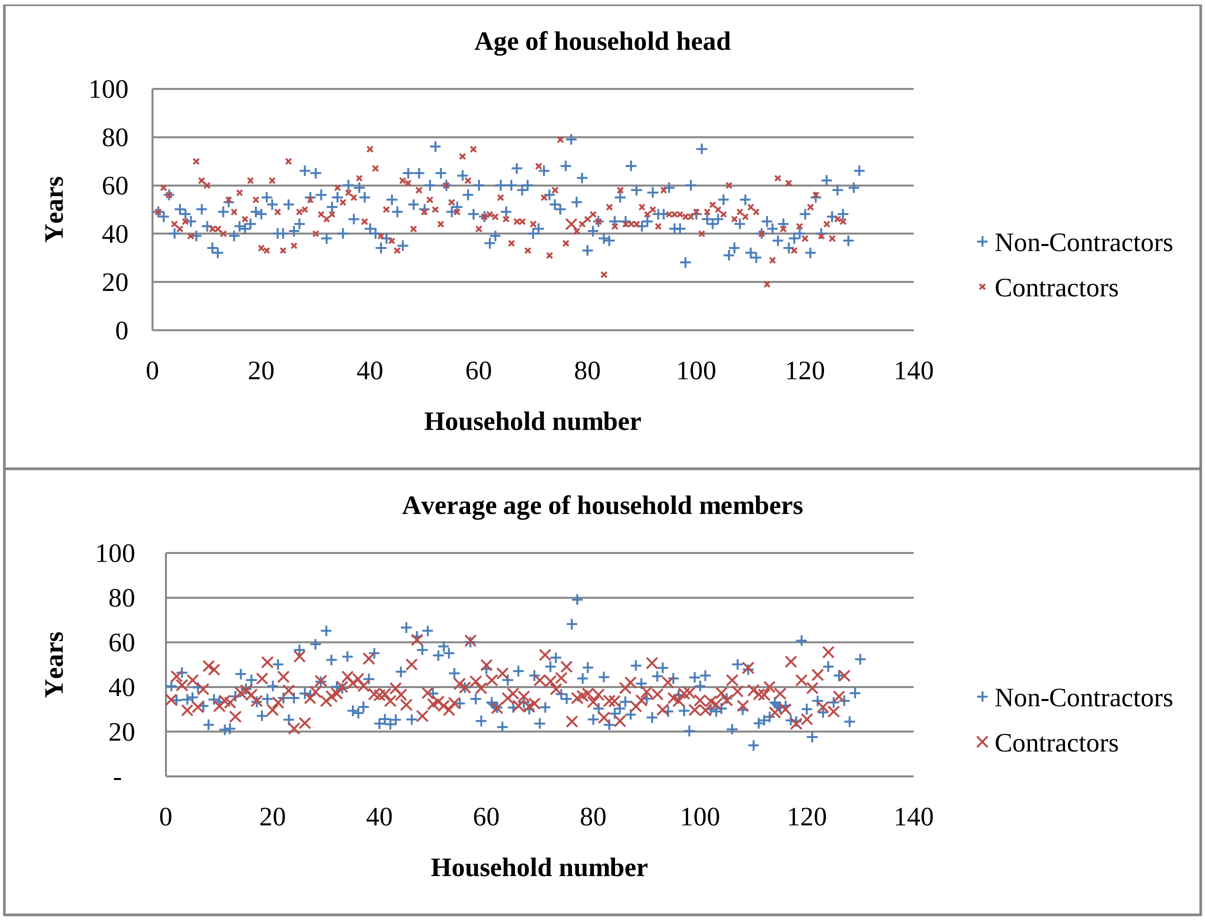

Figure 6.1: Age and average age of household heads and household members
(**Source**: Calculated from the survey research crop year 2010/2011)

Years of formal schooling of household heads and household members

Education levels are calculated as number of years of education completed by household heads and household members. For non-contractors, approximately 40 per cent completed four years of formal schooling; 25 per cent six years; and 13 per cent 12 years (13 per cent). Forty-three per cent of contractors' household heads had completed six years of education, 24 per cent had completed nine years and 17 per cent, four years (see Figure 6.2).

Figure 6.2: Formal Schooling Years of Household Head and Household Members

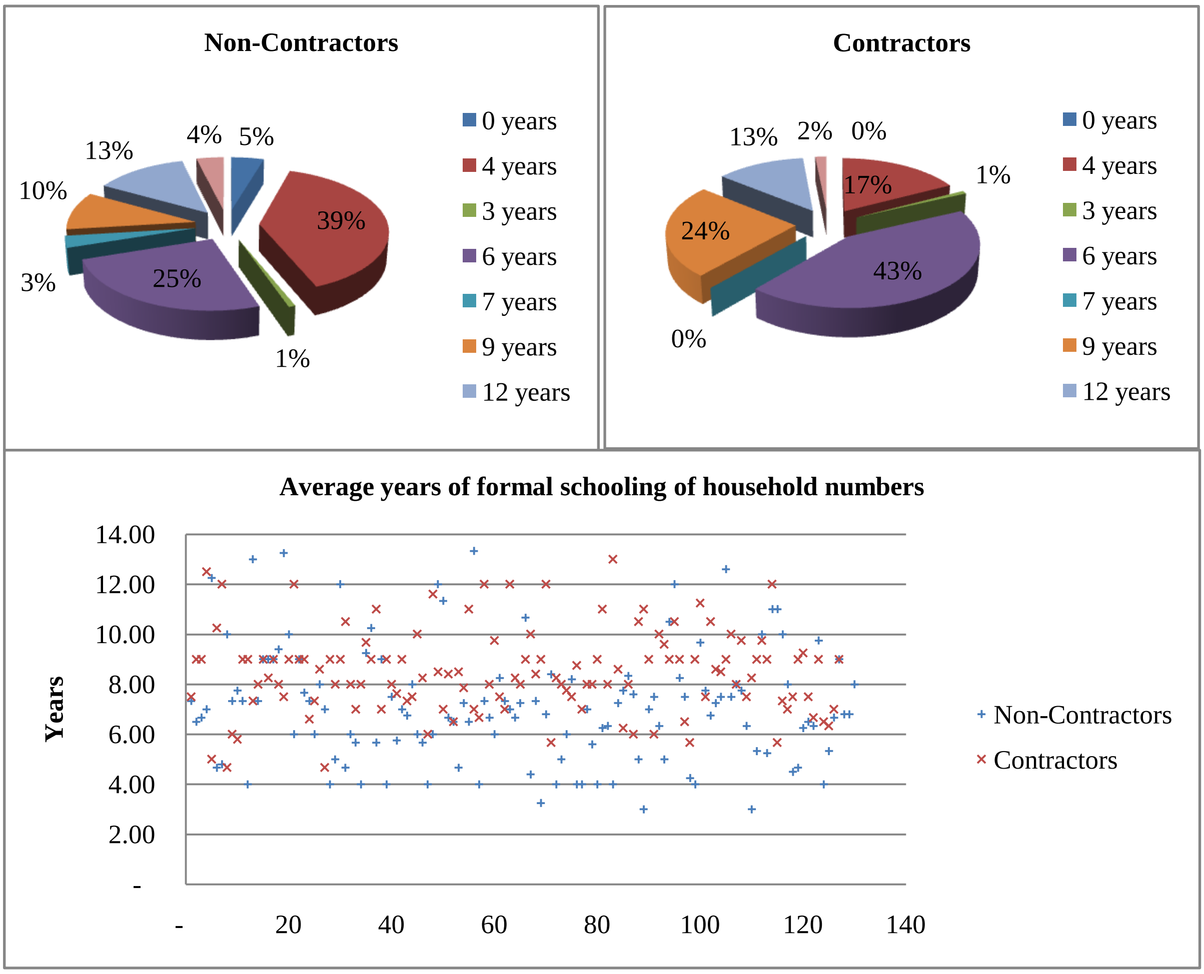

Figure 6.2: Formal schooling years of household head and household members
(**Source**: Calculated from the survey research crop year 2010/2011)

On average, average levels of education completed by household heads of non-contractors and contractors were 6.43 and 7.26 years respectively or just slightly more than primary level education. The means are significantly different with a significance level of 0.04 per cent.

The average number of formal schooling years of non-contractors household members was 7.13 years and the average number of formal schooling years of contractors' household members was 8.47 years; a significant difference with a p-value of 100 per cent.

The level of poverty was related positively to the household caring burden and the level of education of the head of the household. Households with higher caring burdens were poorer than those with lower caring burdens. Households whose heads were uneducated or had only primary education were found to be poorer than households whose heads had secondary education and upwards. The findings in this study confirm the report: non-contractors earned lower incomes compared to contractors and were poorer and had less formal schooling.

In addition, the size of contractors' families was smaller compared to non-contractors' families and accounted for 3.05 persons. This consisted of head of household, spouse (0.79 persons), sons or daughters (1.27 persons) and others (0.23 persons). There were 3.38 persons in non-contractors' family on average including the head of household, spouse (0.80 persons), sons or daughters (1.35 persons) and others (0.27 persons) on average. The averages of family sizes between the two groups are significantly different with a p-value of 100 per cent.

Experience in growing cassava for surveyed households

In crop year 2010/2011, the average years of experience for non-contractors and contractors were 14.7 and 14.6 years respectively, which is not a statistically different, as shown Figure 6.3.

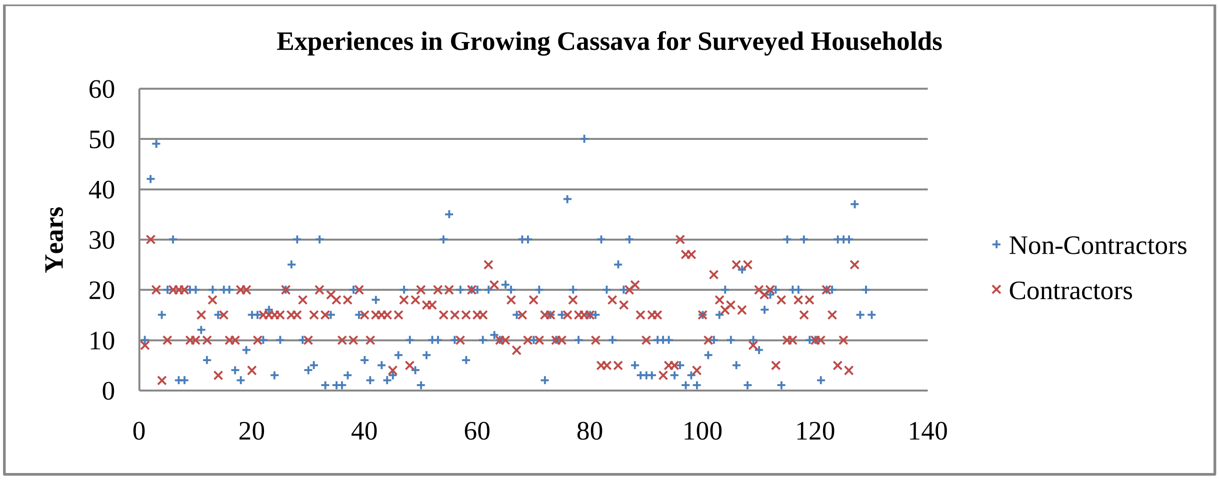

Figure 6.3: Experiences in growing cassava for surveyed households
(**Source**: Calculated from the survey research crop year 2010/2011)

6.4.2 Social capital

Groups and years of participation of household head in agricultural organizations

Social capital data was captured by gathering information about membership of groups and number of years the household head had participated in agricultural organizations. In 2012, there were 305 agricultural groups and 38 agricultural cooperatives in Nakhon Ratchasima province, and 10 and 16 agricultural groups in Khon Buri and Dan Khuntod respectively (Cooperative Promotion Department, 2012). The BAAC, which as a state enterprise, is under the jurisdiction of the Ministry of Finance, extends credit directly to individual farmers as well as through farmer institutions and the National Village and Urban Community Fund, which is a learning centre fund for the welfare of villages and community.

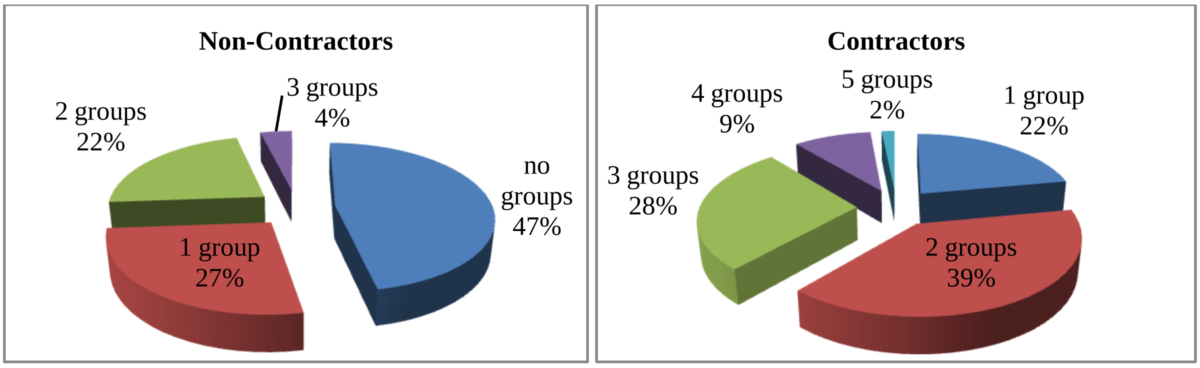

Figure 6.4: Groups of participation of household head in agricultural organizations
(**Source**: Calculated from the survey research crop year 2010/2011)

Non contractors' household heads belonged to an average of 0.83 agricultural organizations and had 10.00 years of participation. Contractors' household heads belonged to agricultural organizations such as Khon Buri Agricultural Cooperatives, Nong Boonmark Agricultural Cooperatives, BAAC and Village Fund with an average of 2.29 groups and 10.67 years of participation. The means of group numbers are significantly different with a p-value of 100 per cent but years of participation are not significantly different as Figure 6.4 shows.

6.4.3 Perception of contracts

In the wake of market liberalization, contracting is more likely to be a principal component of rural development, especially for Thailand because 1) agricultural market requirements have changed rapidly since economic liberalization became more important in world trading, thus, both agricultural firms and farmers are more likely to participate in contracting (Eaton & Shepherd, 2001; MacDonald et al., 2005); 2) competitive pressures in global markets lead to more specialized farm enterprises along with increased demand for large-scale farming to obtain economies of scale; and 3) economic liberalization has increased demand for high value foods, especially for export commodities, frequently characterized by higher income risk from production failure and market price variability. Contracting plays a part in sharing risk between farmers and agribusiness firms (Simmons, 2003).

Figure 6.5 shows the most important reasons why contractors in agricultural cooperatives offered 2010/2011 for their membership of cooperatives. Higher price, increased income and guaranteed markets were the three most important benefits reported by 30 per cent, 22 per cent and 18 per cent of the sample respectively. Moreover, access to credit, technology and training were alsonoted as advantages of CF under cooperatives (see Figure 6.5).

Seventy-four per cent of contractors grew cassava under contracting arrangements since 2008, and 26 per cent started growing cassava for contracting firms in 2009. All contractors had no other experiences with CF in the last five years. All contractors usually graze and plough under cassava residues after harvesting.

The main advantages of contracting for contractors are the guaranteed prices specified by quantity and quality parameters, providing contractors with access to management, extension, knowledge and technical services, guaranteeing access to credit, access to markets, increased cash crop production, and rural employment and contracting has also led to better employment opportunities for women workers.

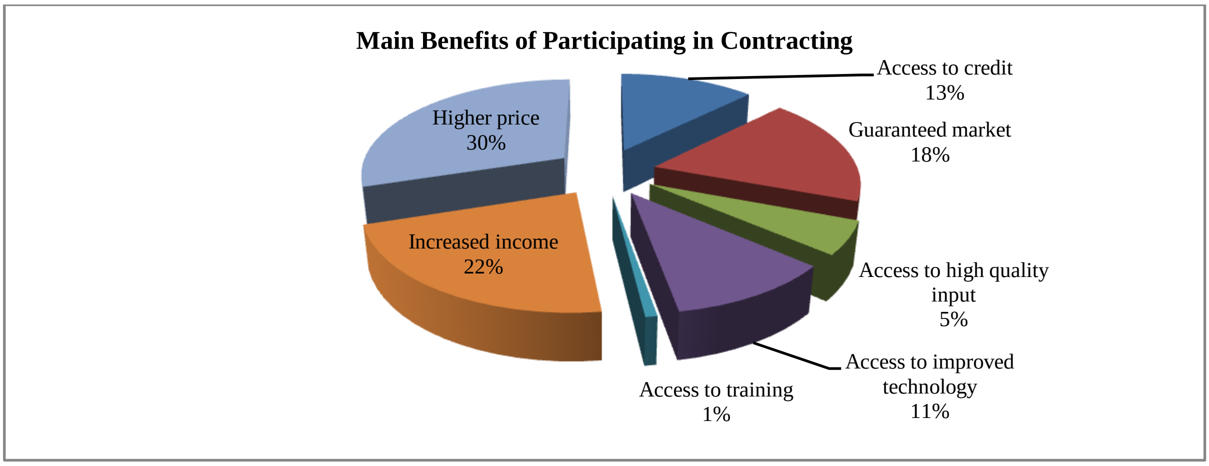

Figure 6.5: Main benefits of participating in contracting
(Source: Calculated from the survey research crop year 2010/2011)

In these contract arrangements, the contract between agribusiness firms and cassava farmers is an oral one between farmers and agricultural cooperatives, and a formal contract agreement between agricultural cooperatives and processors. Thus, there were no written agreements between farmers and agricultural cooperatives. However, the cooperatives benefit by 0.03 baht per kg of fresh cassava if farmers sell their products through a cooperative (in this case, farmers must be members of a cooperative and they will receive a bonus every year), and farmers receive

0.05 baht per kg. However, farmers can directly sell their products to firms and they also get 0.05 baht per kg, but firms prefer buying products through a cooperative rather than directly from farmers because a cooperative would check quality before passing the certified document to farmers to show the firm's approval, as shown in Figure 6.6. For this reason, farmers showed the three most important potential benefits are higher prices than market price (29.92 per cent), increased income (22.05 per cent) and guaranteed market (18.11 per cent). From these results, contracting may have positive benefits for farmers, especially by increasing their income, at least in the short-term, because they are in a better bargaining position and can attain a higher purchase price. However, the controversy over benefits from contracting will arise in the long-term because of market instability effects and management problems from contracting.

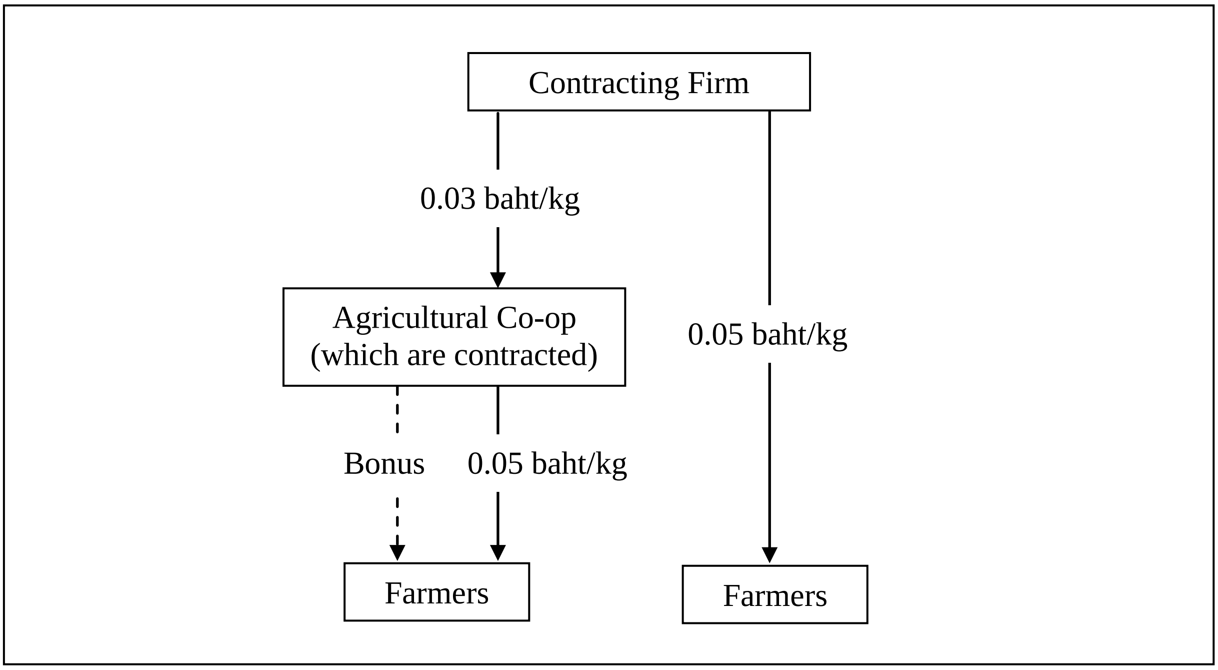

Figure 6.6: Higher prices provided from contracting firm
(**Source**: From the survey research crop year 2010/2011)

Time-consuming meetings and management are the most potential costs or risks which contracting farmers faced, accounting for 40.91 per cent or identified risk, followed by lack of understanding or transparency in contracting (28.35 per cent) and difficulty in managing credit or capital that is provided (13.93 per cent). All farmers receive their revenue after they transport their products to firms.

The main reason identified by farmers for accepting a contract to grow cassava is higher price (85.83%). This result is related to the most benefit which farmers receive. Access to market and access to knowledge and technology are also major considerations for participation in contracting arrangements (35.43% and 11.81% respectively). This means that farmers are likely to want to avoid risks from less capacity than anticipated for their produce, and risks from unpredictable events such as droughts, floods and diseases. Thus, farmers are willing to enter into the contracting and payadditional costs for risk reduction.

If farmers could change the conditions of the contract, 84.25 per cent said they would not change anything because they thought that this agreement between them and the agricultural firm, and between them and the cooperative were suitable and fair. However, 10.24 per cent wanted to change the conditions, such as price and percentage of starch content required. There have been no changes to contract conditions over the years, and farmers have not been forced to change other aspects of their farming operations. As a result, 94.49 per cent of contractors would enter this type of contract arrangement again, less than five per cent of current contractors had not decided yet whether to participate in a future contract and only 0.8 per cent of current contractors would not participate in contracting again.

6.4.4 Attributes

Farm attributes refers to a system of interrelated and closely joined stages in the life cycle of the products of agriculture and includes all processes involved in the production of farm inputs, the farm input used in the cultivation of crops, processing of agricultural raw materials and transferring of these products to the consumers.

Tenancy arrangements and certificates of ownership of land

Eighty-one per cent of non-contractors t owned their cassava planting areas, 10 per cent leased their land, and 9 per cent owned shares in planting areas. Fifty-eight per cent of land certificate ownership[18] was Por Bor Tor 5,[19] 25 per cent was Sor Por Kor.4-01[20] and 16 per cent had title

[18] Under the land registration system in Thailand, for each parcel registered, either with a title deed (NS 4) (certificate of title) or a certificate of utilization (N.S. 3, N.S. 3 K, N.S. 3 Khor, a parcel file (or dealings file) is created and maintained.

[19] Por Bor Tor 5: this document is a land tax return (property tax return) and receipt given to anyone who comes to pay land tax in local administration offices.

[20] Sor Por Kor 4-01 is not a land title deed. It refers to land allotted by the Land Reform Committee with the strict provision of agricultural or forestry usage for certain persons (such as farmers). The land is surveyed and marked

deeds[21]. All contractors are owners of land and all of the land certificate ownership is land allotted with strict rules for agricultural or forestry usage.

Size of land and years of ownership or management

Figure 6.7 provides the data used to create the key variables for physical assets. Information about the land operated by households was obtained directly from the questionnaire. On average, non-contractors operated approximately 24.75 rai of cassava planting area and the average years of ownership or management was around 16.95 years. Contractors operated 36.62 rai on average with 16.35 years of ownership or management. The means of both groups are significantly different with a significance level of 0.02 per cent.

6.4.5 Agronomic factors in cassava production

This sub-section provides details of cassava production including the main problems faced by farmers, experience in growing cassava, present variety of cassava, planting period, length and age of cassava, chemical fertilizers, manures, and herbicides and pesticides for cassava planting.

There are four steps in cassava planting: i) land preparation: in Thailand, the soil is frequently prepared by hired tractor using a 3-disk plough followed by a 7-disk plough and sometimes ridging in straight lines parallel to roads to plot borders, irrespective of slope direction. The subsoiling should be followed by either a 3-disk plough to loosen the soil and weed control by loosening the soil to decrease weed competition. ii) Planting: stems are cut from mature cassava trees with at least five nodes and they are stuck into the top of the ridged soil either vertically or at an angle. iii) Crop maintenance (weed control, fertilization), the crop responds well to the application of fertilizer with chemicals and manures and spraying the newly-planted area during the first three days with a pre-emergence herbicide. iv) Harvesting, includes loading: when the tree stems are to be used for planting, they should be cut and handled fairly carefully, de-branched, bundled and transported to keep them for up to three months for planting and transporting rootstocks to the processor.

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with corner poles. However, it is not allowed for anyone to buy; it may only be transferred to the direct heirs of the owner.

[21] Title deed or N.S. 4 means land title, or land title deed. It is equivalent to a certificate of title in the Torrens system in Australia or land certificate in England.

Figure 6.7: Four Steps of Cassava Plating

Figure 6.7: Four steps of planting cassava
(**Source**: From the survey research crop year 2010/2011)

Varieties of Cassava

One of the countries most active in improving varieties of cassava is Thailand. In 1994, the Thai government created a special program for rapid multiplication and distribution of new varieties with early harvest-ability, high harvest index, high productivity potential and high root starch content. The program involved the Thai Department of Agriculture, the Thai Tapioca Development Institute, Department of Agricultural Extension and the Faculty of Agriculture at KU (Howeler et al., 2013). As noted in Chapter Two, there are five major varieties of cassava cultivated in Thailand (Senadee et al., 2008): Rayong 60, Kasetsart 50, Rayong 5, Huay Bong 60 and Huay Bong 80. Figure 6.8 shows that 63.85 per cent of non-contractors plant the cassava variety named "Kasetsart 50", and "Houy Bong" 60, "Rayong 5" and "Kandaeng", accounting for 32.31 per cent, 2.31 per cent and 1.54 per cent respectively.

"Kasetsart 50" is the most important cassava cultivar in Thailand and probably the most important cultivar in the world. In 2006, this cultivar was planted over 57 per cent (633,700 ha) of the cassava growing area in Thailand. This cultivar also is grown extensively in Vietnam and Indonesia (named KM 94).

Two other varieties are also popular: 49.61 and 46.46 per cent of contractors plant cassava varieties named "Houy Bong 80" and "Houy Bong 60" due to their higher fresh root yield potential, higher root starch content and higher dry matter content compared to "Kasetsart 50". Their compact root structure is also more suitable for machine harvesting. Huay Bong 80 is widely adopted for modern cassava production under narrow spacing and mechanization conditions.

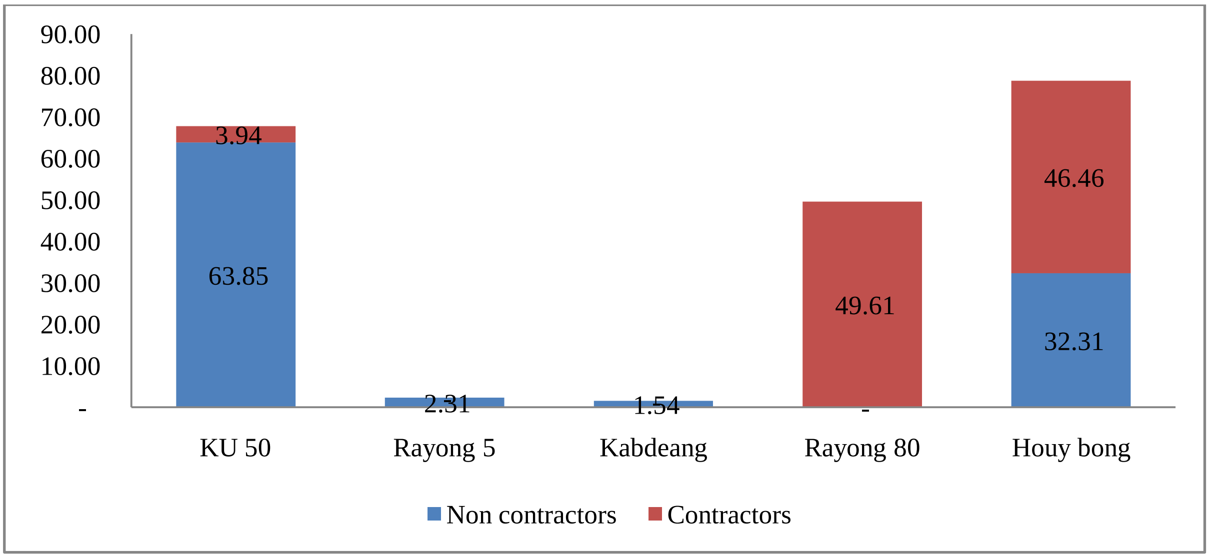


Figure 6.8: Cassava varieties of non-contractors and contractors
(Source: Calculated from the survey research crop year 2010/2011)

Planting Period

Even though cassava can grow in drought conditions, it is very sensitive to soil water shortages during the first three months after planting. Water stress at any time in that early period considerably decreases the growth of shoots and roots, and damages storage roots growth. Once established, cassava can grow in areas that receive just 400 mm of average annual rainfall. However higher cassava yields have been produced with much higher levels of water supply (Howeler et al., 2013).

Figure 6.9 shows that 44 per cent of non-contractors grew cassava for 12 months, 19 per cent for 11 months, and 18 per cent for nine months. Thirty-four per cent grew cassava in March so they could harvest in the following March and accounted for 46 per cent. The average planting period was 10.98 months. Sixty-seven per cent of contractors grew cassava for 11 months, 20 per cent for 13 months and 9 per cent for 12 months. The average planting period for contractors was 11.43 months. They grew cassava in the same month as non-contractors around 67 per cent and harvested in February 59.84 per cent. The means for planting period are highly significantly different at a significance level of 100 per cent. The best planting period for cassava not only depends on the conditions of climate at planting time, however, but also depends on marketing conditions at expected harvesting time. Cassava root prices depend on root starch content, so cassava farmers want to maximize both starch content and yield at harvesting time. Cassava prices also rely on market conditions. Thus, cassava farmers harvest their products in different months in order to get higher prices.

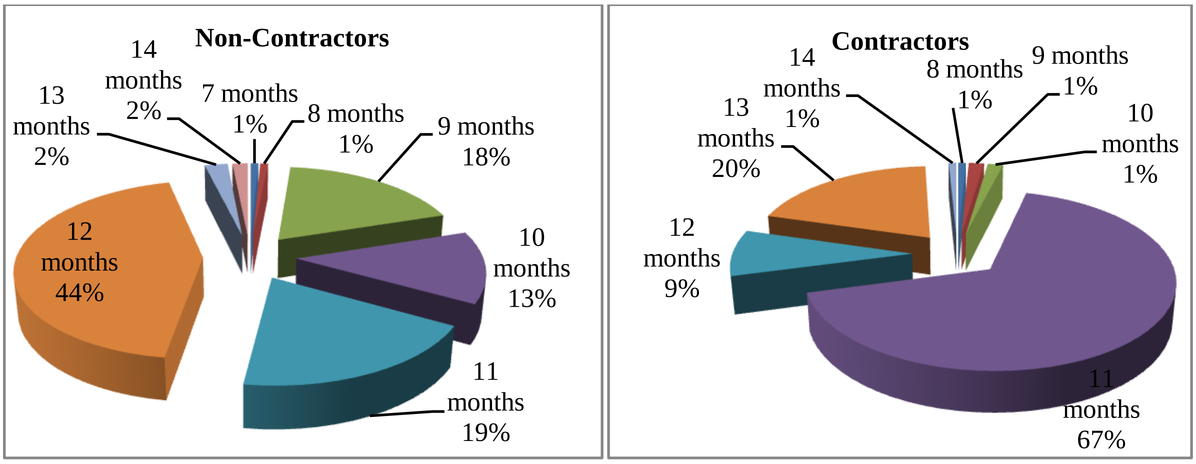


Figure 6.9: Planting season of cassava production
(Source: Calculated from the survey research crop year 2010/2011)

Cassava can be planted at the beginning of the rainy season (February-May) and the end of the rainy season (November-January). Cassava planted during the end of the rainy season has a less steady growth than that planted at the beginning of the rainy season, especially when the long-stored stem is used (TTSA, 2012).

Howeler et al., (2013) suggested total rainfall of approximately 1,700 mm during the fourth to eleventh month after cassava is planted could produce the maximum cassava production. Cassava also responds well to irrigation; if planted in the earlyrainy season, it would normally produce the highest yields because the cassava would have enough soil moisture during the most critical part of the growth cycle. However, if cassava was planted during the dry season, plant survival and the rates of stake sprouting were considerably higher when stakes were planted on the flat, due to the slightly higher soil moisture content of the topsoil. However, it should be planted a little deeper in light-textured and dry soils to avoid lack of moisture and surface heat.

Length and age of stakes

Cassava is usually planted using stem cuttings called “stakes”. The best length of stakes for germination is 15-20 centimetres. To obtain a minimum of 80 per cent germination, cassava stakes should be stored in the dark and for no longer than a half month to two months. Germination capacity is lost after 3-4 weeks of storage (George, Mohankumar, Nair and Ravindran, 2000; Howeler, 2007).

The survey found that 41 per cent of non-contractors used 25 centimetre length stakes, 28 per cent used 20 centimetre stakes and 25 per cent used 15 centimetres stakes. They used four, three and two weeks of rootstocks prior planting (44 per cent, 21 per cent and 18 per cent, respectively). Ninety-eight per cent of contractors used 15 centimetres length of rootstocks for planting. Two per cent used 18 centimetres and 20 centimetres lengths. Ninety-nine percent of contractors used four-week old of rootstocks for planting 99 per cent, with one per cent using one week old of rootstocks. The means for stakeslength used for the two groups are highly significantly different with a significance level of 100 per cent, but other means are not significantly different as shown as Figure 6.10.

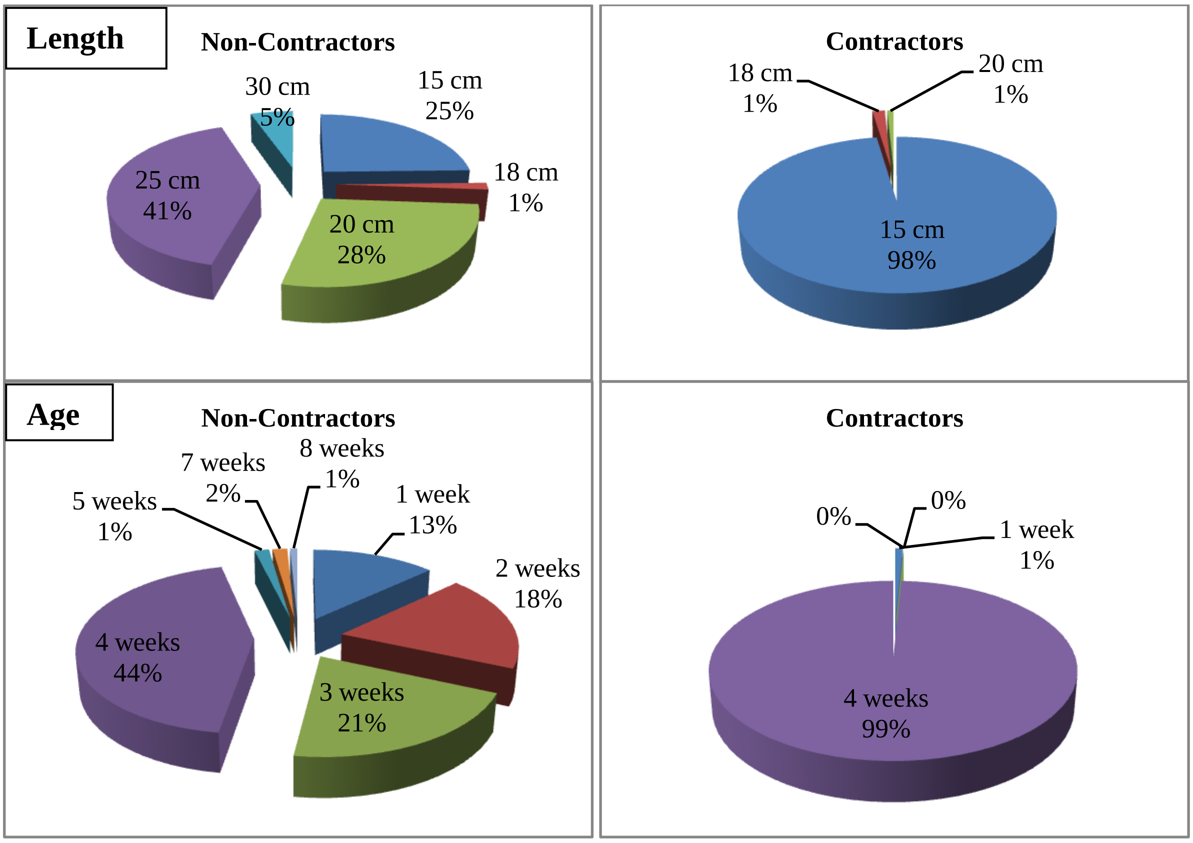


Figure 6.10: Length and age of cassava rootstock for planting
(**Source**: Calculated from the survey research crop year 2010/2011)

Chemical fertilizers and manures

Cassava is particularly tolerant of acid soils, growing well even at a pH as low as 4.2-4.5. However, when the nutrient content in soil is depleted, such as occurs when farmers grow cassava on the same land for many years, yields would be decreased unless farmers return the nutrients, which can be in the form of chemical fertilizers or manures.

When initially planting, cassava should be fertilized with about the same amounts of nitrogen (N), phosphorus (P) and potassium (K). However, if cassava is planted for many years continuously in the same areas, the N-P-K balance needs to be modified because soil nutrients are depleted at varying levels, particularly of potassium. Nutrients can be returned to the soil using compound fertilizers that are high in N and K, but relatively low in P (Howeler et al., 2013).

To cut their input costs, farmers should reduce volatilization of nitrogen and losses of nutrients to runoff and erosion by always covering the applied fertilizers with soil. While mineral fertilizer can help to boost yields, alone they cannot sustain crop production in the long-term on degraded land (Howeler et al., 2013):

1. Intercropping with grain legumes makes some nitrogen available to the cassava crop.
2. Alley cropping with fast-growing leguminous trees may also be an effective means of improving soil fertility.
3. Green manure, such as mulching legume crop residues before planting cassava also improves soil fertility. Effective green manures include groundnuts, cowpeas, velvet beans and pigeon peas.
4. Animal manure and compost are good sources of organic matter. They improve soil structure, enhances water holding and exchange capacity, supply micronutrients and promote the below-ground activity of bacteria, earthworms and fungi.

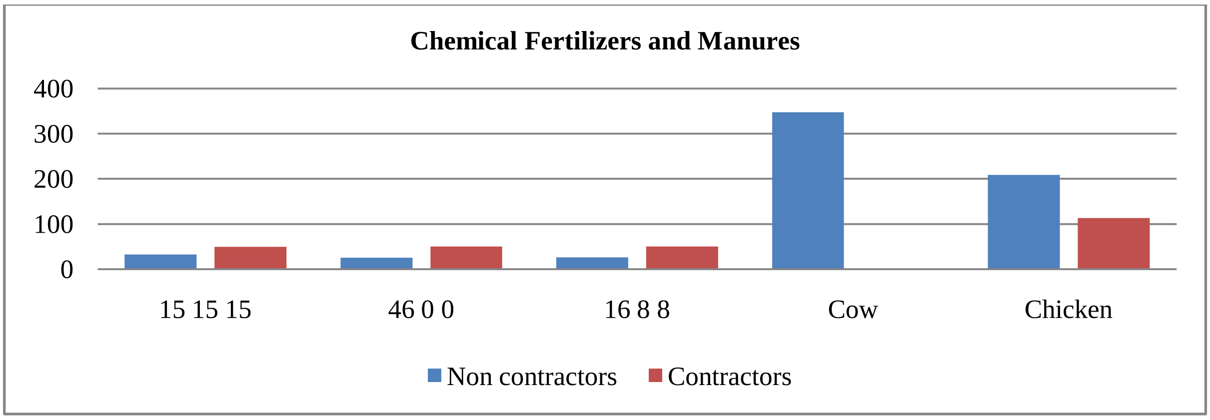


Figure 6.11: Chemical fertilizers and manures
(**Source**: Calculated from the survey research crop year 2010/2011)

For manures, as a rough comparison, 50 kg of chemical fertilizer formulated 15-15-15 contains nearly the same amounts of N, P and K as 1,000 kg of wet pig manure (Howeler, 2000). Non-contractor farmers apply cow and chicken manures at about 350 and 200 kg per rai but contractor farmers apply only chicken manures at 125 kg per rai. Animal manures are important sources of S, Ca, Mg and other micronutrients but contain very low amounts of N, P and K and contribute to improving the physical condition of the soil (Howeler, 2000). A large amount of manures is perhaps economical only if the manures are available locally; otherwise, application and transportation costs might be higher than chemical fertilizers costs.

Herbicide and Pesticide

Using pesticides to protect cassava is hardly ever economical and generally not effective. Use of non-chemical practices could help farmers decrease costs and losses as well as caring for the environment and the ecosystem.

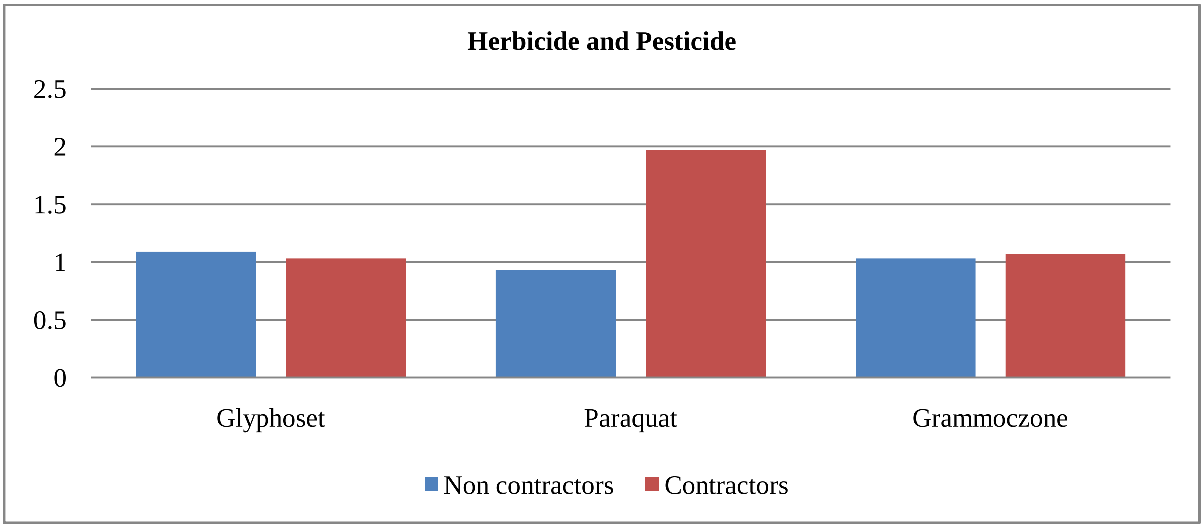


Figure 6.12: Herbicides and pesticides
(**Source**: Calculated from the survey research crop year 2010/2011)

As with the other types of crop, cassava is vulnerable to diseases or pests which can heavily reduce yield. In several areas, the frequency of diseases and pests is rising because the crop is grown intensively over bigger areas and planted throughout the year for industrial processing. Synthetic herbicides, fungicide and insecticide can interrupt the balance of the natural crop ecosystem and make diseases and pest problems worse. A plant protection approach which improves the biodiversity and biological practices which support cassava production should be used to reduce the use of herbicides and pesticides through integrated pest management.

There are three major diseases that can affect cassava in Thailand:

1. One of the most common cassava diseases is bacterial blight, which is spread by infected farm tools and planting material. The bacterium infects the leaves first. They will turn brown in large patches and eventually die. The vascular tissues of the petioles and woody stems will then become infected.
2. Root rot arises generally in poorly drained soils during intense rainy periods and is caused by a wide range of bacterial and fungal pathogens. It causes the loss of leaves, dieback in stems and shoots, and root deterioration.

3. Viral diseases are generally transmitted through infected planting material.

There are also two major types of insects that affect Thai cassava production:

1. Whiteflies are almost certainly the most damaging insect pest in all cassava planting areas. Even though some farmers use insecticide to control whiteflies, it is frequently not effective. However, if they do not use insecticide, the biological control, whitefly's natural enemies will kill them.
2. Mealybugs which feed on cassava leaves, petioles and stems inject a toxin which causes curling leaf, decreased growth rates and then leads to withering leaf. The result from this type of insect is decrease in cassava yields could be up to 100 per cent of the leaves and 60 per cent of the roots. Mealybugs were introduced accidentally into Thailand and have spread throughout the country within a year. At its peak in May 2009, mealybugs destroyed around 230,000 ha of cassava plantings. The outbreaks also overcame the cassava harvest in 2010 which dropped from 2009 levels by nearly 10 million tonnes. To avoid future outbreaks from mealybugs in Thailand, cassava farmers were recommended to avoid planting in the late rainy season and in early summer. They were also advised to soak stakes in an insecticide solution before planting. Researchers and scientists also identified some native parasites and predators but they could not effectively decrease this type of insect population. Therefore, the recommendations for controlling them could be: 1) monitor cassava plantations every two or four weeks to detect focal points of infestation, 2) conserve the population of natural enemies by not spraying synthetic pesticides, 3) avoid the transportation of planting material from one area to other areas and minimize the transportation of planting material from infested to non-infested areas, and 4) remove and burn the infested parts of plants (Howeler et al., 2013).

In general, weeding is most frequently carried out by hand tractor, animal drawn cultivator, hoe, tractor-mounted cultivatoror herbicides. When farmers employ herbicides, non-contractor farmers use spot application of Glyphosate[22] or Paraquat at about one litre per rai immediately after planting, while contractor farmers apply one or two litres per rai, as shown as Figure 6.11. Both non-contractor and contractor farmers apply Grammoczone at around one litre per rai for pesticides.

[22]Glyphosate is a non-selective, broad spectrum, systemic, post-emergence herbicide that has been used extensively throughout the world (Nadula, Duke & Poston, 2005, p 183).

6.4.6 Alternative production

Agricultural products grown in addition to cassava by farmers are tree crop production and livestock production. On average, only 9.23 per cent (12 farmers) or only 9.23 grew tree crops such as coriander, chilli, watermelon and mixed vegetables. Approximately 14.70 rai were used in such products with the average total cost of producing the alternative crops was/being 2,042.12 baht and benefits were 7,349.75 baht. No contract farmers grew alternative crops.

Two, three and two non-contract farming families farmed cattle, local chickens and pigs respectively. Eighteen contract farmer families produced local chickens and no contract farmer families farmed cattle or pigs.

Figure 6.13 summarizes data concerning incomes from off-farm, tree crop and livestock activities. These incomes are calculated for each crop activity. On average, off-farm incomes of non-contractor farmers and contractor farmers were 79,947.69 and 50,834.65 baht respectively. Incomes from Tree crop and livestock for non-contractor farmers were 6,840.92 and 2,822.31 baht respectively. In contrast, contractor farmers earned 156.49 baht for livestock incomes only.

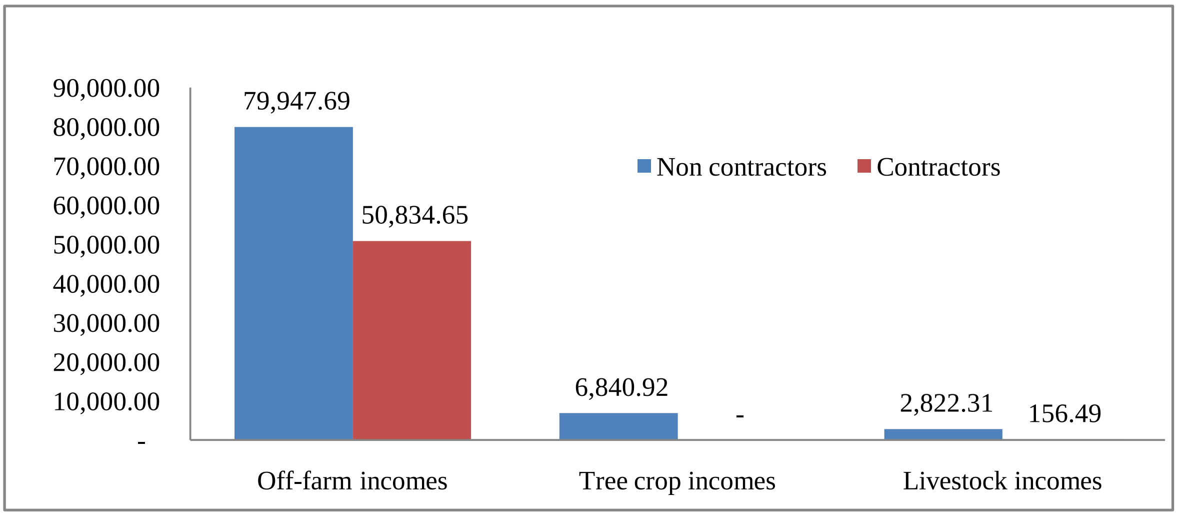


Figure 6.13: Off farm, alternative crops and livestock incomes
(**Source**: Calculated from the survey research crop year 2010/2011)

6.4.7 Householders' credit

Eighty-six per cent of non-contractor farmers required additional credit. Figure 6.13 shows that non-contractor farmers required 113,336 baht credit, on average, and 70 per cent of contractor farmers required additional credit on average of 91,500 baht. Most farmers obtained their loans fromBAAC, the bank created by the government to extend credit directly to individual farmers as well as through farmer institutions; as a result farmers did not face difficulties in accessing credit, as shown as Figure 6.14.

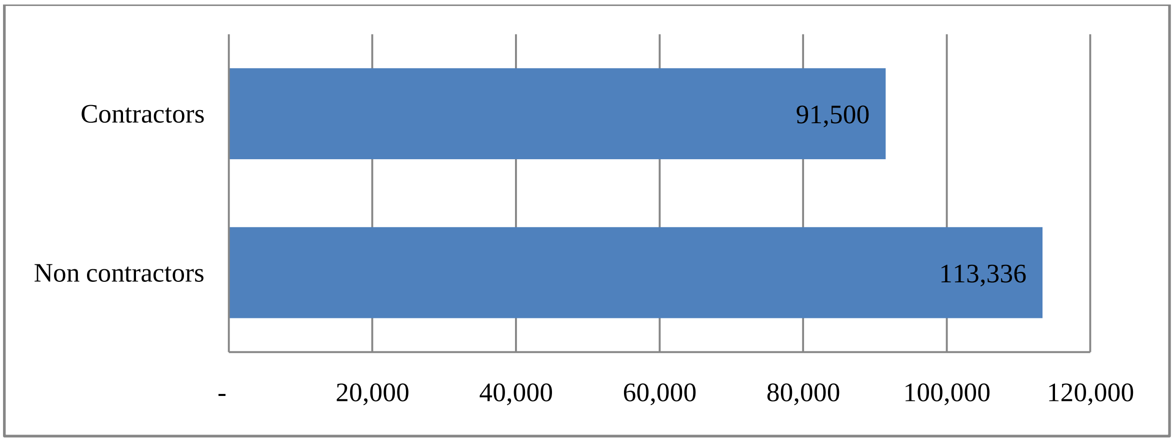


Figure 6.14: Householders' credit (baht)
(**Source**: Calculated from the survey research crop year 2010/2011)

BAAC has played an important role in creating jobs, boosting the rural economy and value adding in the chain of agricultural products in Thailand. Seventy-five per cent of the total loan portfolio is focused primarily on providing retail credit to local farmers; only 25 per cent is wholesale credit to farmer associations, agricultural cooperatives and farmer institutions related to their agricultural activities (BAAC, 2010). The bank also supports the rural community to develop efficiencies in producing agricultural products and reducing production costs, and provide funds for villages, and supplying sufficiency economy funds. BAAC employs 19,922 officers in 77 provinces with 1,118 branches throughout Thailand to ensure it services its customers well (BAAC, 2010). It has launched several projects to support government policies (2012) including:

1. Credit cards for farmers. BAAC has so far approved 2.1 million of these cards; 1.38 million were issued to farmers who have used them to secure loans totalling 3.73 billion baht to buy inputs for production, such as fertilizer, seeds, agricultural-related chemicals and fuel.
2. Debt moratorium for low-income earners and small-scale farmers with debts not exceeding 500,000 baht. This offer drew 784,000 people applying to place their 2011 debts totalling 44.21 billion baht under the moratorium scheme in March 2011. Approximately two million people placed their 2012 debts totalling 196 billion baht under the scheme.

3. Cassava pledging project for the crop year 2012/2013. The BAAC paid 171,000 farmers for 8.26 million tonnes of fresh cassava worth 22.48 billion baht.

Asset values

The value of assets is calculated as the sum of the value of non-land assets (for example, car, television and laundry) and land assets, including farmland and livestock. On average, the values of household assets of non-contractor and contractor farmers were 330,826.22 and 703,898.77 baht, but the range of assets values was large. The means of both groups are highly significantly different with a significance level of 100 per cent.

6.4.8 Main problems faced by farmers

Drought, mealy bug and floods are the three most important problems non-contractor farmers face, accounting for 34 per cent, 29 per cent and 24 per cent of cassava crop losses respectively. Approximately 70 per cent of contractor farmers have faced no problems. However, the most important problems of those contractor farmers who did face problems are similar to the problems of non-contractor farmers: drought (21 per cent), mealy bug (six per cent) and floods (four per cent), as shown in Figure 6.15.

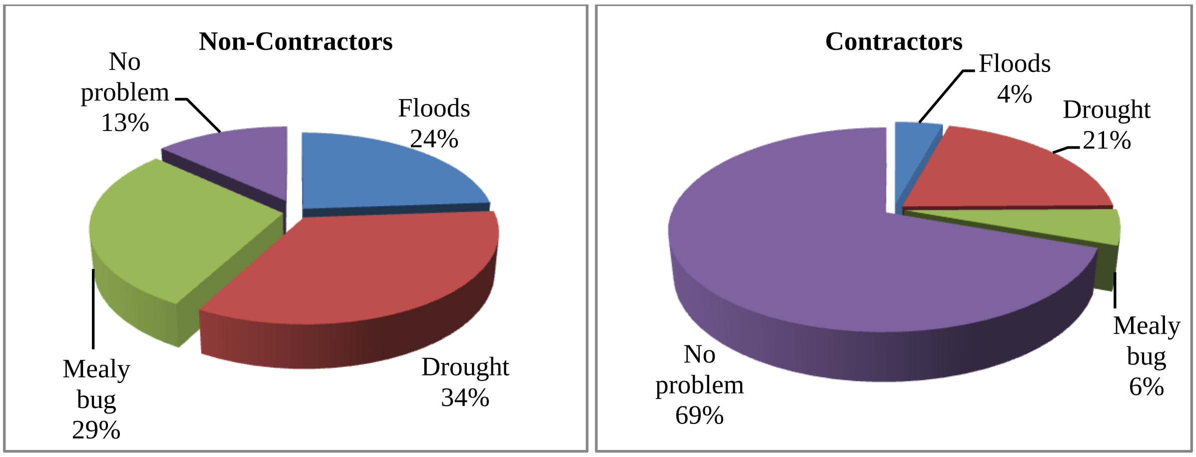


Figure 6.15: Main problems faced by non-contractor and contractor farmers
(**Source**: Calculated from the survey research crop year 2010/2011)

The reason that mealy bug is not a problem for contractor farmers is because, after they cut stakes for planting, they soak them in insecticides named Thiamethoxam or Dinotefuran, for 5 to10 minutes before planting.

When considering problems faced by farmers over a span of a number of years, three shared problems were evident:

1. Low productivity, since most cassava is planted on marginal land;
2. Long-run cassava cropping as a mono-crop together with lack of soil management, leading to soil deterioration and low levels of fertility in most cassava planting areas;
3. Farmers were not motivated to invest in improving technology and creating production plans because they were uncertain about price fluctuations.

6.5 Summary

This chapter has outlined how and what type of data was collected. Data was collected using a survey. The stratified sample was selected by: i) selection of sample region, ii) selection of province and districts, and iii) choosing of sample households. Within the stratified sample, 257 were randomly selected including 127 farmers who worked under contracts to produce cassava and 130 farmers who did not hold contracts.

Primary data from the contract farming survey can be divided into two sets of information: i) quantitative, and ii) qualitative. Supplementary information was also collected from various secondary sources for validating information from the field survey and supporting the explanation of statistical results.

The main findings from the survey data are:

1. Oral contracts between farmers and agricultural cooperatives, and formal contract between agricultural cooperatives and processors were the norm. Cooperatives would benefit by 0.03 baht per kg of fresh cassava if farmers sell their products through the cooperative, and farmers would receive 0.05 baht per kg.
2. Cassava represents a totally new market that will possibly increase significantly in the future as oil reserves run out. Cassava farmers have a guaranteed market for their crops because their products are part of a bio-fuel production chain.
3. Summary results from the calculation of key variables for human capital of contractors and non-contractors are shown in Table 6.5.

Table 6.5: Summary of results from the conclusion of key variables for contractor and non-contractor

		Non-contractors	Contractors	Pr.
	Human capital			
1	Age of household head (years)	49.04	48.83	0.8756^{ns}
2	Average age of household member (years)	37.86	24.92	0.0000^{**}
3	Formal schooling (household head)	6.43	7.26	0.0401^{*}
4	Average years of formal schooling (household member) (years)	7.13	20.50	0.0000^{**}
5	Experience in growing cassava (years)	14.70	14.60	0.9242^{ns}
	Social capital			
6	Groups of participation of household head in agricultural organization (groups)	0.83	2.29	0.0000^{**}
7	Years of participation of household head in agricultural organization (years)	10.00	10.66	0.3402^{ns}
	Farm attributes			
8	Tenancy arrangement (%)			
	- Owner	80.77	100.00	
	- Lease	10.00	-	
	- Share	9.23	-	
9	Certificate ownership (%)			
	- Title indeed	16.15	-	
	- N.S.3	0.77	-	
	- P.B.T.	57.69	-	
	- Tax land return	25.38	100.00	
10	Size of land (rai)	24.75	36.62	0.0220*
11	Years of owner or management	16.95	16.35	0.6728 ns
12	Assets value (baht)	330,808.70	703,898.80	0.0000**
	Agronomic factors in cassava production			
13	Present variety of cassava (%)			
	- KU 50	63.85	3.94	
	- Rayong 5	2.31	-	
	- Khan-Daeng	1.54	-	
	- Rayong 80	-	49.61	
	- Houy Bong 60	32.31	46.46	
14	Planting period of cassava production	10.98	11.43	0.0017^{**}
15	Length of stakes (cm)	21.32	15.09	0.0000^{**}
16	Age of stakes (weeks)	3.12	3.98	0.0000^{**}
17	Chemical fertilizers (litres or kg)	43.40	49.78	0.0950^{ns}
18	Manures (kg)	236.55	113.25	0.0000^{**}
19	Herbicides (litre)	1.04	1.07	0.9236^{ns}
20	Pesticides (litre)	1.28	0.98	0.0282^{*}

(**Source**: Calculated from the survey research crop year 2010/2011)

CHAPTER 7: METHODOLOGY

7.1 Introduction

The theoretical concepts to guide the analysis of smallholder decisions regarding participation in CF were discussed in Chapter 5. The data set used covered the main economic activities of cassava farmer as well as endogenous and exogenous factors such as incomes, prices and credit access. This is needed to test the model, which was then presented in Chapter 6. This chapter discusses methodological issues relevant to the analysis of contracting.

This chapter is organized as follows: Section 7.2 discusses the binary choice model including: linear probability, probit and logit models. The treatment effect model, using Propensity Score Matching and the problem of self-selection bias is discussed in Section 7.3. Section 7.4 provides the Instrumental Variables with 2SLS estimate and testing endogeneity. The final Section 7.5 is a summary of the material in this chapter.

In this study, the dependent variable for analysis of contract participation is binary: 127 contractor farmers and 130 non-contractor farmers involved in cassava production. The standard econometric method for explaining discrete dependent variables such as ‘yes’ or ‘no’ is a binary choice model. In this framework, comparison between results from the linear probability, probit and logit models is based on the magnitude and sign of the forecasts from the three estimates. Since the marginal effects in the probit and logit models are close to the coefficients in the linear probability model, particularly for the sign effects and significance of the correlation, the three estimates can be said to have no systematic differences (Angrist & Imbens, 1995; Greene & Hensher, 2003).

Then, to evaluate the effects of contract participation on outcomes including total costs of cassava production, cassava income, farm gross margins, and employment in cassava production, participation variable will be specified as dummy exogenous regressors in equations. However, in these cases, unobserved variables, such as farmers’ ability, are correlated with both contract participation and outcome; if the correlation is omitted, it may lead to an underestimation or overestimation of contracts effects (Greene & Hensher, 2003). This is called simultaneity or selection bias.

Whether farmers participate in CF or not is dependent on these characteristics, hence the decision of farmers to participate is based on each farmer's self-selection instead of random assignment. On the other hand, latent variables denote the difference between utility from participating in contract farming and the utility from not participating. Farmers will participate in CF if the utility of participation is greater than the utility of non-participation. It should be noted that the relationship between participating in CF and an outcome, such as income, could be correlated. Thus, participating in CF can increase incomes and, as such, richer households may be better disposed to participate in CF. Therefore, treatment assignment is not random, with the group of farmers being systematically different. Particularly, selection bias occurs if unobservable factors influence both the error terms of the income equation and the participation choice equation resulting in correlation of the error terms in the outcome and participation choice equations (Greene & Hensher, 2003). Due to the selection bias problem, correlation of the error terms in the outcome and participation choice equation, which estimate effects of contract participation on outcome with only OLS, may lead to biased estimates.

To address the problem of selection bias, several strategies have been used: the instrumental variable (IV) approach, which uses the 2SLS estimator to overcome the endogeneity problem and to obtain unbiased estimations (Pindyck & Daniel, 1998). Instrumental variable methods can be implemented using cross-section or panel data. Selection bias in model parameters is corrected by using instrumental variables. These variables should be correlated with participation but not correlated with unobserved characteristics affecting the outcome (Dehejia & Wahba, 2002). These instruments are used to predict program participation. The regression discontinuity design method extends instrumental variable and experimental methods. This method allows for observed and unobserved heterogeneity in comparing participants and nonparticipants.

Another approach is to use the propensity score matching (PSM) model. The PSM is useful in the absence of an experiment as cross sectional and panel data (Caliendo & Kopeinig, 2008). It compares treatment effects across participants and matched non-participants based on the propensity to participate. The matching is carried out based on observed characteristics.

7.2 Binary choice models

Two basic techniques can be used to estimate a model: i) least square regression analysis (linear estimates) such as by using the linear probability model, and ii) maximum likelihood methods (non-linear estimates), such as probit, logit and Weibull models. When using non-linear estimates, the most common frameworks in econometric applications are probit and logit models. The probit model is based on the standard normal distribution while the logit model is based on the logistic distribution. The two distributions are similar except in the tails, and the two distributions tend to give similar probabilities of the dependent variable taking a value of one when the value of the independent variables is in the intermediate range. However, for independent variables with very small values, the logistic distribution tends to give higher probabilities to their likelihood (Greene& Hensher, 2003).

7.2.1 Linear probability model

This study was interested in explaining the reasons why participation in contracting occurs, and what factors enter into the decision process and how much each factor influences the decision. Such choices can be represented by binary variables with a value zero or one.

For this approach, Wooldridge (2009, p. 246) describes a standard form. Farmers participating in contracting are given the value $C = 1$ and farmers not participating in contracting are give the value $C = 0$. Factors, such as gender, education, asset values, and credit access, are gathered in a vector w, which explain the decision. Thus, $C$is a random variable. The linear probability model is:

$$C = \beta_0 + \beta_1 w_1 + \beta_2 w_2 + \ldots + \beta_k w_k + u, \tag{7.1}$$

β_j cannot be described as the change in C given a one unit increase in w_j, holding all other factors fixed: C either changes from 1 to 0, from 0 to 1 or does not change. However, β_j can provide useful insights. If we assume that a zero conditional mean holds such that $E(u|w_1, \ldots w_k) = 0$, then we have

$$E(C|\boldsymbol{w}) = \beta_0 + \beta_1 w_1 + \beta_2 w_2 + \ldots + \beta_k w_k, \tag{7.2}$$

where$\boldsymbol{w}$is shorthand for all of the explanatory variables.

The key point is that when C is a binary variable taking on the values 0 and 1, it is always true that $P(C = 1|\boldsymbol{w}) = E(C|\boldsymbol{w})$: the probability of success, that is, the probability that $C = 1$, is the same as the expected value of C. Thus, we have the important equation:

$$P(C = 1|\boldsymbol{w}) = \beta_0 + \beta_1 w_1 + \beta_2 w_2 + \ldots + \beta_k w_k, \tag{7.3}$$

which specifies that the probability of success, say, $p(w) = P(C = 1|\boldsymbol{w})$, is also called the response probability. Because probabilities must sum to one, $P(C = 0|\boldsymbol{w}) = 1 - P(C = 1|\boldsymbol{w})$ is also a linear function of the w_j.

The multiple linear regression model with a binary dependent variable is called the linear probability model (LPM) because the response probability is linear in the parameters β_j. In the LPM, β_j measures the change in the probability of success when w_j changes, holding other factors fixed:

$$\Delta P(C = 1|\boldsymbol{w}) = \beta_j \Delta w_j \qquad (7.4)$$

With this in mind, the multiple regression model can allow us to estimate the effect of various explanatory variables on qualitative events. The mechanics of OLS are the same as before. If the estimated equation can be written as:

$$\hat{C} = \hat{\beta}_0 + \hat{\beta}_1 w_1 + \cdots + \hat{\beta}_k w_k, \qquad (7.5)$$

with$\hat{C}$ the predicted probability of success, $\hat{\beta}_0$ is the predicted probability of success when each w_k is set to zerothis may or may not be interesting. The slope coefficient $\hat{\beta}_1$ measures the predicted change in the probability of success when w_1 increases by one unit.

Wooldridge (2009, p. 575) also shows that the LPM is simple to estimate and use. However, the model has some drawbacks. The two most important difficulties are: i) the partial effect of any explanatory variable is constant, and ii) the fitted probabilities can be less than 0 or greater than 1. These limitations of the LPM can be overcome by using more sophisticated binary response models. In a binary response model, interest lies primarily in the response probability.

$$P(C = 1|\boldsymbol{w}) = P(C = 1|w_1, w_2 \dots w_k), \qquad (7.6)$$

where$\boldsymbol{w}$denotes the full set of explanatory variables.

7.2.2 Probit and logit models

In the LPM, the assumption is that the response probability is linear in a set of parameters. To avoid the limitations of the LPM, consider a class of binary response models of the form:

$$P(C = 1|\boldsymbol{w}) = G(\beta_0 + \beta_1 w_1 + \beta_2 w_2 + \dots + \beta_k w_k) = G(\beta_0 + \boldsymbol{\beta w}), \qquad (7.7)$$

where$G$ is a function taking on values strictly between 0 and 1, for all real numbers z. This ensures that estimated response probabilities are strictly between 0 and 1.

A range of nonlinear functions have been suggested for the function G to ensure that the probabilities are between 0 and 1. The two used in this study are also used in the vast majority of applications along with the LPM. In the logit model, G is the logistic function:

$$G(z) = \frac{\exp(z)}{[1+\exp(z)]} = (z), \tag{7.8}$$

which is between0 and 1 for all real numbers z. This is the cumulative distribution function for a standard logistic random variable.

In the Probit Model, G is standard normal cdf, which is expressed as an integral:

$$G(z) = \Phi(z) \equiv \int_{-\infty}^{z} \phi(v)dv, \tag{7.9}$$

where$\phi(z)$ is the standard normal density

$$\phi(v) = (2\pi)^{-1/2}\exp(\frac{-z^2}{2}), \tag{7.10}$$

This choice of G again ensures that equation (7.7) is strictly between 0 and 1 for all values of the parameters and the w_j.

The G functions in equation (7.8) and (7.9) are both increasing functions. Each increases most quickly at $z = 0$, $G(z) \to 0\ as\ z \to -\infty$ and $G(z) \to 1\ as\ z \to \infty$. The standard normal cdf has a shape very similar to that of the logistic cdf.

Logit and probit models can be derived from an underlying latent variable model. Let C^* be an observed or latent variable determined by

$$C^* = \beta_0 + \boldsymbol{\beta w} + e,\ C = 1[C^* > 0] \tag{7.11}$$

where the notation 1[.] is introduced to define a binary outcome. The function 1[.] is called the indicator function; it takes on the value of 1 if the event in blanket is true and 1 otherwise. Thus, $C = 1$ if $C^* > 0$ and $C = 0$if $C^* \leq 0$. The assumption is that e is independent of $\boldsymbol{w}$and that e either has the standard logistic distribution or the standard normal distribution. In either case, e is symmetrically distributed about 0 which means that $1 - G(-z) = G(z)$ for all real numbers z.

From equation (7.11) and from the assumptions given, it is possible to derive the response probability for C.

$$P(C = 1|\boldsymbol{w}) = P(C^* > 0|\boldsymbol{w}) = P[e > -(\beta_0 + \boldsymbol{\beta w}|\boldsymbol{w})$$

$$= 1 - G[-(\beta_0 + \boldsymbol{\beta w})] = G(\beta_0 + \boldsymbol{\beta w}),$$

which is the same as equation (7.7).

In most applications of binary response models, the primary goal is to explain the effects of the w_j on the response probability $P(C = 1|\boldsymbol{w})$. The latent variable formulation tends to give the impression that the main interest is the effect of each w_j on C^*. As will become obvious, for logit and probit, the direction of the effect of w_j on $E(C^*|\boldsymbol{w}) = \beta_0 + \boldsymbol{\beta w}$and on $E(C|\boldsymbol{w}) = P(C = 1|\boldsymbol{w}) = G(\beta_0 + \boldsymbol{\beta w})$ isalways the same. However, the latent variable C^* rarely has a well-defined unit of measurement (for instance, C^* might be the difference in utility levels from two difference actions). As a result, the magnitudes of each β_j are not, by themselves, particularly useful. Mostly, the aim is to estimate the effect of β_j on the probability of success $P(C = 1|\boldsymbol{w})$; however, this is complicated by the nonlinear nature of $G(.)$.

To find the partial effect of roughly continuous variables on the response probability, it is necessary to rely on calculus. If w_j is a roughly continuous variable, its partial effect on $p(\boldsymbol{w}) = P(C = 1|\boldsymbol{w})$ is obtained from the partial derivative:

$$\frac{\partial p(\boldsymbol{w})}{\partial w_j} = g(\beta_0 + \boldsymbol{\beta w})w_j, \text{ where } g(z) \equiv \frac{dG}{dz}(z). \tag{7.12}$$

Because G is the cdf of a continuous random variable, g is a probability density function. In the logit and probit estimates, $G(.)$ is a strictly increasing cdf. And so $g(z) > 0$ for all z. As a result, the partial effect of w_j on $p(\boldsymbol{x})$ depends on $\boldsymbol{x}$through the positive quantity $g(\beta_0 + \boldsymbol{\beta w})$, which means that the partial effect always has the same sign as β_j.

In terms of choices between the two models, there are no theoretical grounds to justify a preference for either. The logit model sometimes is simpler to use compared to the probit model (Train, 1995; Crown, 1998; Fabra & Schmidheiny, 2010). In this regard, most applied economists find that, in most applications, choices between two models are not likely to make much difference to results. Thus, the logit model is used as an alternative to the probit estimate for binary choice cases. However, both models are nonlinear, computationally burdensome and more complicated compared to the LPM (Crown, 1998).

7.2.3 Maximum likelihood estimation of logit and probit models

Under the linear model assumption, the OLS estimator is the maximum likelihood estimator (conditional on explanatory variables). For estimating limited dependent variable models, the maximum likelihood estimation (MLE) is indispensable because maximum likelihood estimation is based on the distribution of Cgiven $\boldsymbol{w}$, the heteroskedasticity in $Var(C|\boldsymbol{w})$ is automatically accounted for.

Assume that there is a random sample of size n. To obtain the maximum likelihood estimator, conditional on the explanatory variables, it is necessary to have the density of $C_i$given $\boldsymbol{w_i}$.

$$f(C|\boldsymbol{w_i};\boldsymbol{\beta}) = [G(\boldsymbol{\beta w_i})]^C[1-[G(\boldsymbol{\beta w_i})]^{1-C}, C = 0,1, \tag{7.13}$$

where, for simplicity, the intercept is absorbed into the vector $\boldsymbol{w_i}$. It is easily to see that when $C = 1$, $G(\boldsymbol{\beta w_i})$is the result,and when $C = 0$, $1 - G(\boldsymbol{\beta w_i})$is the result. The log-likelihood function for observation i is a function of the parameters and the data $(\boldsymbol{w_i}, C_i)$, and is obtained by taking the log of equation (17.10).

$$\ell_i(\boldsymbol{\beta}) = C_i \log[G(\boldsymbol{\beta w_i})] + (1 - C_i)\log[1 - G(\boldsymbol{\beta w_i})]. \tag{7.14}$$

Because $G(.)$ is strictly between 0 and 1 for the logit and probit, $\ell_i(\boldsymbol{\beta})$ is well defined for all values of $\boldsymbol{\beta}$.

The log-likelihood for a sample size of n is obtained by summing equation (7.14) across all observations: $\sum_{i=1}^{n} \ell_i(\boldsymbol{\beta})$. The MLE of $\boldsymbol{\beta}$, denoted by $\widehat{\boldsymbol{\beta}}$, maximizes this log-likelihood. If $G(.)$ is the standard logit cdf, then $\widehat{\boldsymbol{\beta}}$is the logit estimator; if $G(.)$ is the standard normal cdf, then $\widehat{\boldsymbol{\beta}}$is the probit estimator.

Due to the nonlinear nature of the maximization problem it is not possible to write the formulas for the logit or probit maximum likelihood estimates. The common theory of MLE for random samples implies that under very common conditions, the MLE is consistent, asymptotically normal and asymptotically efficient.

7.3 Treatment effect models

A treatment effect is the average causal effect of a binary variable (0 and 1) on an outcome variable of policy or scientific interest. The term of treatment effect was created in medical literature to compute the causal effects of binary, yes-or-no treatments. The causal effect of a subsidized training programme is probably the mostly widely analysed treatment effect in economics (Heckman & Robb, 1985).

7.3.1 Propensity score matching method

In matching methods, an individual from the comparison is matched with one from the treatment group,then the difference in outcome variable of interest in the intervention computed (Caliendo & Kopeinig 2008, p. 31). PSM has become an extremely popular evaluation method to estimate treatment effects (Ali & Abdulai, 2010; Rosenbaum &Rubin, 1983). Both in the academic and applied literature, the amount of research based on matching methods has been steadily growing. Its application in the evaluation of agricultural interventions has grown markedly in the last few years (Ali & Abdulai, 2010). Rosenbaum and Rubin (1983) defined the propensity score as the conditional probability of assignment to a treatment given a vector of covariates. The method has also been widely applied in evaluating labour market policies and other various fields of study. Its popularity stems from the fact that it can be applied in any situation where one has a group of treated individuals and a group of untreated individuals. The nature of treatment may be very different. Some authors have, therefore, argued that matching is the best available method for selecting a matched comparison group which resembles the treatment group of interest.

(i) PSM

If contract participation was randomly assigned to cassava farmers, it is possible to evaluate the causal effect of contract participation on cassava farmers' wellbeing as the difference in average wellbeing between contractor farmers and non-contractor farmers. However, with observed data, it is necessary to use statistical solutions to the crucial problem of causal inference. It is possible to refer to a reduced form model defining household income equation and contract participation as follows (Mendola 2007, p. 375):

$$y_i^C = f^C(x_i) + e_i^C, C = 0, 1 \quad (7.15)$$

$$C_i = g(w_i) + u \quad (7.16)$$

wherey_i^C is cassava income of cassava farmer i who participates in contracting C, thus, y_i^1 would be income of contractors and y_i^0 would be income of non-contractors.

Income depends on a vector of observed variable x_i and unobserved variable e_i.

$C_i$is a binary variable equal to 1 if they are contractors and 0 otherwise.

$w_i$is a subset of x_i and includes observed variables affecting the choice to participate in contracting; other unobserved variables are summarized by the random variable u.

The interest in this study is the question: *does contract participation increase cassava outcome.* In a counterfactual approach, the quantity of interest is the average treatment effect, shown by Rosenbaum and Rubin (1983) as:

$$\alpha = E(C_i^1 - C_i^0) \tag{7.17}$$

A basic problem in estimating the causal effect of equation (7.17) is that it is possible to observe only $C_i^1$and C_i^0, and not both for each farmer. Formally, it is possible to state the observation as follows:

$$y_i = C_i y_I^1 + (1 - C_I) y_I^0, C = 0,1 \tag{7.18}$$

As a result, it is possible to state the expression for α as follows:

$$\alpha = p.[E(y^1|C = 1) - E(y^0|C = 1)] + (1 - p).[E(y^1|C = 0) - E(y^0|C = 0)] \tag{7.19}$$

Where p is the probability of observing farmers with $C = 1$ in the sample.

Equation (7.19) shows that the effect of contract participation for the whole sample is the weighted average of the effect of contract participation in the two groups of cassava farmers; contractors or *treated* is the first term), and non-contractors or *controls* is the second term. They are weighted by their relative frequency. However, it is still not possible to estimate unobserved counterfactuals $E(y^1|C = 0)$ and $E(y^0|C = 1)$ because of the problem of causal inference effect (Heckman, Ichimura, & Todd, 1998).

If contract participation was assigned randomly to cassava farmers, it would be possible to, basically, replace unobserved counterfactuals, $E(y^1|C = 0)$ with the actual incomes $E(y^1|C = 1)$, as the two would be equal or close to equal. On the other hand, as already noted, contract participation is not random but there is "self-selection into treatment". The problem can be solved through different estimation methods that entail making accurate assumptions with reference to the simultaneous model defining contract participation and incomes. The set of assumptions concerns two dimensions which are: i) the correlation and distributions of the random components of the two equations, e_i^C and u; and ii) the functional form of $g(.)$ and $f^C(.)$ and their specification.

Depending on the combination of identifying conditions the analyst is willing to assume, an unbiased estimate of the causal effect of contract participation on cassava farmer incomes can be obtained. If it is possible to assume that, once the vector of observed variables x are controlled, contract participation is random, and it is possible to assume the constant effect of contract participation, then, it is possible to estimate the causal effect α as the coefficient of the binary variable in a linear OLS regression. As a result, recalling equation (7.19) and exploiting linearity, the income equation can be re-written as follows:

$$y = C(\delta^1 + \beta x + e^1) + (1 - C)(\delta^0 + \beta x + e^0) = \delta^0 + \beta x + C(\delta^1 - \delta^0) + e, \quad (7.20)$$

where $e_i = e_i^0 + C_i(e_i^1 - e_i^0)$.

Since the error term is highly non-standard, it could lead to a biased OLS estimate of the causal effect (α).

The matching approach is consistent with the theoretical argument that there are many reasons to expect that the effect of contract participation on outcome is the result of an interaction with many other variables. PSM is a non-experimental method for estimating the average effect of social programs (Rosenbaum & Rubin 1983; Heckman et al., 1998). The method compares average outcomes of participants and non-participants conditional on the propensity score value. Therefore, the closer the propensity scores for the treatment and control means, the better the match.

The main feature of the matching procedure is the creation of the conditions of a randomized experiment; in order to evaluate a causal effect it is necessary to make the conditional independence assumption, which states that contract participation selection is random and uncorrelated with income. Thus, it is possible to write the participating effect as:

$$\alpha(x) = E(y^1 - y^0|x) = E(y^1|C = 1, x) - E(y^0|C = 0, x), \quad (7.21)$$

where the average participating effect is $\alpha = E\{\alpha(x)\}$

As long as contract participation is random, it is possible to compare incomes of similar cassava farmers in different contract-participating status, which are contractors and non-contractors, defining the similar cassava farmers according to the values of $\boldsymbol{x}$**.** However, due to the high dimension of the latter, the PSM method decreases the dimensionality of the conditioning problem by comparing cassava farmers with the same probability of selecting the CF, given the relevant controls of x (Rosembaum & Robin, 1983). Thus, it is necessary to define the conditional probability that farmers i participate in contracting, given the controls x as follows:

$$p_i = p(x_i) = prob[C_i = 1|x_i] \tag{7.22}$$

This conditional probability is the propensity score, which enables identification of similar cassava farmers.

The latter argument entails that those cassava farmers with a similar propensity score should have the same distribution of x, irrespective of their participating status. This is the balancing property and needs to be tested, for it is important to check if cassava farmers' behaviour within each group is really similar.

The participating effect for cassava farmers with a similar propensity score can be rewritten in the following way:

$$\alpha(p(x) = E(y^1|C = 1, p(x)) - E(y^0|C = 0, p(x)), \tag{7.23}$$

Where the effect for the whole population is $\alpha = E\{\alpha(p(x))\}$ and the expectation operator is taken over by the distribution of $p(x)$.

Note that: i) If there is a missing variable in covariate $\boldsymbol{x}$ ($\boldsymbol{x} = x_1, x_2, \dots, x_k$) then, the propensity score itself will be biased and the matching method is not reliable.

ii) If there are missing variables in covariates $\boldsymbol{x}$, the regression method will be biased in OLS coefficients. This can be corrected by instrumental variables with the use of a two-stage least square.

iii) in the case when the assumption that $\boldsymbol{x}$is complete and $\boldsymbol{x}$contains all factors that affect the probability of contract participation, then PSM is a better method because it does not assume a linear relationship between treatment effect and all the contractors. It also does not assume all cassava farmers have the same effects from contract participation.

(ii) Matching algorithms

A matching algorithm is selected based on the data at hand after undertaking a matching quality test. Matching is a general technique used to select control subjects who are matched with the treated subjects on background covariates that the investigator believes need to be controlled. Heinrich, Maffioli, and Vazquez (2010, p. 42) explained two of the most popular matching algorithms as follows.

Nearest neighbour matching. An individual from the comparison group is chosen as a match for a treated individual in terms of the closest propensity score or observed characteristics. Variants of nearest neighbour matching include "with replacement" and "without replacement," where, in the former case, an untreated individual can be used more than once as a match and, in the latter case, is considered only once. To avoid the risk of poor matches, radius matching specifies a "caliper" or maximum propensity score distance by which a match can be made. The basic idea of radius matching is that it uses not only the nearest neighbour within each caliper, but all of the comparison group members within the caliper. In other words, it uses as many comparison cases as are available within the caliper but not those that are poor matches. By using only one nearest neighbour, it is possible to guarantee that the most similar observation/s to construct the counterfactual is being used. This minimizes the bias, since the characteristics between both units will be, in general, very similar.

Kernel and local-linear matching are nonparametric matching estimators that compare the outcome of each treated person to a weighted average of the outcomes of all the untreated persons, with the highest weight being placed on those with scores closest to the treated individual. One major advantage of these approaches is the lower variance, which is achieved because more information is used. Using this technique ignores a lot of information from the sample, since many untreated units are not used for the estimation. Therefore, the reduction in the bias comes with an increase in the imprecision of the estimates caused by a higher variance that is a decrease in efficiency. On the other hand, when using many neighbours, the estimator is more efficient since it exploits a larger quantity of information from the untreated pool, but at the price of increasing the bias by using poorer matches.

Basically, these methods numerically search for neighbours that have a propensity score for non-treated individuals that is very close to the propensity score of treated individuals. The non-neighbour matching method is the most straight-forward matching method. It involves finding, for each individual in the treatment sample, the observation in the non-participant sample that has the closest propensity score, as measured by the absolute difference in scores (Caliendo & Kopeinig, 2008, p. 31).

7.3.2 Self-selection

Heckman (1979) suggested that the impact of an intervention is essentially an estimation of a treatment effect in policy analysis. On the other hand, change in an outcome of a treatment is often a function of multiple endogenous and exogenous factors. Often, the problem arises in identifying part of the change in the outcome variable for the target population due to treatment. This problem arises due to the problem of observing the counterfactual corresponding to any change induced by a treatment. However, it is necessary to observe the counterfactual if the impact is to be assessed. Given that the decision of households to participate or not to participate in the treatment may be related to the net benefits from participation, the issue of self-selection becomes extremely crucial. If contract participation was randomly assigned to cassava farmers, it would be possible to estimate the causal effect of contract participation on cassava farmers' wellbeing or incomes as the difference in average incomes between contractor farmers and non-contractor farmers. However, with observational data, it is necessary to use statistical solutions to the crucial problem of causal assumption.

Wooldridge (2009, p. 253) also shows that a problem that often arises in policy and problem evaluation is that individuals or firms choose whether or not to participate in certain behaviours or programs. For example,children eligible for programsmake decisions and this affects student outcomes; thus, it is necessary to control for these factors when examining the effect of Head Start. This problem is commonly known as the self-selection problem in economics. Literally, the term comes from the fact that individuals self-select into certain behaviours or programs; participation is not randomly determined. The term is used generally when a binary indicator of participation might be systematically related to unobserved factors. Thus, a simple model can be written as:

$$y = \beta_0 + \beta_1 participation + u \qquad (7.24)$$

where$y$ is an outcome variable and $participation$ is a binary variable equal to unity if the individual participates in a program. The concern is that the average value of u depends on participation: $E(u|participation = 1) \neq E(u|participation = 0)$. As is known, this causes the simple regression estimator of β_1 to be biased, and so it will not uncover the true effect of participation. Thus, the self-selection problem is another way that an explanatory variable ($participation$) can be endogenous.

It is known that multiple regression analysis can improve the self-selection problem. Factor terms in equation (7.35) that are correlated with $participation$ can be included in a multiple regression equation, assuming that it is possible to collect data on these factors. Unfortunately, in many cases, the concern is that unobserved factors are related to participation, in which case multiple regression produces biased estimators.

Hout (1989, p. 168) noted that a selection difficulty does not exist in two types of situation:

1. It could be the case that the unmeasured factors affecting the selection equation are uncorrelated with the unmeasured factors affecting the outcome equation. In other words, it is possible to assume that the unmeasured personal characteristics of non-contractors growing cassava are uncorrelated with the unmeasured factors affecting cassava income, and:
2. There is no selection problem if every variable affecting selection is controlled in the outcome equation. However, the problem is that most of the selection processes are complex and the complete list of variables affecting selection is often unknown or unmeasured. If these types of situation do not occur, the selection bias problem will exist.

Note that: i) If there is no self-selection bias, then the propensity score matching is the better method because it does not assume linear relationship between outcome and other covariates. It also does not assume the impact of contract participation, which is the same for every cassava farmer.

ii) If there is self-selection bias, the only choice is to use instrumental variables with 2SLS estimation. It is necessary to assume: impact is the same for every cassava farmer and it is a linear relationship.

7.3.3 Regression models

(i) IV estimation

Greene (2007, p. 116) showed a dummy variable takes the value of 1 for some observations to indicate the presence of an effect or membership in a group, and 0 for the remaining observations. In recent applications, researchers in many fields have studied the effects of treatment on some kind of response. One of the important issues in policy analysis concerns measurement of such treatment effects when the dummy variable results from an individual participation decision. For example, the treatment dummy might be measuring the latent motivation and initiative of the participants rather than the effect of the program itself. It is common for researchers to include a dummy variable in a regression to account for something that applies only to a single observation. For example, in time-series analyses, an occasional study includes a dummy variable that is 1 only in a single unusual yearsuch as the year of a major strike or a major policy event.

In this section, the focus is on the endogeneity explanatory variables problem in multiple regression models. It is possible to obtain the bias in the OLS estimate when the important variables are omitted and, thus, the OLS estimate is generally inconsistent under this problem. However, omitted variables bias can be reduced if an appropriate proxy variable is specified for an observed explanatory variable. Unfortunately, appropriate proxy variables are not constantly available. This study reviewed this estimation from Wooldridge (2009, p. 507), which takes the approach to the endogeneity problem using the technique of IV to explain the difficulty of endogeneity (the errors in variables problem), at least under certain assumptions.

Motivation: Omitted variables in a simple regression model

Wooldridge (2009, p. 507) discussed three options when faced with the prospect of omitted variables bias:

1. Ignore and suffer the consequences and the problem of biased and inconsistent estimators; however, this response can be satisfied if the estimates are coupled with the way of the biased for the explanation parameters,
2. Seek to find and use an appropriate proxy variable for an unobserved variable. For this solution, it is possible to obtain a good result, but it is generally impossible to find a good

proxy. These approaches to efforts to explain the omitted variable difficulty use replacement of an unobserved variable with a proxy variable.

3. Suppose that the omitted variable does not ultimately change and use the fixed effects. This approach leaves the unobservable variable in the error term; however, before estimating the method by OLS estimate, it uses an estimation technique that distinguishes the existence of the omitted variable. This is what the method of IV does.

The proxy variable solution can also produce satisfying results. However, it is not always possible to find a good proxy. This approach attempts to solve the omitted variable problem by replacing the unobserved variable in a proxy variable.

Another approach leaves the unobserved variable in the error term, but rather than estimating the model by OLS estimate, it uses an estimation method that recognizes the presence of the omitted variable. This is what the method of instrumental variables does.

For illustration, consider the problem of unobserved $ability$ in an income equation for working adults. A simple model is:

$$\log(wage) = \beta_0 + \beta_1 education + \beta_2 ability + e \,, \tag{7.25}$$

where$e$ is the error term.

Under certain assumptions, a proxy variable such as IQ can be substituted for $ability$ and then a consistent estimator of $\beta_1$is available from the regression of:

$$\log(wage)\; on\; edu, IQ,$$

Suppose that the proxy variable is not available, then$ability$ is inserted into the error term and the simple regression model is the result:

$$\log(wage) = \beta_0 + \beta_1 education + \beta_2 ability + u \text{when} u \text{ contains } ability \tag{7.26}$$

Of course, if equation (7.26) is estimated by OLS, a biased and inconsistent estimator of β_1 results if $education$ and $ability$ are correlated.

It turns out that it is possible to continue to use equation (7.26) as the basis for estimation, provided it is possible to find an instrumental variable for $education$. It is possible to explain this approach with the simple regression model:

$$y = \beta_0 + \beta_1 x + u \tag{7.27}$$

where we think that x and u are correlated:

$$Cov(x, u) \neq 0 \tag{7.28}$$

The IV method works whether or not x and u are correlated; the OLS estimate should be used if x and u are not correlated. In order to achieve consistent estimators of β_0 and β_1 when x and u are correlated, it is necessary to obtain further information. The information comes by way of a new variable that satisfies assured properties. Assume that an observed variable $z$exits/exists that satisfies these two assumptions: z_1 is not correlated with u, that is:

$$Cov(z, u) = 0 \tag{7.29}$$

and$z$ is correlated with x, that is

$$Cov(z, x) \neq 0 \tag{7.30}$$

Then it is possible to call z an IV for x. However, the requirement that the instrument z satisfies equation (7.29) is summarized by saying z is exogenous in equation (7.27). Thus, it is possible to refer to equation (7.29) as instrument exogeneity (which means that z should have no partial effect on y and z should be uncorrelated with the omitted variables) (Wooldridge, 2009, p. 507).

Equation (7.30) means that z must be completely correlated with the endogenous explanatory variable x. This condition is sometimes referred to as instrument relevance.

The condition that z is correlated with x can be tested by estimating a simple regression between $x$and z. In population that is:

$$x = \pi_0 + \pi_1 z + v \tag{7.31}$$

Then, because $\pi_1 = \frac{Cov(z,x)}{Var\,(x)}$, assuming that $Cov(z, x) \neq 0$ holds only if $\pi_1 \neq 0$ thus, it should be possible to reject the null hypothesis; $H_0 : \pi_1 = 0$, against the two-sided alternative $H_0 : \pi_1 \neq 0$, at a suitably small significance level (5% or 1%). If this is the case, it is possible to be fairly confident that $Cov(z, x) \neq 0$ holds.

IV estimation in the multiple regression model

The IV estimator for the simple regression model is easily completed to the multiple regression case. In fact, consider a normal linear model with two explanatory variables:

$$y_1 = \beta_0 + \beta_1 y_2 + \beta_2 z_1 + u_1 \quad (7.32)$$

The equation (7.32) is called a structural equation to emphasize that the interested/interest?lies with β_j, which simply means that the equation is believed to compute a causal relationship. Information is used here to decide endogenous from exogenous variables. The dependent variable y_1 is obviously endogenous, as it is correlated with u_1. The variables y_2 and z_1 are the explanatory variables and u_1 is the error.

Typically, the supposition is that the estimated value of u_1 is 0: $E(u_1) = 0$. $z_1$is used to indicate that this variable is exogenous in equation (7.32), in which z_1 and u_1 are not correlated.

$y_2$is used to indicate that y_2 is suspected of being correlated with u_1.There is no explanation of why y_2 and u_1 are correlated, but the rationale is that u_1 includes an omitted variable which is correlated with y_2.

The information in equation (7.32) creates an immediate equations model. However, it is more usual to simply decide exogenous from endogenous explanatory variables in a multiple regression model.

It is known that if equation (7.32) is estimated by OLS, all of the estimators will be inconsistent and biased. Consequently, an IV is used for y_2, because the assumption is that z_1 is not correlated with u_1; however, z_1 cannot be instrument for y_2 because $z_1$appears as an explanatory variable in equation (7.32). Hence, another exogenous variable, called z_2, is needed, which does not appear in equation (7.32). Thus, key assumptions are that z_1 and z_2 are not correlated with u_1. The assumption is also that u_1 has 0 expected value, which is without loss of majority when the equation has intercept:

$$E(u_1 = 0, Cov(z_1, u_1) = 0 \; and \; Cov(z_2, u_1) = 0 \quad (7.33)$$

Given the mean assumption, the concluding two assumptions are equivalent to $E(z_1 u_1) = E(z_2 u_1) = 0$ and so the process of moments approach proposes obtaining estimators $\widehat{\beta_0}$, $\widehat{\beta_1}$ and $\widehat{\beta_2}$ by solving the sample equivalents of equation (7.33):

$$\sum_{i=1}^{n}(y_{i1}-\hat{\beta}_0-\hat{\beta}_1 y_{i2}-\hat{\beta}_2 z_{i1})=0$$

$$\sum_{i=1}^{n} z_{i1}(y_{i1}-\hat{\beta}_0-\hat{\beta}_1 y_{i2}-\hat{\beta}_2 z_{i1})=0$$

$$\sum_{i=1}^{n} z_{i2}(y_{i1}-\hat{\beta}_0-\hat{\beta}_1 y_{i2}-\hat{\beta}_2 z_{i1})=0 \qquad (7.34)$$

This is a set of three linear equations in the three unknown variables $\hat{\beta}_0$, $\hat{\beta}_1$and $\hat{\beta}_2$ and it is easily solved given the data on $y_1, y_2, z_1\ and\ z_2$. The estimators are called IV estimators. If the belief is that y_2 is exogenous and $z_2 = y_2$ is chosen, equations (7.34) are the first order conditions for the OLS estimators.

The instrumental variable z_2 needs to be correlated with y_2 but the sense in which these two variables have to be corrected is difficult because of theexistence of y_2 in equation (7.32). Now, it is necessary to position the assumption in terms of partial correlation. The easiest method to position the condition is to write the endogenous explanatory variable as a linear function of exogenous variables and an error term:

$$y_2 = \pi_0 + \pi_1 z_1 + \pi_2 z_2 + v_2 \qquad (7.35)$$

where, by construction, $E(v_2) = 0, Cov(z_1, v_2) = 0$ and $Cov(z_2, v_2) = 0$ and π_j are unknown parameters. The key identification condition is that: $\pi_2 \neq 0$.

In other words, after partialing out, variables z_1, y_2 and z_2 are still correlated. This correlation can be negative or positive but not 0. By testing $\pi_2 \neq 0$, it is possible to estimate equation (7.35) by OLS estimate and a t-test making it robust to heteroskedasticity. It is always possible to test this assumption. Unfortunately, it is not possible to test that z_1 and z_2 are not correlated with u_1.

Equation (7.35) is an example of a reduced form equation, which means that an endogenous variable has been written in terms of exogenous variables. Adding more exogenous explanatory variables to the model is straightforward. The structural model can be written as:

$$y_1 = \beta_0 + \beta_1 y_2 + \beta_2 z_1 + \cdots + \beta_k z_{k-1} + u_1 \qquad (7.36)$$

wherey_2 is thought to be correlated with u_1.

Let z_k be variables not in equation (7.33) that is also exogenous. Thus, the assumption is:

$$E(u_1) = 0, Cov(z_j, u_1) = 0, j = 1 - i \quad (7.37)$$

Under equation (7.37),$z_1, \dots, z_{k-1}$are the exogenous variables that appear in equation (7.36). In effect, this acts as their own instrumental variables in estimating the β_i in equation (7.36). The special case of $i = 2$ is given in the equation (7.34), along with z_2, z_1 appearing in the set of moment conditions used to obtain the instrumental variables estimate. More commonly, $z_1, \dots, z_{k-1}$ are used in the moment conditions along with the instrumental variables for y_2, z_k.

The reduced form for y_2 is:

$$y_2 = \pi_0 + \pi_1 z_1 + \cdots + \pi_{i-1} z_{i-1} + \pi_i z_i + v_2 \quad (7.38)$$

and a partial correlation between z_i and y_2: $\pi_i \neq 0$ is needed.

Under equation (7.37) and $\pi_i \neq 0$, z_k is a valid instrumental variable for y_2. A minor additional assumption is that there are no perfect linear relationships among the exogenous variables; this is similar to the assumption of no perfect collinearity in the context of the OLS estimate.

Angrist (1995) suggested that the LPM can be used to estimate a binary dependent variable in the first step. Then in the second step, a predicted result from the LPM is specified as an endogenous regressor to the equation of primary interest. This is actually the 2SLS approach. The main difficulty with this approach is that the LPM has several potential problems. However, these biased estimates may not be a serious issue in dealing with the nature of the statistical variability of the forecast (Domencich & McFadden, 1975). However, the use of the conventional 2SLS approach has several limitations (Gujarati, 2004). If R-square values in the first-stage regressions are very low, results from the 2SLS estimate will be meaningless because a predicted value for independent variables will be very poor proxies for the original variables. In addition, the 2SLS estimate may lead to biased estimation for a small sample. Unfortunately, this contentious debate remains unsettled and the empirical literature treatment effects using dummy endogenous regressors continues to be dominated by two-step estimation (Greene & Hensher, 2003)

(ii) Two-stage least square (2SLS) estimation

Suppose that y_2 is a single endogenous explanatory variable along with $y_{2,}$ which is one instrumental variable. However, it frequently occurs that there is more than one exogenous variable that is excluded from the structural model and might be correlated to the instrumental variable (y_2), which means they are valid instrumental variables for y_2. Woolridge (2009, p. 521) discussed how to use multiple IVs.

Consider the structure model equation (7.32), which has one exogenous and \one endogenous explanatory variable. Assume that there are two exogenous variables excluded from equation (7.32) which are z_2 and z_3 then also assume that z_2 and z_3 do not appear in equation (7.32) and are uncorrelated with the error u_i, called exclusion restrictions.

If z_2 and z_3 are correlated with y_2, it is possible to use z_2 and z_3 as instrumental variables. However, there would then be two instrumental estimators and neither of these wouldnormally be efficient because each of z_1, z_2 and z_3 is correlated with the error term u_1, and any linear combination is also uncorrelated with the error u_1; thus, any linear combination of exogenous variables is a valid instrumental variable. To find the best instrumental variable, choose the linear combination that is the most highly correlated with y_2. This can be described in the reduced form from the equation for y_2:

$$y_2 = \pi_0 + \pi_1 z_1 + \pi_2 z_2 + \pi_3 z_3 + v_2 \tag{7.39}$$

where$\mathrm{E}(\mathrm{v}_2) = 0, \mathrm{Cov}(\mathrm{z}_1, \mathrm{v}_2) = 0, \mathrm{Cov}(\mathrm{z}_2, \mathrm{v}_2) = 0$ and $\mathrm{Cov}(\mathrm{z}_3, \mathrm{v}_2) = 0$

The best instrumental variable for y_2 is the linear combination for the z_j in equation (7.39) which is called y_2^*:

$$y_2^* = \pi_0 + \pi_1 z_1 + \pi_2 z_2 + \pi_3 z_3 \tag{7.40}$$

As these instruments are not completely correlated with z_1 it is necessary that at least one of $\pi_2\ or\ \pi_3$ is different from 0: $\pi_2 \neq 0\ or\ \pi_3 \neq 0$.

This is the key identification assumption and the assumption is that z_j are all exogenous. The structure equation (7.32) is not identified if $\pi_2 = 0$and $\pi_3 = 0$. When y_2^* is the part of y_2, which is correlated with the error term u_1, and v_2 is possibly correlated with the error term u_i, y_2 could possibly be endogenous.

Given data on the z_j, it is possible to compute y_2^* for each observation, presented we know by the population parameters π_j. This is not true in practice. However, it is possible to estimate the reduced form by OLS estimate; thus, y_2 is regressed on z_1, z_2 and z_3 and the fitted values are obtained:

$$\hat{y}_2 = \hat{\pi}_0 + \hat{\pi}_1 z_1 + \hat{\pi}_2 z_2 + \hat{\pi}_3 z_3 \tag{7.41}$$

At this point, it is possible to prove that $z_2$andz_3 are jointly significant in equation (7.39) at a practically small significance level, no larger than 5%. If $z_2$andz_3 are not jointly significant in equation (7.39), the instrumental variable estimation is not useful (Wooldridge, 2009, p. 522).

Once $\hat{y}_2$ is obtained, it is possible use it as the instrumental variable for y_2. The three equations for estimating β_0, β_1 andβ_2 are the first two equations of equation (7.38) with the third replaced by:

$$\sum_{i=1}^{n} \hat{y}_{i2}(y_{i1} - \hat{\beta}_0 - \hat{\beta}_1 y_{i2} - \hat{\beta}_2 z_{i1}) = 0 \tag{7.42}$$

Solving the three equations in three unknowns provides the instrumental variable estimators.

With the multiple instruments, the IV estimators using $\hat{y}_{i2}$ as the instrument is called the two stage least squares (2SLS) estimator. The reason is simple. Using the algebra of OLS estimate, it can be explained that when $\hat{y}_2$is usedas the IV for y_2, the IV estimates$\hat{\beta}_0, \hat{\beta}_1and\hat{\beta}_2$ are identical to the OLS estimate from the regression of $y_1$on $\hat{y}_2$ and z_1. In other words, it is possible to take the 2SLS estimator in two stages (Wooldridge, 2009, p. 521). The first is to run the regression in equation (7.41) where the fitted value$\hat{y}_2$is used, and the second is the OLS regression; because$\hat{y}_2$ in y_2 is replaced the 2SLS estimate can be significantly different from the OLS estimate.

Some economists interpret the regression in equation of $y_1$on $\hat{y}_2$ and z_1 as follows: the fitted value, $\hat{y}_2$ is the estimated version of y_2^* and y_2^* is not correlated with u_1. As a result, 2SLS first eliminates $y_2$of its correlation with u_1 before doing the OLS regression in the equation of $y_1$on $\hat{y}_2$ and $z_1$as:

$$y_1 = \beta_0 + \beta_1 y_2^* + \beta_2 z_1 + u_1 + \beta_1 v_2 \tag{7.43}$$

Now the combination of error $u_1 + \beta_1 v_2$ has 0 mean and is correlated with $y_2^*$and z_1, which is why the OLS estimate in equation $y_1$on $\hat{y}_2$ and z_1 works.

(iii) Testing for endogeneity

Wooldridge (2009, p. 527) shows that the 2SLS estimator is less efficient than the OLS estimate if the explanatory variables are exogenous: the 2SLS estimate can have very large standard errors, thus, it is useful to have a test for endogeneity of an explanatory variable that shows whether 2SLS is even necessary. Obtaining such a test is rather simple.

To demonstrate, assume there is a single suspected endogenous variable,

$$y_1 = \beta_0 + \beta_1 y_2 + \beta_2 z_1 + \beta_3 z_2 + u_1 \quad (7.44)$$

wherez_1 and z_2 are exogenous, there are two additional exogenous variables, z_3 and z_4 which do not appear in the equation (7.44). If y_2 is not correlated with u_1, equation (7.44) by OLS estimate should be used.

It is also possible to test this endogeneity by the Hausman test, which directly compares the OLS and 2SLS estimates and determines whether the differences are statistically significant. After all, OLS and 2SLS estimates are consistent if all variables are exogenous. If OLS and 2SLS estimates are significantly different, it is possible toconclude that y_2 must be endogenous.

To determine whether the differences of OLS and 2SLS estimates are statistically significant use the regression test which is based on estimating the reduced form for y_2:

$$y_2 = \pi_0 + \pi_1 z_1 + \pi_2 z_2 + \pi_3 z_3 + \pi_4 z_4 + v_2 \quad (7.45)$$

Now, since each z_j is not correlated with u_1, y_2 is not correlated with u_1 if and only if, v_2 is not correlated with u_1, this is what the desired test. Write $u_1 = \delta_1 v_2 + e_1$, where e_1 is not correlated with v_2 and has zero mean.

Then, u_1 and v_2 are not correlated if and only if $\delta_1 = 0$. The easiest way to test this is to include v_2 as an additional regressor in equation (7.44) and to do a t-test. There is only one problem with implementing this: v_2 is unobserved since it is the error term in equation (7.45). Because it is possible to estimate the reduced form for y_2 by OLS estimate, it is possible to obtain the reduced form residuals,$\hat{v}_2$. As a result, the estimate is:

$$y_1 = \beta_0 + \beta_1 y_2 + \beta_2 z_1 + \beta_3 z_2 + \delta_1 \hat{v}_2 + error \quad (7.46)$$

by OLS estimate and test $H_0: \delta_1 = 0$ using a t-statistic.

If H_0 is rejected at a small significance level, it is possible to conclude that y_2 is endogenous because u_1 and v_2 are correlated.

To test for endogeneity of a single explanatory variable, estimate the reduced form for $y_2$by regressing it on all exogenous variables including those variables in the structure equation and the additional IV, obtain the residuals, $\hat{v}_2$ and add $\hat{v}_2$ to the structure equation, which include $y_2$and test for significance of $\hat{v}_2$ using an OLS estimate. If the coefficient on $\hat{v}_2$ is statistically different from 0, the conclusion is that y_2 is indeed endogenous. It may be desirable to use a heteroskedastisity-robust t-test.

7.4 Summary

To estimate the factors affecting the decision of cassava farmers to participate in contract farming, binary choice models will be used:LPM, and probit and logit models. The logit model is popular as the logit model is simpler compared to the probit model, which requires the use of integral calculus to calculate the cumulative normal probabilities. The logit model has a closed form that permits these probabilities to be calculated without integration. However, both models are nonlinear, computationally burdensome and more complicated in comparison with the LPM. The LPM is likely to be used less frequently in econometric applications except as a basis for comparison to non-linear estimates.

To estimate the effects of contract participation on outcomes, including cassava income, farm gross margin, total costs and labour used of cassava production, whether the farmers who participate in contracting or not, is dependent on the characteristics of farmers and farms. Thus, the decision by farmers to participate in contracting is based on each farmer’s self-selection instead of random assignment. Farmers will participate in contracting if the utility of contract farming is greater than the utility of non-contract farming. However, to estimate the outcome equation and contract participation, the relationships between two equations are correlated. Thus, treatment assignment is not random, and selection bias occurs because unobserved variables influence both error term of outcome and participation equations. Hence, estimating with OLS will lead to biased estimation.

IV estimate with 2SLS estimate can be used to overcome the problem of endogeneity. It is also possible to use PSM to compare the effects of contract participation on outcomes between contractors and non-contractors; this method compares average outcomes of participants and non-participants, conditional on the propensity score value. The closer the propensity scores for the treatment and the controlthe better the match.

CHAPTER 8: EMPIRICAL RESULTS

8.1 Introduction

The discussion in this chapter is focused on four objectives of this study, which are: i) To identify types of smallholders who are likely to participate in CF, and to examine the role of CF in the profitability of cassava production and why people participate in these types of contracts. In meeting this objective, factors to consider are those that influence the adoption of CF by farmers; and ii) To estimate the factors affecting contract participation on outcomes, including total costs of cassava production, incomes, gross margins and employment.

This chapter is organized as follows. Section 8.2 discusses types of smallholder farmers, based on ownership of land and assets. The key variables used in subsequent analysis and factors influencing contract participation are discussed in Section 8.3. Section 8.4 presents the procedures for evaluating effects of contract participation on outcome, followed by the results of effect of contracting on outcome, including total costs of cassava production, cassava incomes and farm gross margins in Section 8.5. The results of effect of contracting on employment will be discussed in Section 8.6. Section 8.7 summarizes the discussion in this chapter.

In this study, we refer to participation in contracts by farmers even though there is no formal, written contract between farmers and cooperatives. A formal contract exists between the cooperative and ethanol producers, and an "agreement" exists between farmers and cooperatives to sell cassava to the cooperative. Such agreements are understood by farmers to enable them to increase their income, plus attain other benefits, from cassava production.

8.2 Types of smallholders based on ownership of land and assets

In this section, we classify the cassava smallholders (farmers) into four groups characterized by the mean value of their farmland and assets. The mean size of land ownership by smallholders was 30.63 rai (4.90 hectares) and the mean value of assets was 515,361 baht (A$17,178). Smallholders with both land and assets below these average levels are classified as Type-one smallholders and those with above average values for these variables are described as Type-four smallholders. Smallholders with less than 30.63 rai (4.90 hectares) and more than 515,361 baht (A$17,178) are classified as Type-two smallholders and the converse, Type-three smallholders. Figure 8.1 below describes this classification.

Land holding

Mean (30.63 rai or 4.90 Ha)	**Type-three smallholders:** **"larger farmland and lower assets value"** *37 respondents included this type*	**Type-four smallholders:** **"larger farmland and higher assets value"** *35 respondents included this type*
	Type-one smallholders: **"smaller farmland and lower assets value"** *136 respondents included this type*	**Type-two smallholders:** **"smaller farmland and higher assets value"** *49 respondents included this type*

Mean (515,36 baht) or $17,178 AUD　　Assets value (baht)

Figure 8.1: Types of smallholders based on ownership of land and assets
(**Source**: Calculated from the survey research crop year 2010/2011)

Type-one smallholders are generally lower-income smallholders because they are constrained by small asset holdings and limited planting area and, thus, limited cassava production. Cash constraints make it difficult to undertake new activities to obtain more income.

Although it is difficult to describe Type-two smallholders in simple terms, these smallholders are included in the lower and middle-income types in rural areas, and mostly are small-scale famers. They have more opportunities to be involved in new activities that may give them additional returns than Type-one smallholders because they face less cash constraints.

Type-three smallholders are mostly the middle- and upper-income classes in rural areas. This type of smallholder has limited assets and has difficulties finding cash to pay for operational costs and new capital equipment that may be needed for new activities. Although home consumption needs, especially for food, are satisfied, they tend to be conservative investors. Type-four smallholders are relatively wealthy.

8.3 Factors influencing contract participation

A single dependent variable, participation in growing cassava for sale through cooperatives, indicates whether the farmer participates in CF. The indicator variable obtains the value of 1 if the farmers participate and it is 0 if the farmer does not. To determine factors affecting the two processes for each state, a number of explanatory variables are specified to reflect the influence of transaction costs.

These explanatory variables are divided into three constructs in the transaction costs framework: i) household structure; ii) access to assets or household endowmentthat is asset value (baht), off-farm income (baht), credit access (0 = access to credit, 1 = not access to credit) and irrigated land owned and operated (rai); and iii) access to information, household head education (years) and number of agricultural groups (groups). The quality of the decisions made by the farmers depends on their information base. The structure of household tends to capture a number of possible concepts of farmers' behaviour. In CF, these may reflect the attitude of households towards risk. Risk associated with CF is caused by quantity fluctuations and price. The attributes of farmers' structure allowing for risk-taking are associated with creating the circumstances for a possible lowering of transaction costs. Access to assets is an indication of wealth and endowment. Normally, the more endowed farmers tend to experience lower transaction costs and more flexibility in allocating resources to contract activities. Access to information tends to improve decision-making skills, which influence the probability of CF. As a result, the more information the farmers have on contracting, the less the transaction costs.

8.3.1 Expected variables influencing participation in contract farming

The first construct, household structure, is described by two variables: gender and the age of the household head. The gender of household head reflects CF participation because CF can negatively affect household food security and food production because females are an important household resource on contracted crops (Glover 1994; Kirsten & Sartorius, 2002). Female-headed households have a greater likelihood of participation in the cassava markets than male-headed households, as shown in the study by Alene et al. (2008) on maize markets in Kenya, and in the study by Makhura (2001) on livestock markets in South Africa. The gender of the head of the household may be associated with the belief that female farmers will face lower transaction costs since they tend to have more credibility. Singh (2003) found women supervised potato growing because they were regarded as more reliable than men supervisors, thus most of the grading labour in India is done by women. Moreover, in Australia, women are employed in managerial and professional categories at 25 per cent greater rates than men in regional and remote Australia because they are well-qualified to be in leadership positions (Sheridan, McKenzie, & Still, 2011). The variable assumed the value of 1 if the household head was a female and 0 for male household heads. Female farmers are expected to participate in CF more than males.

Age of household head is a factor that can influence CF participation. Fritz, et al. (2004) reported that there were significant differences in perception and acceptance of CF between youths and adults. Age of household head was statistically significant in selection for the seed corn contract participation in East Java, Bali, and Lombok, Indonesia (Simmons & Winters, 2005) and the probability of participating in CF decreased by seven per cent with a ten-year increase in age of the household heads (Santosa, 2006). Age was measured in number of years. Thus, a negative relationship is expected between ages of household heads (years) and cassava contract participation under agricultural cooperatives.

The second construct for transaction costs is access to assets. This has been measured in terms of access to production assets (off-farm income, asset value, credit access, machinery costs, selling price, and irrigated land owned and operated). Total income of farmers per year had positive and significant effect on CF. The implication was that farmers with high income per year are the ones most likely to join CF. High income is an indication of the size of the operation, lower unit costs and success in producing and selling farm produce. Hence, farmers with high income could be associated with those operating large-scale production businesses and, as a result, become attracted by firms to sign a contract with them (Anim, 2011). Access to non-cassava production income was measured by the amount of income from service provision, business activities, salary and wage earning by the household members in Baht units. This variable is expected to positively affect participation in contract farming since some of these people are hypothesized to be entrepreneurs.

Miyata, Minot, and Hu (2009) studied the impact of CF on income in China and reported that there were factors which indicated significant differences (5%) between apple farmers working under contracts and those not working under contracts: agricultural assets (yuan), the age of trees (years) and location of farm. However, for green onion farmers, areas of farms (hectares) and land irrigated (hectares) were five per cent statistically significant.

Credit access to financial institutions, such as commercial banks, village funds and BAAC, is expected to positively influence CF participation. The variable assumes the value of 1 if the farmer has access to credit from financial institutes, and zero forno access.

The more land owned and operated, the higher the cassava production levels are likely to be and, consequently, the higher the probability of contract participation. Access to irrigated land owned and operated was measured in terms of the size of the land used for cassava production. Previous studies such as Simmons and Winters (2005) found that irrigated land owned and operated was statistically significant in selection for the seed corn contract participation in East Java, Bali, and

Lombok, Indonesia. Furthermore, Arumugam, Arshad, and Mohamed (2011) showed that the estimated odds ratio (OR)[23] of farmers with bigger land holding of more than five acres was 2.5 times higher than the farmers with smaller land holdings, indicating that bigger land-holding farmers were more inclined to be involved in contract farming than small land-holding farmers. Therefore, this variable is expected to positively influence cassava contract participation under agricultural cooperatives.

The third construct is access to information, which consists of household head education and the number of agricultural groups the farmer participates in. The related variable is education. With regard to contract farming for local farmers, sometimes the information about the contract is difficult to understand. Those who cannot understand the information and details in the contract have difficulty in participating in contract decisions. The variable reflecting ability to retrieve and understand the contract was measured by the highest year of schooling by household head. Miyata et al., (2009) reported that highest year of schooling by household head was statistically significant in selection for seed rice contracts. Additionally, Arumugam et al. (2011) found the education level of farmers was significant at the 99 per cent significance level, and had positive and significant effect on the probability to be involved in CF. Educated farmers are more likely to be involved in CF. The OR for educated farmers is 3.3 more than uneducated farmers. Hence, a positive relationship with cassava contract participation under agricultural cooperatives is expected.

In addition, contacts with other farmers who participate in agricultural organizations tend to improve farmers' access to information. Normally, cassava farmers help each other with technology, production and marketing information. This variable was measured by asking cassava farmers how many agricultural groups they participated in. As found by Simmons and Winters (2005), the number of agricultural groups was statistically significant in selection for the seed corn contract participation in East Java, Bali, and Lombok, Indonesia. Additionally, Kureh, Menkir, Tarfa, and Amaza (2006), Okoye, Onyenweaku, and Ukoha (2010) and Anim (2011) indicated that number of farm organizations, for example commodity organizations, are believed to be centres of information which can be accessed by farmers. Members and individuals are also motivated by other farmers to join beneficial organizations such as CF ones. As a result, number

[23] An odds ratio (OR) is a measure of association between an exposure and an outcome. The OR represents the odds that an outcome will occur given a particular exposurecompared to the odds of the outcome occurring in the absence of that exposure. ORs are most commonly used in case-control studies; however, they can also be used in cross-sectional and cohort study designs (with some modifications and/or assumptions).

of agricultural groups, was positively and highly significant in joining CF. Moreover, contact with extension officers tends to improve farmers' access to information (Lapar, Holloway, & Ehui, 2002). Therefore, this variable is expected to positively influence cassava contract participation under agricultural cooperatives.

8.3.2 Factors affecting contract participation

Smallholders will choose to participate in cassava contracting if the expected benefits from participation are greater than the costsincluding all transaction costs smallholders face in the process of contract participationof doing so. An objective of this study is to identify the factors that influence contract participation and, thus, identify the characteristics of smallholders who participate in these types of contracts.

Statistical analysis is used to determine the relationship between participation by cassava farmers in a contract by using the variable, called *CONTRACT*, and a set of independent variables that affect participation.

In this study, the dependent variable for determining the relationship between participation by cassava farmers in a contract is binary, with 127 farmers with contracts (contractors) and 130 farmers not involved with cooperatives (non-contractors). The standard econometric method for explaining discrete dependent variables such as ‘yes’ and ‘no’ is a binary choice model. As explained in Chapter 7, with non-linear estimates, the most common frameworks used in econometric applications are probit and logit models. The probit model is based on the standard normal distribution, while the logit model is based on the logistic distribution. However, for independent variables with very small values, the logistic distribution tends to give higher probabilities to their likelihood (Greene & Hensher, 2003). The LPM will be used as a basis for comparison.

Results from estimated probit and logit models are provided in Table 8.1. This table also reports regression co-efficient and Wald tests. Results based on the estimated LPM are also reported as a basis for comparison with the results from the probit and logit estimations. Results show that results from the probit, logit and LPMs were similar in terms of signs, significance and predictive power.

The explanatory power of the specified variables based on the Pseudo R^2 value was relatively low, with factors accounting for little variation in the outcome variable *CONTRACT,* which takes a value of 1 when a contract is in place and zero elsewhere, Pseudo R^2 takes a value between 0 and 1 with larger values, reflecting better predictive performance; it provides an approximate measure of the proportion of the variation in the dependent variable explained by the model. For probit and logit estimations, the pseudo R^2 values were 0.6539 and 0.6544 respectively, and the R^2 for LPM estimation was 0.6220.

Also predicted was numbers of contractors and non-contractors after estimating the factors affecting contract participation using LPM, probit and logit estimates. It was found that the predicted number of contractors are 135, 133 and 133 contractors for LPM, probit and logit estimates respectively, and non-contractors 122, 124 and 124 respectively. The actual numbers of contractors and non-contractors are 127 and 130 respectively.

Table 8.1: Determinants of contract participation

Explanatory variables	Linear Probability		Probit model		Logit model	
	Coef.	**t**	**Coef.**	**z**	**Coef.**	**z**
[1]Gender of household head	**-0.2586**	**-5.51*** **	**-1.4196**	**-4.90*** **	**-2.4707**	**-4.56*** **
Age of household head (year)	0.0016	0.74	0.1945	1.36	0.0354	1.29
Education of household partner (year)	**0.0231**	**2.37** **	**0.1410**	**2.90*** **	**0.2499**	**2.75*** **
Planting area (rai)	**0.0009**	**1.88* **	**0.0078**	**2.60*** **	**0.0146**	**2.76*** **
Total family labour (person)	-0.0045	-0.15	0.1628	0.66	0.3293	0.61
Inputs costs (baht)	**-0.0002**	**4.58*** **	**-0.0011**	**-3.59*** **	**-0.0019**	**-2.98*** **
Machinery costs (baht)	**0.0001**	**5.14*** **	**0.0009**	**3.77*** **	**0.0016**	**3.56*** **
Labour expenses (baht)	**-0.0002**	**-3.53*** **	**-0.0010**	**-3.47*** **	**-0.0019**	**-3.50*** **
[2]Credit access	**-0.1399**	**2.83*** **	**-0.8280**	**-2.92*** **	**-1.4378**	**2.76*** **
Number of agricultural groups (groups)	**0.1947**	**11.83*** **	**1.1239**	**6.56*** **	**2.0614**	**6.05*** **
Constant	0.2056	1.23	-2.4239	-2.13**	-4.6578	-2.07**

For LP: F (10, 246) = 77.16 (Prob>F = 0.0000) and R^2 = 0.6220
Wald Chi^2 of Probit model is 80.08; Prob > Chi^2 = 0.0000 and Pseudo R^2 = 0.6539
Wald Chi^2 of Logit model is 66.71; Prob > Chi^2 = 0.0000 and Pseudo R^2 = 0.6544
[1]Gender and [2]Credit is for discrete change of dummy variables from 0 and 1
***: significant at the 99% level, **: significant at the 95% and *: significant at the 90%

(Source: Calculated from the survey)

Ten variables were included in the estimation: gender of household head, age of household head, schooling year of household head's partner, cassava planting area, total family labour, input costs, machinery costs, labour expenses, credit access and number of agricultural groups influencing CF participation. The significance of goodness of fit was calculated using Chi Square and F Ratio tests. The ρ values were close to zero indicating jointly low overall significance. Robust estimation was used to compute heteroskedasticity-consistent estimates of the OLS coefficients.

Table 8.1 shows that eight variables significantly influence participation in contracting at 90 per cent or higher level of significance using LPM, and probit and logit models. These variables are:

1. Gender of household head *(GENDER)*: Female household heads are more likely to participate in CF than male household heads. This is consistent with findings by Makhura (2001) who examined contracting in livestock markets in South Africa, and Alene et al. (2008) who examined contracting in maize markets in Kenya. The gender of the household head reflects that women may face lower transaction costs since they have superior access to credit. At present, participation of women and their role as leaders and decision-makers is increasing in CF. CF gives more opportunities and better employment for labour, particularly for women. Women cassava contractors in Thailand often have large farm sizes, and they may work their farms by using local hired machinery and hired family labourers. Husbands support the women in various ways in order to obtain influence in decisions regarding the cassava process. Women also grow cassava together with their husbands on family farms, and this cassava production is completely controlled by both them and their husbands. Kimani, Ngonde, Kang'ethe, and Kiragu (2007) and Shaffril, D'Silva et al. (2010) found that both male and female youth have a similar level of acceptance of CF.
2. Educated farmers and family members are more likely to participate in CF (Arumugam et al., 2011). Education of household partners *(PEDU)* was found to positively influence farmers' likelihood of participating in contracts at a 95 per cent level of confidence. Possibly farmers who have completed higher education benefit more from extension programs and participate more in contracting channels. Moreover, technical assistance and knowledge transfer can spill over onto adjacent fields and into nearby villages.
3. Cassava planting area *(PLOTSIZE)* has a positively significant effect on contract participation, which means that if the size of the farm is larger, it is more likely to participate in CF. These results are consistent with the relevant studies in the literature such as the results by Wu-Yueh (2013) and Simmons and Winters (2005).
4. Inputs costs *(INPUTS),* including chemical fertilizer, herbicide, pesticide and manure for cassava production, negatively influence participation, with the co-efficient having a 99 per cent level of significance. The probability of participating in CF decreases by 2-19 per cent for each 1,000 baht increase in input costs of cassava production. This indicates that lower production costs may make it more attractive for farmers to participate in CF under cooperatives and thus farmers who face lower costs and are likely to be more profitable are more attracted to this type of agreement. This result is consistent with the findings of Key and Runsten (1999) for Mexican contractors.

5. Machinery costs *(MACHIN)*: One thousand baht in machinery costs, including hiring tractors for land preparation, planting, harvesting and transportation increases the probability that smallholders will participate in CF by approximately 1-16 per cent. This variable significantly influences participation in CF under cooperatives with the significance coefficient at the 99 per cent level. This result indicates that higher production costs in growing cassava increases the probability of contract participation.
6. A one thousand baht increase in labour expenses or labour costs *(LABEX)*of cassava planting activities from pre-harvesting to post-harvesting increases the probability of contract participation by 2-19 per cent. This result indicates that a higher cost in growing crops increases the probability of contract participation. Note that the contracting firm provides credit and advances for these inputs through the cooperative that will be deducted from the post-harvest payments.
7. Farmers who do not get credit *(CREDIT)* from financial institutions, such as the BAAC, commercial banks and village funds, are more likely to participate in CF than the farmers who have access to credit. This reflects that contractors received credit in the form of advances of capital inputs and services rather than cash. These types of advances are usually given on the security from the anticipated value of the crop or on the value of land. Loan recoveries are usually made from service charges or crop sales. Sometimes farmers obtain loans separately from an existing bank or credit agency, in which case the contract itself can serve as collateral.
8. Numbers of agricultural groups: The number of agricultural groups *(GROUPS)* that the household participates in positively effects contract participation. The coefficient was significant at the 99 per cent level. Each additional agricultural group participation rate increases the probability of contract participation by 0.19-2 per cent; that is, the results show that the probability of participating in contracting increased with household participation in relevant agricultural organizations. A study by Kureh et al. (2006) indicates that agricultural organizations, such as commodity organizations, may be centres of information that can be accessed by households. This type of social capital may also play a role with members and individuals motivated by other farmers to participate. In essence, if farmers communicate with other farmers who are already participating in contracts, then their confidence to participate may increase. Agricultural groups also impart useful information to farmers, which could result in increased knowledge, productivity and income.

According to Williamson (1981), transaction costs occur "when a good or a service is transferred across a technologically separable interface" (p.548). Consequently, transaction costs occur every time a product or service is being transferred from one stage to another, where new sets of technological capabilities are needed to add value to the product or service.

Further, given the ownership of land and assets, smallholders have other resources such as education, family labour and irrigation. In this framework, these resources are divided into two types of resources (See Table 8.2). The first type of resource is related to the smallholder’s capability determined by internal factors influencing smallholder’s decisions, such as age of household head, household members’ education and number of family labourers. The second type of resource is related to the smallholder’s capability determined by external factors affecting smallholders’ decisions, such as difficulty to access credit.

Table 8.2: Four types of smallholder capabilities

Types of smallholder's capability		**Internal Factors**		**Total**
		High transaction costs	**Low transaction costs**	
External Factors	High transaction costs	Type-four capability (34.63%) (non-contractors)	Type-three capability (13.23%) (ambiguous)	47.86%
	Low transaction costs	Type-two capability (22.18%) (ambiguous)	Type-one capability (29.96%) (contractors)	52.16%
Total		56.81%	43.19%	100.00%

(**Source**: Calculated from the survey research crop year 2010/2011)

In the analysis of participation decision, the first type of resource is measured by asset values, planting area and number of agricultural groups participated in. Based on three variables, the first type of resource will be scored 0 when their values in the sample are below average. They are scored 1 when their values in the sample are above average.

The second type of resource is also measured by two variables: machinery costs and price of cassava per kilo. Similar to the first type of resource, the second type of resource is scored as 0 and 1. As a result, both types of resources take a binary form reflecting the “lowest” and “highest” levels of smallholder’s capability.

Based on the results from the probit estimation, the probability of contract participation under cooperatives for each type of capability can be predicted. Figure 8.2 shows the relationship between the types of smallholders' capability and the probability of contracting. Figure 8.2 shows that smallholders with Type-one capability tend to participate in CF because they have the lowest transaction costs and the highest values of factors contributing to CF participation. Type-four capability smallholders have the lowest value of factors contributing to CF participation, such as assets value, cassava planting area and selling price, and highest transaction cost. However, for smallholders with Type-two and Type-three capabilities, the probability of contract farming under cooperatives is difficult to predict. Figure 8.2 illustrates that contract farming under cooperatives will become attractive for smallholders with better prices for cassava. As a result, from the perspective of ethanol processors, higher prices for cassava production and lower transaction costs may be the best choice for attracting farmers to CF.

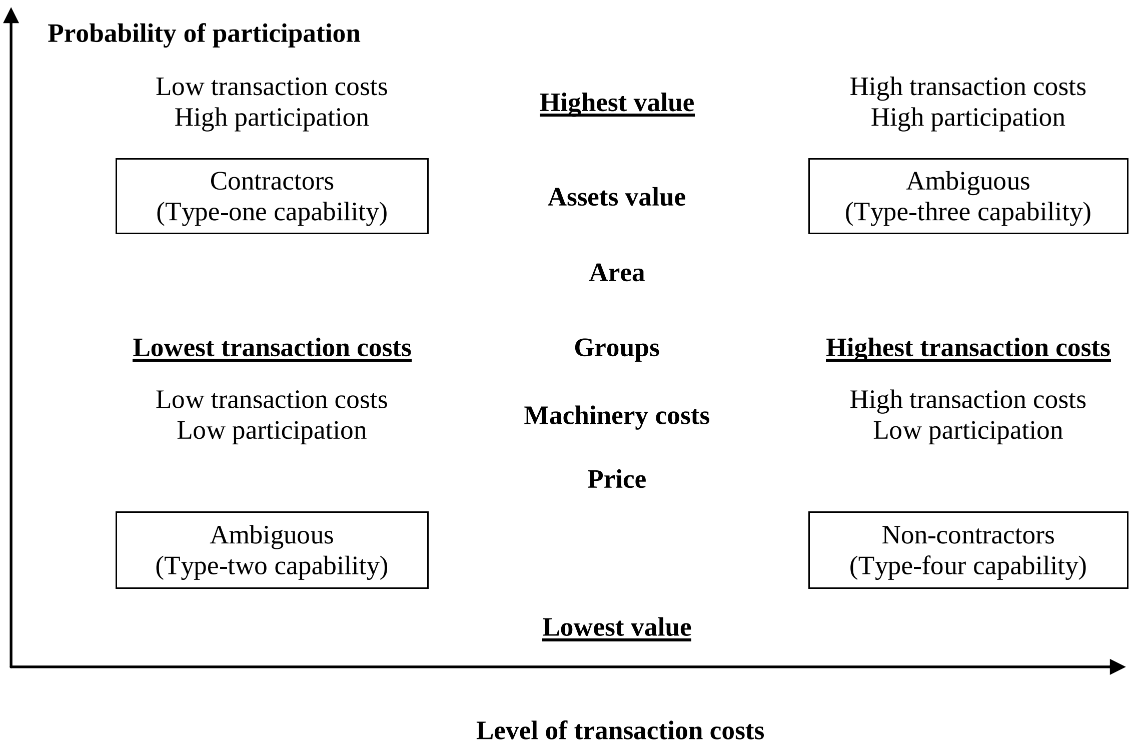


Figure 8.2: Probability of contract participation based on capability
(Source: Author by summarizing the combination of results from Table 8.1 and 8.2**)**

8.4 Procedures for evaluating effects of contract participation on outcome

In this section research methods are discussed for measuring impact on smallholder standards of living, indicated by income, costs and labour use. Income enters into the analysis as two variables: total income from cassava production and farm gross margins. A gross margin refers to the total income derived from cassava production activity and the variable costs incurred in the enterprise. The farm gross margins represent the farm returns to land, agricultural capital and family labour. Total income was calculated as the sum of income received from cassava production activity in the previous 12 months. Costs is analysed as the total costs of cassava production and employment is analysed as two variables: total labour and non-family labour.

In the first step, after estimating the factors affecting contract participation decision with LPM, and probit and logit models, the effects of contract participation on outcome, including cassava income, farm gross margin, total costs and labour used of cassava production, will be evaluated. Contract participation is specified as dummy endogenous regressors in outcome equations using different functional forms.

The model for evaluating effects to contract participation on outcome is:

$$OUTCOME_i = \beta x_i + \delta CONTRACT_i + \varepsilon_i \tag{8.1}$$

where $CONTRACT_i$ is a dummy variable indicating whether or not the individual participates in CF; x_i is a vector of exogenous characteristics such as gender of household head, age of household head, education of household head and planting area; and $OUTCOME_i$ is cassava income, farm gross margin, total costs and labour used for cassava production.

Due to the selection bias problem, estimating effects of contract participation on outcome with OLS estimate will lead to biased estimates. To address the problem of selection bias, the IV approach used the 2SLS estimator to overcome the endogeneity problem and obtain unbiased estimations.

The leading contemporary application of selection methods and endogenous sampling is in the measure of treatment effects. We considered two approaches to analysis of treatment effects: regression methods and propensity score matching.

In the treatment effect estimated, the net benefit to contractors compared with non-contractors is given by the latent variable:

$$CONTRACT_i = \gamma w_i + u_i, \tag{8.2}$$

where$CONTRACT_i$ is a dummy variable where $CONTRACT_i = 0$ means non-contractors and $CONTRACT_i = 1$ means contractors.

In the second step, we separate the sample into two groups: i) treatment effect treated by PSM and ii) endogeneity problem using IV estimate with 2SLS estimate.

PSM is used to investigate the causal effect of contract participation on the outcome equation, including cassava income, farm gross margin, total costs and labour used in cassava production, as was demonstrated by in Saigenji and Zeller (2009), Barrett et al. (2012), Wainaina, Okello, and Nzuma (2012), Ito and Bao (2012) ,and Hu (2013). In a counterfactual approach, the quantity of interest is the average treatment effect (ATE):

$$ATE = E(CONTRACT_i^1 - CONTRACT_i^0) \quad (8.3)$$

The expression for ATE can be written as follows:

$$ATE = p.[E(OUTCOME^{CONTRACTORS}|C = 1) - E(OUTCOME^{NON-CONTRACTORS}|C = 1)] + (1 - p).[E(OUTCOME^{CONTRACTORS}|C = 0) - E(OUTCOME^{NON-CONTRACTORS}|C = 0)] \quad (8.4)$$

In terms of endogenous variable, in an effort to overcome this endogeneity problem and identify the causal effect of contract participation on outcome, IV estimate will be used as also used by Santosa (2006), Meshehsa (2011), Barrett et al. (2012), andBolwig, Gibbon, and Jones (2009). Consider the problem of estimating the effect of $CONTRACT$ on cassava $OUTCOME$ including cassava income ($CASSIN$), farm gross margin ($GROSS$), total costs of cassava production ($TOTCOST$), and labour used in cassava production which are total labour ($TOTLAB$) and family labour ($FAMLAB$). There is a possibility that $CONTRACT$ is correlated with other factors in u: such as more able, highly motivated farmers might participate in contracting rather than lower motivated farmers; consequently, a simple regression might not give a good estimate of the effect of contract participation on outcome including cassava income, farm gross margin, total costs and labour used in cassava production.

The IV estimator for the simple regression model is easily adapted to the multiple regression case. In fact, consider a normal linear model with two explanatory variables:

$$OUTCOME = \beta_0 + \beta_i x_i + \beta_c CONTRACT + \varepsilon \quad (8.5)$$

The equation above is a structural equation. The dependent variable $OUTCOME$ is obviously endogenous, as it is correlated with ε. The variable x_i and $CONTRACT$are the explanatory variables. If equation (8.5) is estimated by OLS, all of the estimators will be inconsistent and biased. Consequently, we use the IV for $CONTRACT$because x_i is supposed not to be correlated with ε.

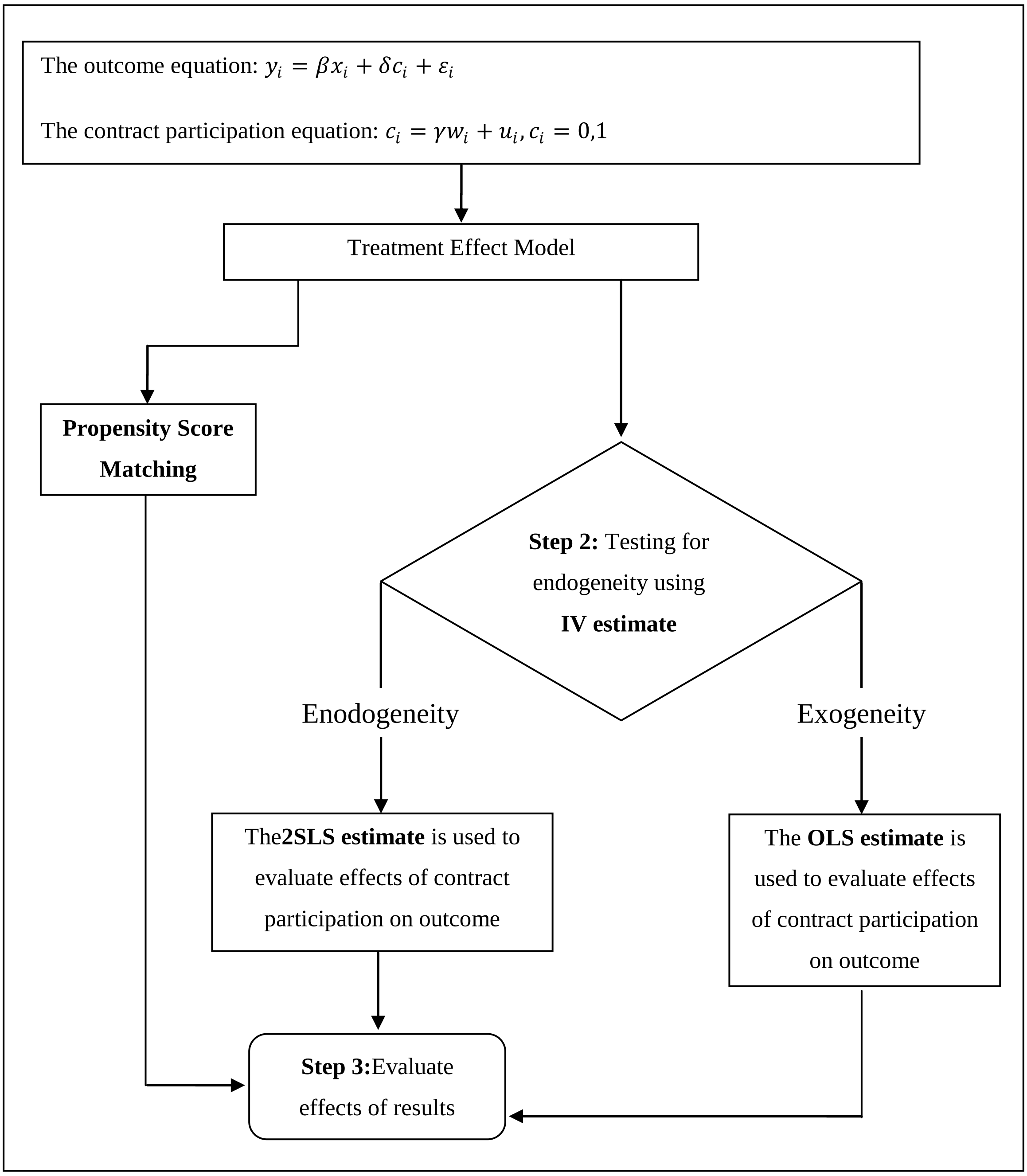


Figure 8.3: Procedures for evaluating effects of contract participation on outcome
(**Source:** Author by summarising and discussion)

Assume that education of household's partner, $PEDU,$ is exogenous, which implies that these excluded exogenous variables must be correlated with $CONTRACT$but not correlated with other unobserved factors influencing $OUTCOME$and also uncorrelated with $OUTCOME$. In addition, suppose that ε has zero expected value, which is without loss of majority when the equation has an intercept. These estimators are called IV estimators.

Now, it is necessary to position the assumption in terms of partial correlation. The easiest method to position the condition is to write the endogenous explanatory variable as a linear function of exogenous variables and an error term:

$$CONTRACT = \pi_0 + \pi_1\ PEDU + v \quad (8.6)$$

However,if the variable for contract participation is an exogenous dummy regressor in the outcome equation, the OLS approach is used to evaluate the effect of contract participation on outcome including cassava income, farm gross margin, total costs and labour used of cassava production. Note that, the use of the OLS estimate is not entirely appropriate for the theoretical framework developed in the analysis of this study.

The final step is to use the OLS estimate if contract participation is exogenous for the outcome equation and use 2SLS if contract participation is endogenous. The results of PSM are also reported and compared.

However, confidence with these results is low because the OLS estimate is unlikely to be supported by the theoretical framework. The smallholder's ability to choose different types of farm enterprises is supposed to influence not only income but also the contract decision and, thus, the relationship between outcome and contract equations should, technically, be recursive or at least co-dependent.

8.4.1 Effects of contract participation on total costs of cassava production

As discussed in Chapter 1, the most important raw materials for bio-ethanol in Thailand are cassava, sugar cane and molasses. Cassava has been promoted as a feedstock for bio-ethanol in Thailand because it requires minimal inputs for planting, is highly productive, and able to be planted and harvested year round (Zhang et al., 2003; Sriroth & Piyachomkwan, 2008). Additionally, the total cost of ethanol from cassava is low compared to cost of production from sugar cane and molasses, with respective prices of 14.68, 18.43 and 27.23 baht per litre (Pingmuang & Luengsumrit, 2009).

Figure 8.4 shows the cost structure of cassava bio-ethanol production in Thailand between 2002 and 2005. On average, the feedstock cost is the biggest, accounting for 59.3 per cent, followed by net operating cost (22.3%) and investment cost (18.4%) (Nguyen et al., 2008; Seumpakdee, 2009; Bell et al., 2010; Sorapipatana & Yoosin (2011). To cut their input costs, farmers should reduce volatilization of nitrogen and losses of nutrients to runoff and erosion by always covering the applied fertilizers with soil. While mineral fertilizer can help to boost yields, alone they cannot sustain crop production over the long-term on degraded land. As with the other types of crop, cassava is vulnerable to diseases or pests, which can heavily reduce yield. For sustainability of cassava production and the ecosystem, non-chemical practices can help farmers decrease losses to diseases and pests.

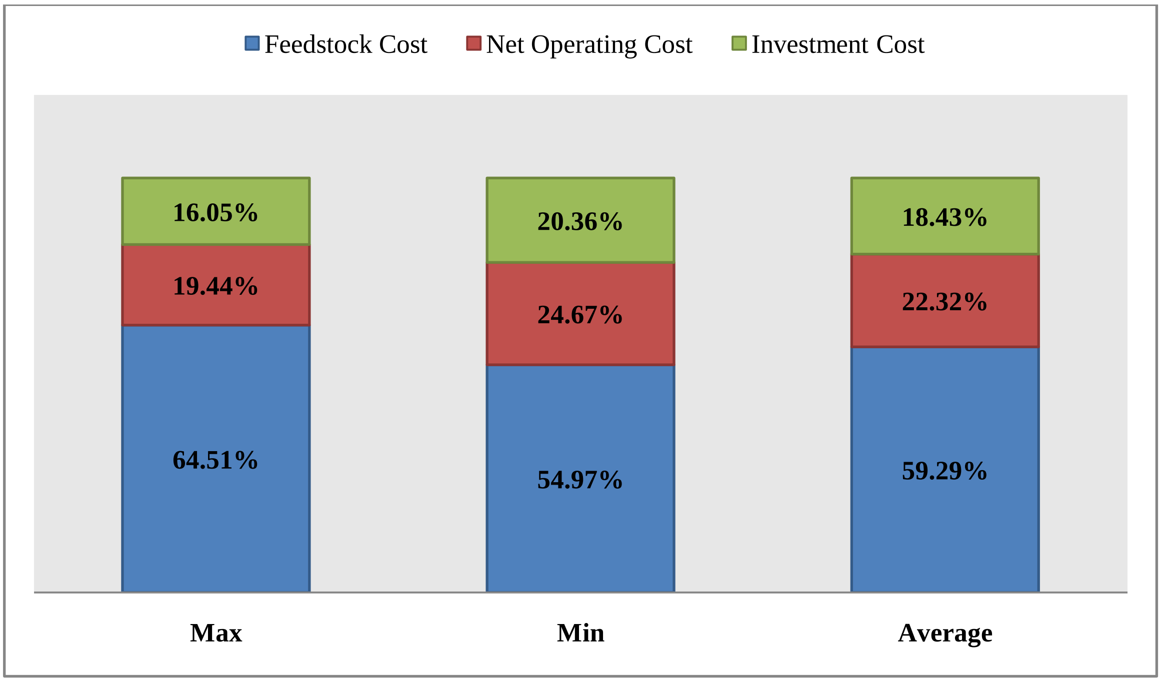


Figure 8.4: Cost structure of ethanol production from roots of cassava in Thailand for the years 2002–2005
(Source: Suthamma & Chumnong, 2011)

In this section, therefore, the focus is on the third objective of the research, which is to estimate the effects of contract participation on total cost of cassava production. Based on the transaction cost approach, when markets are imperfect, the smallholders' choice of farm enterprise may reduce transaction costs, resulting in increased income.

Tatlidil and Akturk (2004) showed that the unit crop cost of farmers under contract was lower than the unit crop cost of farmers not under contract in the case of tomato production in Turkey. Similarly, the production costof contracting rice farmers in Taiwan was about 13 per cent lower than non-contracting farmers (Chang, Chen, Chin, & Tseng, 2006).

Table 8.8 shows the costs structure of cassava production by smallholders in Thailand. Non-contractors had average input costs of 2,407.02 baht per rai with 562.57 baht of chemical fertilizer formula 15-15-15 (the highest input costs) followed by chemical fertilizer formula 46-0-0 (406.63 baht), chicken manure (398.92 baht), root stocks or stakes (345.99 baht), chemical fertilizer formula 16-8-8 (248.61 baht), herbicides: Grammocxone, Glysophate and Paraquat(119.40, 101.18 and 94.46 baht), and cow manure (24.24 baht) respectively.

Table 8.3: Cost structure in cassava production

	Non-Contractors	Contractors
Total Costs (baht/rai)	**3,487.53**	**3,063.93**
Input Costs (baht/rai)	**2,407.02**	**868.41**
Stakes	345.99	294.39
Chemical Fertilizers		
- 15-15-15	562.57	357.17
- 46-0-0	406.63	12.60
- 16-8-8	248.61	37.80
Manure		
- Cow	24.24	-
- Chicken	398.92	74.71
Herbicide		
- Glysophate	101.18	102.71
- Paraquat	94.46	96.92
- Grammocxone	119.40	-
Operation Costs (baht/rai)	**2,251.05**	**2,195.52**
Land preparation	0.61	-
1st plough	366.52	251.86
2nd plough	318.60	247.17
Planting	499.41	203.34
Fertilizing	93.36	104.68
Weeding	125.66	5.80
Spraying	91.98	71.82
Stem cutting	107.58	435.07
Harvesting	292.76	507.91
Transport	428.48	-

(**Source:** Calculated from the survey)

The input costs of cassava production planted by contractors are 868.41 baht per rai. The most important of input costs of this group is also chemical fertilizer formula 15-15-15, which costs 357.17 baht, followed by root stocks or stakes, herbicides: Glysophate and Paraquat, chicken manure, chemical fertilizer formula 16-8-8 and 46-0-0, at 294.39, 102.71, 96.92, 74.71, 37.80 and 12.60 baht respectively.

The research area data showed farms operated by non-contractors had operation costs of 2,251.05 baht per rai higher than contractors, at 2,195.52 baht per rai. Among the operation costs of non-contractors, planting costs had the highest share with 499.41 baht per rai, followed by transportation costs at 428.48 baht per rai, the first plough at 366.52 baht per rai, the second plough at 318.60 baht per rai, and the costs of harvesting at 292.76 baht per rai.

The operation cost of cassava production by contractors was 2,195.52 baht per rai, with the highest cost being harvesting cost (507.91 baht) followed by the costs of stem cutting (435.05 baht), first and second plough with 251.86 and 247.17 baht respectively, and the costs of planting at 203.34 baht per rai.

The total cost of cassava production expended by non-contractors was higher than the total costs of cassava production expended by contractors, at 3,487.53 baht per rai and 3,063.93 baht per rai.

Having established these facts, the procedures for evaluating effects of contract participation on total costs of cassava production to fit the estimating of the effects of contract participation on total costs is applied. The treatment effects model to correct the possible selection bias and yields unbiased and consistent estimates in total costs model is also fitted.

Table 8.4 shows that contract participation has reduced the total cost of cassava production of individual contractors by 6.60 baht on average using the Kenel-based method (KBM) when the nearest neighbour method (NNM), contract participation, has raised total cost of cassava production of individual contractors by 108.05 baht.

Table 8.4: Participating effect on total cost of cassava production by PSM

Variable	Sample	NNM	KBM
Total costs of cassava production	Unmatched	-423.5991	-423.5991
	ATT	**108.0500**	**-6.5923**
	ATU	10.5669	0.2914
	ATE	**68.14082**	**-3.8863**

(**Source:** Calculated from the survey)

Moreover, contract participation reduced total cost of cassava production of all cassava farmers by 4 baht using KBM method and increased total costs by 68 baht using NNM method.

To compare the two groups of cassava farmers, *CONTRACT=1* and *CONTRACT=0*, we model the total costs as a function of human capital, physical assets and accessibility reflecting smallholders' ability to contracting we model already.

Variables entering into the contract participation equation are *HGENDER*, *HAGE*, *PEDU*, *PLOTSIZE*, *TFAMLAB*, *INPUTS*, *MACHIN*, *LABEX*, *CREDIT* and *GROUPS*. Variables entering to total costs equation are *CONTRACT*, *AGASSET*, *PLOTSIZE*, *TLAB*, *CHEMUSE* and *MANURE*.

Thus, the interest is in fitting the model:

$$CONTRACT = \gamma_0 + \gamma_1 HGENDER + \gamma_2 HAGE + \gamma_3 PEDU + \gamma_4 PLOTSIZE + \gamma_5 TFAMLAB + \gamma_6 INPUTS + \gamma_7 MACHIN + \gamma_8 LABEX + \gamma_9 CREDIT + \gamma_{10} GROUPS + u$$

$$TOTCOST = \beta_0 + \beta_1 CONTRACT + \beta_2 AGASSET + \beta_3 PLOTSIZE + \beta_4 TLAB + \beta_5 CHEMUSE + \beta_6 MANURE + \varepsilon$$

Table 8.5 shows results from the estimated models for the effects of contract participation on total costs of cassava production.

Table 8.5: Effect of contract participation on total cost of cassava production using OLS and 2SLS estimates

Total Costs of Cassava Production (baht)	2SLS		OLS estimate	
	Coef.	Z	Coef.	t
Contract participation *(CONTRACT)*	-99.1379	-0.21	-265.4971	-2.12**
Agricultural asset value (baht) *(AGASSET)*	**-0.0012**	**-4.55*****	**-0.0013**	**-4.78*****
Planting area (rai) (*PLOTSIZE)*	-3.9658	-2.28**	-3.6810	-1.56
Total labour *(TLAB)*	48.8072	0.80	38.5209	0.57
Chemical use (kg) *(CHEMUSE)*	**10.3827**	**4.02*****	**9.7969**	**3.46*****
Manure use (kg) *(MANURE)*	**1.3480**	**3.76*****	**1.3505**	**3.23*****
Constant	3045.2300	9.36***	3153.0590	18.09***
Wald (Chi^2) for 2SLS, F-test for OLS	80.40***		13.88***	
R^2	0.2448		0.2504	
Durbin (score) Chi^2(1)	0.140047 (p = 0.7082)			
Wu-Hausman F(1,249)	0.135762 (p = 0.7128)			
Sargan (score) Chi^2 (1)	4.02428 (p = 0.0448)			
Basmann Chi^2 (1)	3.96103 (p = 0.0466)			
***: significant at 99% level, **: significant at 95% level and *: significant at 90% level				

(**Source:** Calculated from the survey)

CONTRACT is treated as an endogenous variableand the belief is that the correlation between *CONTRACT* and $\varepsilon$is not equal to zero. However, assuming *PEDU* and *CREDIT* are correlated with *CONTRACT*, but not error term, are exogenous and these excluded exogenous variables must not affect total costs of cassava production *(TOTCOST)* directly. Together, *PEDU* and *CREDIT* constitute the study's set of instruments. Then, the test is whether endogenous regressors in the model are in fact exogenous. After carrying out the 2SLS estimation, the Durbin score and Wu-Hausman statistics are reported. If *CONTRACT* is exogenous, the 2SLS estimates are still consistent. On the other hand, if *CONTRACT* is in fact endogenous, the OLS estimates would not be consistent.

The results of Durbin and Wu-Hausman tests show Durbin (score) Chi^2 (1) = 0.1400 (p = 0.7082) and Wu-Hausman F(1,249) = 0.1358 (p = 0.7128). These indicate that both test statistics are not significant. As a result, the null hypothesis of exogeneity is not rejected. This indicates that *CONTRACT* is in fact endogenous. Thus, the OLS estimates would not be consistent.

The results of both test statistics Sargan (score) Chi^2 (1) = 4.0243 (p = 0.0448) and Basmann Chi^2 (1) = 3.9610 (p = 0.0466) indicate that they are significant, which means either one or more of the IV are not valid or that the structural model is specified incorrectly. However, results from the IV indicate that the 2SLS approach can be used for evaluating effects of contract participation on farm gross margin. However, a result from the OLS estimate is still comparable in terms of signs and significance.

Table 8.5 shows that there are three variables that significantly and strongly influence total costs of cassava production at 90 per cent or higher levels of significance using 2SLS and OLS estimates. The three variables are:

1. Higher value of agricultural assets lower costs for producing of cassava;
2. One kilogram of increased chemical use leads to an increase in total cost of cassava production, and;
3. Use of manure increases the total cost.

However, contract participation significantly and strongly influences to total costs of cassava production at 95 per cent level of significance using OLS estimate.

The discussion in Chapter 5 concluded that smallholders who face high transaction costs tend to participate in CF. Hence, when the transaction costs are high, contract farming can be seen as an alternative way to generate additional income. This indicates that the costs of ethanol production based on cassava could be decreased using a contract participation approach; thus, the price of ethanol is likely to reduce and could be competitive with fossil fuel.

8.4.2 Effects of contract participation on cassava income

There are many previous studies which have shown that contract participation favours higher income farmers. For example, Saigenji and Zeller (2009) studied the effect of CF on productivity and income of small holders in the case of tea growing in north-western Vietnam. They found that, on average, contract participation increased daily income by approximately 40 per cent. In addition, contracts also affected the income of organic honey production in south-west Ethiopia (Meshehsa, 2011) and had a positive impact on income of sugarcane farmers in Sawannakhet, Laos (Saichay & Ayuwat, 2013). Moreover, in the case of tomato production in Turkey, farmers earned 19 per cent more innet profit and 13 per cent more in gross margin (Tatlidil & Akturk, 2004). Additionally, Miyata et al., (2009) reported thatcontracting increased per capita income by 45 per cent of the average income of green onion farmers and by 22 per cent of the average income of apple farmers. Consequently, the effect of contracting on per capita income is positive and statistically significant.

Wainaina et al. (2012) studied the impact of contracting on poultry farmers' income using PSM and concluded thatparticipation in contracting on poultry production improved the welfare of contractors, which reduced rather than entrenched rural poverty, with 27 per cent of net revenue increase if farmers participate in contracting. The results are the same as those found in the study by Hu (2013). However, Ito & Bao (2012) found that there was no difference between participants and non-participants in agricultural co-operatives on farm income but there was a significant difference in the farm income between late participants and non-participants. This indicated that late participants have benefitted from participating.

The same procedures for evaluating effects of contract participation on total costs of cassava production to fit the estimated effects of contract participation on incomes and gross margins is applied. The treatment effects model to correct the possible selection bias and yields unbiased and consistent estimates in total costs model is also fitted.

The 257 observations with 127 contractors and 130 non-contractors will be illustrated. Let *CONTRACT* be the dummy variable indicating whether the individual participates in contracting. With this definition, the sample contains the following distribution of participating in contracting. If individuals choose whether to participate in contracting and the error term of the model that gives rise to this choice is correlated with the error term in the income equation, then there is not a consistent estimate of the marginal effect of contract participation on income (Barnow, Cain, & Goldberger, 1996). The suspicion is that individuals with higher abilities would be more likely to participate in contracting and earn higher income. Such ability is, of course, unobserved. Furthermore, if the error term in the model for participating in contract agreement is correlated with ability and the error term in the income equation is correlated with ability, the two terms should be positively correlated. These conditions make the problem of signing the selectivity bias equivalent to an omitted variable and contracting positive, and the suspicion is that the OLS estimate is biased upward. To account for the bias, the treatment effects is fitted. This term corrects for possible selection bias and yields unbiased and consistent estimates in the income equation.

Table 8.6: Participating effect on cassava income by PSM

Variable	Sample	NNM	KBM
Cassava Incomes	Unmatched	2370.4185	2370.4185
	ATT	**3938.7152**	**3998.9149**
	ATU	937.3995	691.3267
	ATE	**2709.9887**	**2698.6906**

(Source: Calculated from the survey)

The use of PSM is to investigate the causal effect of contract participation on cassava income in comparison between contractors and non-contractors. Table 8.6 shows the matching estimates of the ATE of contract farming on cassava income. NNM and KBM are used to assess the results.

For individual farmers of contractors, contract participation has raised the cassava income by approximately 4,000 baht on average using both NNM and KBM. Moreover, for all farmers, contract participation increases cassava income by 2,700 baht using both NNM and KBM. The conclusion is that participation in contract farming has a positive effect on cassava income. This income effect can be due to the higher price that contracting firms offer to farmers. The difference in planting techniques and market access provided by contracting firm also contributes to the income difference between contractors and non-contractors through both quantity and quality. To estimate the effect of contract participation on cassava income with an endogenous problem IV estimate is used. To compare two groups of cassava farmers:*CONTRACT=1* and *CONTRACT=0*, the income as a function of human capital, physical assets, farm expenses and accessibility reflecting smallholders' ability to contracting is modelled.

Variables entering into the contract equation are *HAGE, PEDU*, *PLOTSIZE*, *TFAMLAB*, *INPUTS, MACHIN*, *LABEX*, *CREDIT* and *GROUPS*. Variables entering into cassava incomes equation are *CONTRACT*, *HAGE*, *HEDU*, *PLOTSIZE*, *TOTCOST* and *CHEMUSE*.

Thus the interest is in fitting the model:

$$CONTRACT = \gamma_0 + \gamma_1 GENDER + \gamma_2 HAGE + \gamma_3 PEDU + \gamma_4 PLOTSIZE + \gamma_5 TFAMLAB + \gamma_6 INPUTS + \gamma_7 MACHIN + \gamma_8 LABEX + \gamma_9 CREDIT + \gamma_{10} GROUPS + u$$

$$CASSIN = \beta_0 + \beta_1 CONTRACT + \beta_2 HAGE + \beta_3 HEDU + \beta_4 PLOTSIZE + \beta_5 CHEMUSE + \beta_6 TOTCOST + \varepsilon$$

Table 8.7 provides results from the estimated models for the effects of contract participation on cassava income. The z value and Wald is also reported in Table 8.7.

A Wald test for all coefficients in the 2SLS model (except constant) and F-Test in the OLS estimate are zero. With $p < 0.0001$, it can be concluded that the covariates used in the regression model may be appropriate and at least one of the covariates has an effect that is not equal to zero.

Then, *CONTRACT* is treated as endogenous and the correlation between *CONTRACT* and $\varepsilon$is believed to be not equal to zero. However, there is no reason to believe that the correlation between other variables and $\varepsilon$is nonzero. Because *CONTRACT* is being treated as an endogenous regressor, it is necessary to have one or more additional variables that are correlated with *CONTRACT* but uncorrelated with *u*. In addition, these excluded exogenous variables must not affect cassava incomes *(CASSIN)* directly. Thus the assumption is that average education of household partner (wife or husband) (*PEDU)* and *GROUPS* are *exogenous*.

Variables *PEDU* and *GROUPS* are chosen because of the belief that they are correlated with *CONTRACT* but not the error term. Together, *PEDU* and *GROUPS* constitute the set of instruments. Then, the desire is to determine whether endogenous regressors in the model are in fact exogenous. After 2SLS estimation, the Durbin score and Wu-Hausman statistics are reported. If the test statistic is significant, the variables being tested must be treated as endogenous. Even if *CONTRACT* is exogenous, the 2SLS estimates are still consistent. On the other hand, if *CONTRACT* is, in fact, endogenous, the OLS estimates would not be consistent.

Table 8.7: Effect of contract participation on cassava income using OLS and 2SLS estimates

Cassava Incomes (baht)	2SLS		OLS estimate	
	Coef.	Z	Coef.	t
Contract participation *(CONTRACT)*	**2125.4390**	**3.31*****	**1996.2580**	**4.77*****
Age of household head (year) *(HAGE)*	**41.9753**	**2.11****	**42.2761**	**1.95***
Education of household head (year) *(HEDU)*	**133.6023**	**2.05****	**136.5399**	**1.91***
Planting area (rai) (*PLOTSIZE)*	**18.8560**	**3.87*****	**19.0608**	**6.16*****
Chemical use (kg) *(CHEMUSE)*	**-28.5556**	**-4.11*****	**-28.9892**	**-3.65*****
Total cost (baht) *(TOTCOST)*	**0.7509**	**3.88*****	**0.7428**	**3.51*****
Constant	4929.146	3.51***	4993.0380	3.20***
Wald (Chi^2) for 2SLS, F-test for OLS	67.61***		18.67***	
R^2	0.2416		0.2419	
Durbin (score) $Chi^2(1)$	0.065383 (p = 0.7982)			
Wu-Hausman F(1,249)	0.063364 (p = 0.8015)			
Sargan (score) Chi^2 (1)	1.95499 (p = 0.1621)			
Basmann Chi^2 (1)	1.90865 (p = 0.1671)			

***: significant at 99% level and **: significant at 95% level;

(Source: Calculated from the survey)

The null hypothesis of the Durbin and Wu-Hausman tests is that the variable under consideration can be treated as exogenous and the estimate of error variance is consistent. Here both test statistics are non-significant with Durbin (score) Chi^2 (1) = 0.0654 (p = 0.7982) and Wu-Hausman F(1,211) = 0.0634 (p = 0.8015). As a result, the null of exogeneity is not rejected. This indicates that *CONTRACT* is in fact endogenous. Thus, the OLS estimates would not be consistent.

The results of both test statistics Sargan (score) Chi^2 (1) = 1.9550 (p = 0.1621) and Basmann Chi^2 (1) = 1.9087 (p = 0.1671) indicate that they are not significant, which means either one or more of the instrumental variables are valid or that the structural model is specified correctly. Results from the IV indicate that the 2SLS approach can be used for evaluating effects of contract participation on cassava income. However, results from the OLS and 2SLS estimates are still comparable in terms of signs and significance.

Table 8.7 shows that contract participation increases cassava income. Also, there are six variables that strongly and significantly, at 90 per cent level, influence cassava income using 2SLS and OLS estimates:

1. Contract participation is a variable strongly and significantly influencing cassava income;
2. Age of household heads in whicholder farmers who have more experience tend to receive a higher cassava income;
3. Higher education of household head is associated with higher income;

4. Hectares of planting area where larger parcels of land are used increase cassava income;
5. Chemical use in kilograms has a negative effect on cassava income; and
6. Total cost in cassava production, where increasing total cost increases income.

8.4.3 Effects of contract participation on farm gross margins

The treatment effects model is also fitted to correct the possible selection bias, and this yields unbiased and consistent estimates in farm gross margins model.

Table 8.8: Participating effect on farm gross margin

Variable	Sample	NNM	KBM
Cassava Incomes	Unmatched	1615.1687	1615.1687
	ATT	**3069.5365**	**2836.3337**
	ATU	-310.3102	-659.0200
	ATE	**1685.8408**	**1462.2981**

(Source: Calculated from the survey)

Table 8.8 shows that individual contract participation has raised the farm gross margin of contractors by 2,836.33 – 3,069.54 baht on average. Moreover, contract participation increased farm gross margin of all cassava farmers by 1,462.30 – 1,685.84 baht using NNM and KBM methods. The conclusion is that participation in contract farming has a positive effect on farm gross margin.

The two groups of cassava farmers, *CONTRACT=1* and *CONTRACT=0* are also compared. The farmgross margin as a function of human capital, physical assets, farm expenses and accessibility reflecting smallholders' ability to contracting is also modelled.

Variables entering into the contract participation equation are *HGENDER, HAGE, PEDU, PLOTSIZE, TFAMLAB, INPUTS, MACHIN, LABEX, CREDIT* and *GROUPS*. Variables entering to the outcome equation or income equation are *CONTRACT, HGENDER, HAGE, HEDU, PLOTSIZE, TOTCOST* and *CHEMUSE*.Thus the interest is to fit the model:

$$CONTRACT = \gamma_0 + \gamma_1 GENDER + \gamma_2 HAGE + \gamma_3 PEDU + \gamma_4 PLOTSIZE + \gamma_5 TFAMLAB + \gamma_6 INPUTS + \gamma_7 MACHIN + \gamma_8 LABEX + \gamma_9 CREDIT + \gamma_{10} GROUPS + u$$

$$GROSS = \beta_0 + \beta_1 CONTRACT + \beta_2 HAGE + \beta_3 HEDU + \beta_4 PLOTSIZE + \beta_5 CHEMUSE + \beta_6 TOTCOST + \varepsilon$$

CONTRACT is treated as endogenous and the belief is that the correlation between *CONTRACT* and $\varepsilon$is not equal to zero. However, the assumption is that *PEDU* and *GROUPS* are correlated with *CONTRACT*, but not the error term, are exogenous and these excluded exogenous variables must not affect gross margin *(GROSS)* directly. Together, *PEDU* and *GROUPS* constitute the set of instruments. Then, whether endogenous regressors in the model are in fact exogenous are tested. After 2SLS estimation, the Durbin score and Wu-Hausman statistics are reported. If *CONTRACT* is exogenous, the 2SLS estimates are still consistent. On the other hand, if *CONTRACT* is in fact endogenous, the OLS estimates would not be consistent.

The results of Durbin and Wu-Hausman tests show Durbin (score) Chi^2 (1) = 1.5232 (p = 0.2171) and Wu-Hausman F(1,249) = 1.4845 (p = 0.2242), and these indicate that both test statistics are not significant. As a result, the null of exogeneity is not rejected. This indicates that *CONTRACT* is in fact endogenous. Thus, the OLS estimates would not be consistent.

However, the results of both test statistics Sargan (score) Chi^2 (1) = 3.0362 (p = 0.0814) and Basmann Chi^2 (1) = 2.9768 (p = 0.0845) indicate that they are significant, which means either one or more of the instrumental variables are not valid, or that the structural model is not specified correctly.

Table 8.9: Effect of contract participation on farm gross margin using OLS and 2SLS estimates

Farm gross margin (baht)	**2SLS**		**OLS estimate**	
	Coef.	Z	Coef.	t
Contract participation *(CONTRACT)*	**1624.0290**	**2.22****	**917.5577**	**1.94***
Age of household head (year) *(HAGE)*	**57.6374**	**2.55****	**59.2826**	**2.52****
Education of household head (year) *(HEDU)*	**152.2254**	**2.05****	**168.2911**	**2.17****
Planting area (rai) (*PLOTSIZE*)	**19.1376**	**3.45*****	**20.2576**	**6.20*****
Chemical use (kg) *(CHEMUSE)*	**-31.1165**	**-3.93*****	**-33.4878**	**-4.14*****
Total cost (baht) *(TOTCOST)*	0.2423	1.10	0.1979	0.87
Constant	4247.1010	2.66***	4596.518	2.87***
Wald (Chi^2) for 2SLS, F-test for OLS	51.99***		12.33***	
R^2	0.1594		0.1674	
Durbin (score) Chi^2(1)	1.52315 (p = 0.2171)			
Wu-Hausman F(1,249)	1.48454 (p = 0.2242)			
Sargan (score) Chi^2 (1)	3.03615 (p = 0.0814)			
Basmann Chi^2 (1)	2.97681 (p = 0.0845)			

***: significant at 99% level and **: significant at 95% level;

(Source: Calculated from the survey)

Results from the IV indicate that the 2SLS approach can be used for evaluating effects of contract participation on farm gross margin. However, results from the OLS estimate are still comparable in terms of signs and significance.

Table 8.9 shows that there are five variables that significantly and strongly influence farm gross margin of cassava production at 90 per cent or higher levels of significance using 2SLS and OLS estimates. The five variables are:

1. Contract participation is a variable strongly and significantly influencing farm gross margin;
2. Age of household heads where older farmers influence higher gross margin of cassava production;
3. Increasing education of household head reflects higher gross margin;
4. Planting area also has a positive effect on increased gross margin of cassava production; and
5. Increasing chemical use leads to decrease in gross margin of cassava production.

The discussion in Chapter 5 concluded that smallholders who faced high transaction costs tend to participate in CF. Hence, when the transaction costs are high, CF can be seen as an alternative way to generate additional income. On the other hand, from the firms' perspective, [space] CF with lower income farmers may involve relatively high transaction costs. In the long term, the existence of CF may cause worse income inequality in rural areas since there are political, institutional and power structure problems in any reorientation of development strategies that may bias against the very poor (Tambunan, 1998). For farmers who often face difficulties in accessing markets to expand their products, CF can be used as a possible way to improve their living standards.

From these results, governments should support private investment in the production of inputs and provide credit lines to enable private suppliers to manage mass production to guarantee their timely availability. Agricultural organizations which facilitate participation, for example agricultural cooperatives and local agricultural groups, decrease the transaction costs of entering input markets. Smart subsidy ideas can help farmers to buy fertilizer at lower prices, and group-based revolving credit funds are a sustainable source of finance.

Since October 2012, the Thai government had paid approximately 300 billion baht to support price pledging of cassava, rice, red onions and garlic (Pratruangkrai, 2012). However, this scheme had failed. The pledging scheme for cassava production was cancelled in 2008 during the Surayud Chulanont government. Although the Abhisit Vejjajiva administration later launched an income guarantee for cassava, farmers did not participate in the project because the market price was higher than the guaranteed price due to a shortage of cassava following drought and pest infestation. However, the government policy on fuel subsidies resulted in reduced ethanol production because consumers turned to using the cheaper petrol (Pratruangkrai, 2012). The government should carefully consider whether to adopt the pledging scheme for cassava because it would entail additional funding to subsidise crop production over and above the cost of the rice-pledging programme. If the project were to go ahead, the government should carefully consider a fair pledging price to ensure trading growth along with a fair return for farmers. The government might not need to reintroduce pledging for cassava, because supply would still be lower than demand. Moreover, the government should carefully consider related policies, as some measures could affect the development of cassava farming and ethanol production.

In 2012, the government proposed a direct subsidy to help cassava farmers to buy equipment and other materials instead of pledging their output, as occurred in the past, in the upcoming harvest season. The government's rationale was to minimize spending and increase the efficiency of crop management. Under that scheme, the Thai government would provide a subsidy for agricultural equipment directly to 497,000 cassava farmers on the basis of about 0.5 baht per kilogram of output (Pratruangkrai, 2012). However, cassava farmers favour a pledging scheme, which would be more profitable. Additionally, farmers' representatives from Nakhonratshasrima province stated that the direct subsidy would encourage cassava traders to pressure farmers to lower their prices. The price of cassava had fallen gradually during the then harvest season. If the government provided a direct subsidy to the cost of production, the price in the market would continue to fall. Pratruangkrai (2012) showed that in 2010, 84.31per cent of farmers preferred an income guarantee scheme rather than a pledging scheme because an income guarantee scheme had fewer procedures than a pledging scheme. Cassava farmers could sell their product at any price level if they preferred. Total cassava farmers involved in an income guarantee scheme between 2010 and 2011 were 391,000, with 247,000 farmers in the northeast of Thailand. The total government budget used for this scheme was 2,354 million baht and each farmer received 6,187.8 baht.

However, Pratruangkrai (2012) reported that the price of cassava in 2012 remained 1.30-1.90 baht per kilogram, while the pledging price was 2.75-2.90 baht. Thus, traders have not been able to agree on a high pledging price because it did not reflect the market mechanism. As a consequence, less than 700,000 tonnes of cassava entered the pledging scheme compared to the target of 10 million tonnes. If the government was to set a pledging price too high the resulting trading of cassava would be seriously impacted because of tougher competitiveness in neighbouring countries and a greater supply of other cereal crops to replace cassava usage. If Thai traders quoted prices that were too high, Thailand would face difficulty in selling its tapioca products.

As it often does, the pledging scheme has led to corruption associated with the release of government supplies. Taxpayers will no longer be willing to subsidise farmers to the tune of billions of baht while loopholes in the pledging and releasing processes allow corruption that benefits a small group of people.

8.5 Effects of contract participation on employment

On family farms, underemployment may occur when family members are working on a full-time basis, even though the services that they render might actually require much less than full-time. Thus, wage rates in the agricultural sector tend to be the lowest in the economy. There is evidence for this from secondary data about wage rates in Thailand. The results of the 2009 survey concerning type of occupation showed households of employed professional, technical and executive workers earned the most income, about 66,318 baht per month, followed by households of non-farm businesses and economically inactive households (40,270 baht and 35,462 baht, respectively). The lowest income, approximately 12,837 baht per month, was of households of farm workers. Furthermore, households of farm workers had a ratio of expenditure to income of approximately 99 per cent resulting in them having the lowest proportion of their remaining money for saving and debt payment compared to other occupational groups (Statistics Forecasting Bureau, 2010).

There has been increasing competition for labour among sectors. Especially, the labour market in agriculture has come under pressure. The number of employed persons in agriculture dropped from 20.5 million in 1989 to 16.9 million in 1995. The decline in agricultural employment was especially dramatic for 15-24 years old, which decreased to 3.73 million (44 per cent) from 6.66 million between 1989 and 1995 (Poapongsakorn, Ruhs, & Tangjitwisuth, 1998).

Figure 8.4 illustrates the analytical model for effects of contract farming on labour use. To simplify the discussion, there are only two activities: agricultural and non-agricultural activities.

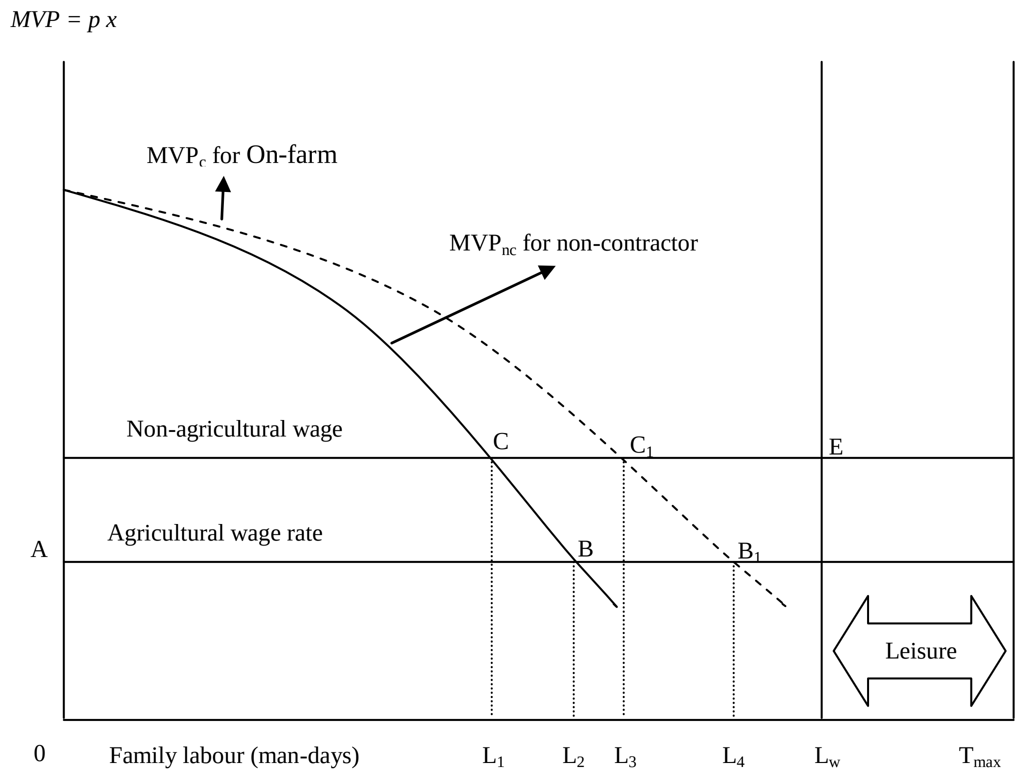
Also, the parcel of land operated by smallholders is given. The wage rate in non-farm work is assumed to be higher than the wage rate in farm work. Thus, in Figure 8.4, the non-agricultural wage rate is depicted above the agricultural wage rate. The vertical line is MVP (Marginal Value Product) and the horizontal line depicts total man-days of family labour owned by smallholders. T_{max} is total man-days of family workers and L_w is workers that might be allocated to either non-farm work or family farms.

For contractors, the optimum agricultural production occurs when MVP_c equals agricultural wage at B_1 and hence demand for labour on family farms is $0L_4$ man-days. Because of higher wages in non-farm work, contractors are willing to allocate $0L_3$ man-days of family labourer to family farms and they will seek outside help by hiring in labour at L_3L_4 man-days. Thus, L_3L_w man-days of family workers are employed on non-farm work. As with contractors, non-contractors prefer to employ $0L_2$ man-days of labour on family farms that consist of $0L_1$ man-days from family labourer and L_1L_2 man-days from hired labour. In this analysis, due to the difference in contractors, they tend to allocate less family labour to non-farm work.

Figure 8.5: Analysis of contract decisions on labour use

Interestingly, Figure 8.5 indicates there are two factors influencing smallholders to employ labour on family farms and to allocate family labour to non-farm work. One is output prices and marginal products. Here, MVP reflects productivity and the magnitude of the marginal product is influenced by human capital and assets held by smallholders, while output prices reflect smallholders' ability to access markets.

In this section, results from the estimated model are presented in two main discussions as effects of the contract participation on total labour, including family and non-family labour,and effects of contract participation on non-family labour. On average, there were three groups of non-family labour and family labour: children, and adult males and females. In terms of non-contractors, there were 1.70 children, 1.25 adult males and 1.20 adult females of non-family



Income for non-contractors = farm gross margin + non-farm income = ABCD + L_1CEL_w

Income for contractors = farm gross margin + non-farm income = AB_1C1D + $L_3C_1EL_w$

Source:(Santosa, 2006)

labour work per day, and 4.75 children, 4.26 adult males and 4.36 adult females of family labour work per day. In contrast, in terms of contractors, there were, on average, 1 child, 1.15 adult males and 1.32 adult females of non- family labour work per day, while there were two children, 3.20 adult males and 4.28 adult females of family labour work per day (see Figure 8.6).

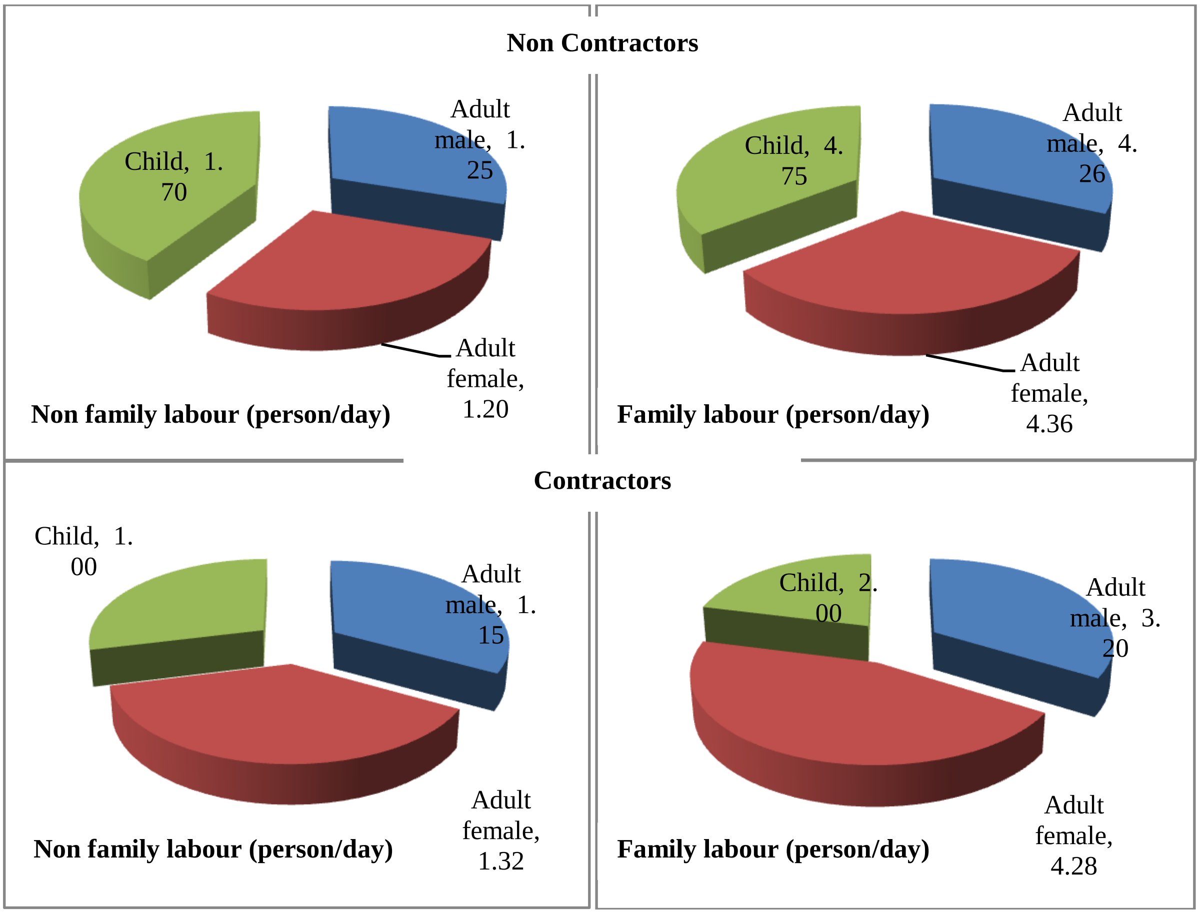


Figure 8.6: Labour use for cassava production
(**Source:** Calculated from the survey research crop year 2010/2011)

8.5.1 Effect of contract participation on total labour in cassava production

The treatment effects model was also fitted to correct the possible selection bias and yields unbiased and consistent estimates in the total labour model.

Table 8.10: Participating effect on total labour in cassava production

Variable	Sample	NNM	KBM
Cassava Incomes	Unmatched	-0.4343	-0.4343
	ATT	**0.9119**	**0.8863**
	ATU	0.7234	0.5763
	ATE	**0.8348**	**0.7645**

(**Source:** Calculated from the survey)

Table 8.10 shows that contract participation has raised the total labour of individual contractors and all cassava farmers by one man on average. We conclude that participation in CF has a small positive effect on total labour.

To evaluate the effects of contract participation on total labour, including family and non-family labour, the comparison between two groups of cassava farmers, *CONTRACT=1* and *CONTRACT=0*, are estimated.

Variables entering into the contract participation equation are *HGENDER, HAGE, PEDU, PLOTSIZE, TFAMLAB, INPUTS, MACHIN, LABEX, CREDIT* and *GROUPS*, and variables entering to the total labour equations are specified as functions of *CONTRACT, AGASSET, PLOTSIZE, MACHIN* and *GROUPS.*

Hence, the interest is to fit the model:

$$CONTRACT = \gamma_0 + \gamma_1 HGENDER + \gamma_2 HAGE + \gamma_3 PEDU + \gamma_4 PLOTSIZE + \gamma_5 TFAMLAB + \gamma_6 INPUTS + \gamma_7 MACHIN + \gamma_8 LABEX + \gamma_9 CREDIT + \gamma_{10} GROUPS + u$$

$$TOTLAB = \beta_0 + \beta_1 CONTRACT + \beta_2 AGASSET + \beta_3 PLOTSIZE + \beta_4 MACHIN + \beta_5 GROUPS + \varepsilon$$

Then, *CONTRACT* is treated as endogenous and the belief is that the correlation between *CONTRACT* and $\varepsilon$is not equal to zero. The assumption is that *PEDU* and *HGENDER* are *exogenous*. In addition, these excluded exogenous variables must not affect *TLAB* directly. Then, it is necessary to determine whether endogenous regressors in the model are in fact exogenous.

The results of the Durbin (score) Chi^2 (1) = 0.3729 (p = 0.5414) and Wu-Hausman tests F(1,250) = 0.3632 (p = 0.5473). These indicate that the test statistics are non-significant, thusthe null of exogeneity is not rejected, *CONTRACT* is in fact endogenous. However, the OLS estimates would not be consistent. Then, the test for over identifying restrictions is carried out. This is possible when there are more instruments than endogenous variables. The test assumes that one instrument is valid and then tests for the validity of all other instruments.

Table 8.11: Effect of contract participation on total labour in cassava production using OLS and 2SLS estimates

Total Labour for Cassava Production (baht)	2SLS		OLS estimate	
	Coef.	Z	Coef.	t
Contract participation *(CONTRACT)*	0.4736	1.09	0.2303	1.20
Agricultural asset value (baht) *(AGASSET)*	**-0.00000008**	**-2.77*****	**-0.00000008**	**-3.20*****
Planting area (rai) (*PLOTSIZE)*	**-0.0098**	**-5.78*****	**-0.0095**	**-4.08*****
Machinery costs (baht) *MACHIN)*	**-0.0006**	**-5.23*****	**-0.0006**	**-6.68*****
Number of agricultural groups (*GROUPS)*	**-0.3027**	**-2.47****	**-0.2406**	**-2.75*****
Constant	2.7675	13.92***	2.7154	12.82***
Wald (Chi^2) for 2SLS, F-test for OLS	90.50***		14.57***	
R^2	0.2574		0.2636	
Durbin (score) $Chi^2(1)$	0.372874 (p = 0.5414)			
Wu-Hausman F(1,249)	0.363245 (p = 0.5473)			
Sargan (score) Chi^2 (1)	0.355685 (p = 0.5509)			
Basmann Chi^2 (1)	0.346477 (p = 0.5561)			
***: significant at 99% level, **: significant at 95% level and *: significant at 90% level				

(**Source:** Calculated from the survey)

The results of both test statistics Sargan (score) Chi^2 (1) = 0.3557 (p = 0.5509) and Basmann Chi^2 (1) = 0.3465 (p = 0.5561) indicate that they are not significant, which means either one or more of our instrumental variables are valid or that the structural model is specified correctly. Results from the IV indicate that the 2SLS approach can be used for evaluating effects of contract participation on total labour. However, results from the OLS estimates are still comparable in terms of signs and significance. There are four variables that strongly and significantly influence total labour of cassava production using 2SLS and OLS estimates:

1. Higher value of agricultural assets makes lower cost for cassava production;
2. Planting area where this variable has a negative effect on total labour of cassava production;
3. Machinery costs have a negative effect on total labour of cassava production; and
4. Number of agricultural groups also has positive effects on total labour.

8.5.2 Effect of contract participation on non-family labour in cassava production by PSM

In comparison with contractors, non-contractors tend to employ more workers, including family and non-family labour, in cassava production because contractors prefer to hire the machinery to work on their farms. In addition, the finding reported in Chapter 7 showed that contractors earned higher gross margins. Thus, the combination of these results indicates that CF can be used as an alternative way to improve employment on farms, particularly when non-family work is difficult to access. However, the issue for income distribution may be more important when contracting tends to exclude lower-income smallholders from participating in contracting, particularly when transactions are costly.

Table 8.12 shows the same result of that contract participation on total labour which is only one man of non-family labour will be increased by contract participation of both contractors and all cassava farmers.

Table 8.12: Participating effect on non-family labour in cassava production

Variable	Sample	NNM	KBM
Cassava Incomes	Unmatched	-0.1222	-0.1222
	ATT	**0.9363**	**0.8845**
	ATU	0.8272	0.6113
	ATE	**0.8916**	**0.7771**

(Source: Calculated from the survey)

Variables entering into the contract participation equation are *HGENDER, HAGE, PEDU, PLOTSIZE, TFAMLAB, INPUTS, MACHIN, LABEX, CREDIT* and *GROUPS* and variables entering into the total labour equations are specified as functions of *CONTRACT, AGASSET, PLOTSIZE, MACHIN* and *GROUPS*.

Hence, the interest is in fitting the model:

$$CONTRACT = \gamma_0 + \gamma_1 HGENDER + \gamma_2 HAGE + \gamma_3 PEDU + \gamma_4 PLOTSIZE + \gamma_5 TFAMLAB + \gamma_6 INPUTS + \gamma_7 MACHIN + \gamma_8 LABEX + \gamma_9 CREDIT + \gamma_{10} GROUPS + u$$

$$TNONFAMLAB = \beta_0 + \beta_1 CONTRACT + \beta_2 AGASSET + \beta_3 PLOTSIZE$$

$$+\beta_4 MACHIN + \beta_5 GROUPS + \varepsilon$$

Then, *CONTRACT* is treated as endogenous and the belief is that the correlation between *CONTRACT* and $\varepsilon$is not equal to zero. The assumption is that *PEDU* and *HGENDER* are *exogenous*. In addition, these excluded exogenous variables must not affect *TNONFAMLAB* directly. Then, the desire is to determine whether endogenous regressors in the model are in fact exogenous.

Table 8.13: Effect of contract participation on total non-family labour in cassava production using OLS and 2SLS estimates

Total Non-Family Labour for Cassava Production (baht)	2SLS		OLS estimate	
	Coef.	Z	Coef.	t
Contract participation *(CONTRACT)*	**0.7175**	**1.75^{*}**	**0.3667**	**2.01^{**}**
Agricultural asset value (baht) *(AGASSET)*	**-0.0000005**	**-1.83^{*}**	**-0.00000004**	**-2.26^{*}**
Planting area (rai) (*PLOTSIZE)*	**-0.0073**	**-4.52^{***}**	**-0.0069**	**-4.42^{***}**
Machinery costs (baht) *MACHIN)*	**-0.0004**	**-3.50^{***}**	**-0.0003**	**-4.33^{***}**
Number of agricultural groups (*GROUPS)*	**-0.2906**	**-2.50^{**}**	**-0.2010**	**-2.39^{**}**
Constant	1.9526	10.35^{***}	1.8774	9.91^{***}
Wald (Chi^2) for 2SLS, F-test for OLS	40.72^{***}		10.09^{***}	
R^2	0.1292		0.1461	
Durbin (score) $Chi^2(1)$	0.869743 (p = 0.3510)			
Wu-Hausman F(1,249)	0.848926 (p = 0.3577)			
Sargan (score) Chi^2 (1)	1.24344 (p = 0.2648)			
Basmann Chi^2 (1)	1.21545 (p = 0.2703)			
***: significant at 99% level, **: significant at 95% level and *: significant at 90% level				

(Source: Calculated from the survey)

The Durbin (score) Chi^2 (1) = 0.8697 (p = 0.3510) and Wu-Hausman tests F(1,250) = 0.8489 (p = 0.3577). These indicate that the test statistics are non-significant, so the null of exogeneity is not rejected; *CONTRACT* is in fact endogenous. However, the OLS estimates would not be consistent. The results of both test statistics Sargan (score) Chi^2 (1) = 1.2454 (p = 0.2648) and Basmann Chi^2 (1) = 1.2155 (p = 0.2703) indicate that they are not significant,which means either one or more of the IVs are valid or that the structural model is specified correctly. Results from the IVs indicate that the 2SLS approach can be used for evaluating effects of contract participation on total non-family labour. However, results from the OLS estimates are still comparable in terms of signs and significance. There are five variables that strongly and significantly influence non-family labour of cassava production using ML, 2SLS and OLS estimates:

1. Contract participation is a variable strongly and significantly influencing total non-family labour of cassava production;
2. Higher value of agricultural assets makes lower cost for cassava production;
3. Planting area where this variable has a negative effect on total non-family labour of cassava production;
4. Machinery costs have a negative effect on total non-family labour of cassava production; and

5. Number of agricultural groups has a negative effect on total non-family labour.

In comparison with contractors and non-contractors, contractors tend to employ more workers. This result indicates that contracting can be used as an alternative way to improve underemployment on family farms, particularly when non-farm work is difficult to access. However, the issue for income distribution may be more important when contracting excludes lower-income smallholders from participating in contract farming, particularly when transactions are costly.

8.6 Summary

Participation in contracts under agricultural cooperatives in cassava production is based on verbal agreement between farmers and agricultural cooperatives, and written contractual agreements between agricultural cooperatives and ethanol processors. There are four types of smallholders: i) Type-one smallholders with limited planting area and thus limited production, ii) Type-two smallholders are both lower- and middle-income types in rural areas and small-scale farmers, iii) Type-three smallholders with limited assets who have difficulties finding cash to pay for operational costs, and iv) Type-four smallholders who are relatively wealthy.

Using LP, Probit and Logit models, eight variables were found to significantly influence smallholder decisions to participate in contract farming: i) gender of household head, ii) education of household partner, iii) cassava planting area, iv) input costs, v) machinery costs, vi) labour costs, vii) credit access, and viii) number of agricultural groups.

Results from estimating the effect of contract participation on outcome including total costs of cassava production, income, farm gross margin and employment by the PSM method show that contract participation increases cassava incomes, farm gross margins and total family labour. At the same time, contract participation decreases total costs of cassava production. This indicates that the costs of ethanol production based on cassava could be decreased using a contract participation approach; thus, the price of ethanol is likely to reduce and could be competitive with fossil fuel. Such decreases in costs could make the consumption of alternative energy sources such as gasohol increase, resulting in reduced greenhouse gas emissions in Thailand.

In terms of effect of contract participation on outcomes using IVs with 2SLS and OLS estimates, contract participation is a variable strongly and significantly influencing outcomes of cassava incomes, farm gross margins and non-family labour. However, CF is a significant factor for reducing total costs of cassava production using OLS estimate. Moreover, variables such as age of household heads, higher education of household head, planting area, chemical use, machinery costs and numbers of agricultural groups also have effects on total costs of cassava production, cassava incomes, farm gross margins, and employment.

CHAPTER 9: SUMMARY, DISCUSSION AND CONCLUSIONS

9.1 Introduction

In this concluding chapter, estimation methods and empirical results are discussed and summarized. The research hypotheses specified in Chapter 1 are examined in the light of the research findings, and limitations of the study and suggestions about factors that might reduce the costs of cassava production to produce lower costs of ethanol for alternative energy and improve living standards for smallholders are made.

9.2 Overview of research

As a Party to the UNFCCC and the Kyoto Protocol, Thailand has made policy adjustments to reduce the country's contribution to climate change. Since fossil fuel prices have been very high, Thailand has introduced policies to encourage increases in bio-fuels production and consumption, and also created an alternative energy plan, which includes biodiesel and, particularly, ethanol. The most important raw material for bio-ethanol in Thailand is cassava, because it requires minimal inputs for planting, is highly productive and can be planted and harvested all-year round. CF of cassava production could decrease production costs, increase efficiency in markets, lower interest rates, decrease risk management and create better information for smallholders.

9.3 Evaluation of the research hypothesis

In this study, four hypotheses were presented in Chapter 1. The first hypothesis is that human capital, physical assets, agricultural expenses and market accessibility are factors influencing contract participation. This hypothesis was specified as a focus for identification of types of smallholders who tend to participate in CF. Discussion in Chapter 8 leads to the conclusion that this hypothesis cannot be rejected. Thus, smallholders who tend to engage in CF can be identified.

The second hypothesis is that CF, which is described by human capital, physical assets, agricultural expenditure and market accessibility, influences outcome, including total costs of cassava production, cassava incomes, farm gross margin and employment. This hypothesis was specified as a focus for identification of relationships between CF and outcome. As discussed in Chapter 8, this hypothesis cannot be rejected. Thus the effects of contract participation on outcomes, including total costs of cassava production, cassava incomes, farm gross margin and employment, can be estimated by a treatment effect model using PSM method and IV with 2SLS estimate, and the results are compared with OLS estimate.

9.4 Empirical results

Participation in contracts in cassava production is based on verbal agreement between farmers and agricultural cooperatives, and a written contractual agreement between agricultural cooperatives and ethanol processors. Agricultural cooperatives and farmers benefit if farmers sell their products through cooperatives, with 0.03 baht for the cooperative and 0.05 baht for farmers. The results from the first objective show that there are four types of smallholders, identified by mean values of farmland and assets. The mean value of land ownership by smallholders was 30.63 rai (4.90 hectares) and the mean value of assets was 515,361 baht (A$17,178): Type-one smallholders have limited planting area and thus limited production; Type-two smallholders are both lower- and middle-income types in rural areas and small-scale famers; Type-three smallholders have limited assets and have difficulties finding cash to pay for operational costs; and Type-four smallholders are perceived to be wealthy.

For the second objective we found that there are eight variables significantly influencing participation in contracting at 90 per cent or higher level of significance using LP, probit and logit models. These variables are:

1. Gender of household head: Female household heads are more likely to participate in CF than male household heads. Women cassava contractors in Thailand often have large farm sizes, and they may completely work their farms using local hired machinery and hired labourers. The women also grow cassava together with their husbands on family farms, Such cassava production is completely controlled by both wife and husband.
2. Education of household partners was found to positively influence farmers' likelihood of participating in CF. Those who have completed higher education benefit more from extension programs and participate more in contracting channels.
3. Cassava planting areas which are larger are more likely to participate in CF.
4. Input costs, including chemical fertilizer, herbicide, pesticide and manure for cassava production negatively influence CF. This indicates that lower production costs may make it more attractive for farmers, and thus low costs farmersare likely to be more profitable and are more attracted to this type of agreement.

5. Machinery costs, such as hiring tractors for land preparation, planting, harvesting and transportation increases the probability of participation in CF. This indicates that higher hired equipment for producing cassava increases the probability of contract participation.
6. Labour expenses or labour costs of cassava from pre- to post- harvest increases the probability of CF.
7. Farmers who do not get creditfrom financial institutions, such as the BAAC, commercial banks and village funds are more likely to participate in CF than the farmers who have access to credit. This is because contractors received credit in the form of advances of capital inputs and services rather than cash. Sometimes the farmers obtain loans separately from an existing bank or credit agency, in which case the contract itself can serve as collateral.
8. Number of agricultural groups impactspositively on CF, indicating that agricultural organizations, such as commodity organizations, may be centres of information that can be accessed by households. This type of social capital also plays a role with members and individuals motivated by other farmers to participate. Agricultural groups also impart useful information to farmers, which could result in increased knowledge, productivity and income.

The third objective is in two sections:

1. Effects of contract participation on total costs of cassava production, as the cost structure of cassava bio-ethanol production in Thailand between 2002 and 2005 showed that the feedstock cost is the biggest accounting for 60 percent of total costs of ethanol production. The results show that contract participation has reduced the total cost of cassava production of individual contractors all cassava farmers estimated by Propensity Score Matching. Additionally, contract farmingsignificantly and strongly influences total costs of cassava production using OLS estimate. To overcome the problem of reducing climate changeby increasing the use of alternative energy such as gasohol, contract farming can decrease the cost of cassava feedstock for ethanol production which makes ethanol production even more effective.
2. Effects of contract participation on cassava income and farm gross margins. The use of PSM is to compare the causal effect of contract participation on cassava income and farm gross between contractors and non-contractors. The PSM estimate showed that CF has a positive effect on cassava income and gross margins. This income and gross margins effect can be due to the higher price that contract farmers attain. The difference in planting techniques and

market access provided to contracting firms also contributes to the income and gross margins difference between contractors and non-contractors.

Results from the IV with 2SLS approach and OLS shows contract participation is a variable strongly and significantly influencing cassava income and farm gross margins. As discussed in Chapter 5, when transaction costs are high, CF can be an alternative way to generate additional income for farmers. These results imply that CF can be used as a strategy to improve the standard of living of cassava farmers.

The fourth objective is to examine the effects of contract participation on employment. As discussed in Chapter 8, there has been increasing competition for labour among sectors; particularly labour for carrying out agricultural work has come under pressure. The results from the estimated model are presented in two parts: effects of contract participation on total labour, including family and non-family labour, and effects of contract participation on non-family labour.There is no evidence that CF influenced total labour, including family and non-family labour. However, CF strongly and significantly influences non-family labour of cassava production, as shown by using 2SLS and OLS estimates. This result indicates that contracting can be used as an alternative way to improve underemployment on family farms, particularly when non-farm work is difficult to access.

9.5 Policy Suggestions may be Advantages

After estimating the effect of CF on the desired outcome of reducing the price of alternative energy, such as gasohol, and, therefore, decreasing the climate change problem, it is possible to conclude that, on marketing aspects, related agencies should proceed with cassava marketing development activities including:

1. Promoting and developing future markets for cassava production emphasi**z**ing the advantages of CF to farmers;
2. Proactively undertaking market access negotiation with new potential markets; and
3. Expanding the Thai cassava export markets through intensive negotiation on tariff reduction with high tariff importing countries.

To attain these objectives, and achieve a sustainable intensification of cassava production, it will be necessary to have political commitment, investment, institutional support and a demanddriven approach to technology development. Particularly, it will be necessary to concentrate on:

1. **Controlling pest and disease threats.** Cassava intensification programs should promote integrated pest management which draws on resistant cultivars, bio-pesticides, biological control agents and habitat management to protect crops. Increased international movement of cassava production will require improved phytosanitary measures to ensure that planting material is free of pests and diseases. The Thai government spent 600 million baht from a reserve budget for the crop year 2011 to help cassava farmers deal with damaged products caused by mealybugs in the crop year of 2011/2012. Such funds could be allocated to the 345,000 farmers to spend on action preventing mealybugs in the 45 provinces in which cassava is planted (Fernquest, 2011). Programs such as the introduction of *Anagyrus lopezi* should be encouraged. In this program, the government arranged for the large-scale multiplication and distribution of the mealybug control wasp, *Anagyrus lopezi*.[24] By May 2012, almost three million pairs of *Anagyrus lopezi* had been released throughout the infested cassava area. The biological control campaign was highly successful, the infested area was decreased to 170,000 ha in 2010, to 64,000 ha in 2011 and decreased to 3,300 ha by 2012 (Howeler et al., 2013).
2. **Reducing farmers' exposure to price volatility.** Guaranteeing a reasonable price for cassava farmers' production will support them to invest in their production. A possible strategy is for the government to provide subsidies. Other ideas, such as promoting CF, could decrease the transaction costs of input supply and output marketing by combining small parcels of planting areas. The Thai government should also promote the availability of crop insurance to help farmers better manage risk.
3. **Supporting technology and research development for cassava production.** Applied research can help the cassava revolution by developing new varieties which resist pests and diseases, and also by developing the irrigation technologies to improve water-efficient and suitable farm machinery. The Government should promote public-private partnerships for technology development and connect them to markets in order to help the up-scaling of successful innovations such as has been demonstrated in the case KU working together with Thailand's Tapioca Development Institute and International Centre for Tropical Agriculture to breed "waxy" starch cassava varieties adapted to Thai growing conditions.
4. **Improving rural infrastructure,** including investment in roads, warehousing and processing capacity in production areas. This is likely to help improve the link cassava

[24] *Anagyrus lopezi,* a natural enemy of the pest, has been imported into Thailand from the IITA laboratories in Benin by Georg Goergen, IITA Entomologist. Goergen brought the materials into Thailand in September 2009.

farmers and processors have to growing markets for cassava that have a longer shelf life. It will also contribute to price stabilization, decrease postharvest losses and thus induce lower transaction costs. Moreover, with appropriate equipment and technology, local processing firms could produce high quality cassava flour, allowing farmers to maintain a bigger share of the value-added product.

9.6 Limitations of the study

An understanding of some limitations on the scope of this study may encourage further work. Limitations of this study arise in three main areas. The first limitation is data quality. The collection and analysis of household-level data is not an easy task. Every effort was made to ensure that all survey forms were completed in a timely and accurate fashion, and that all data were thoroughly checked prior to analysis. However, some inaccuracies and inconsistencies undoubtedly remain. Data on farm and non-farm incomes may contribute to underestimates in calculating household incomes. In addition, data from the survey were mainly aimed at evaluating the benefits of CF. Thus information about incomes in non-farm and farm work was incomplete. In this regard, the difference in income between non-farm and farm work was used as a proxy variable for differences in incomes between non-farm and farm work.

The second limitation of the study is the use of cross-sectional data with a relatively small sample. Ideally, the analysis of smallholder decisions should be conducted with time series or pooled data to evaluate smallholder decisions. The cross-sectional data with a small sample may contribute to the difficulties encountered in the use of the 2SLS approach where values of R-square in first-stage regression tended to be low. As a result, in the second-stage regression, the R-square values sometimes were not easy to interpret. However, in this study, the 2SLS estimate was used only as a basis for comparison with the sample selection estimate to improve confidence in the general approach and in the interpretation.

The third limitation of the study is the use of a single representative farm-household model. Because of time and data constraints, it was difficult to develop several farm household models representing different regions and socio-economic characteristics. Therefore, formal aggregation of the model results was not attempted.

9.7 Concluding remarks

The main focus of this study has been how to reduce contributions to climate change by introducing more effective policies for promoting more sustainable development of alternative energy sources, such as ethanol. It is important in promoting ethanolto reduce its cost of production, which entails changing the pricing of cassava and increasing the productivity of cassava. To decrease the cost of cassava feedstock for ethanol production but not decrease the wellbeing of cassava farmers, CF seems a good solution because a CF approach can reduce the cost of cassava production for both farmers and ethanol processors, and all the participants in the production, processing and marketing of the farm products from farm to the end consumers.

This study shows that CF can be regarded as an alternative way to improve living standards for farmers by decreasing the cost of production and increasing their income, particularly when there is underemployment on family farms. Thus, CF can be used as an intermediate step in the transition from subsistence to modern production. However, lower-income smallholders may face difficulties in participating in CF, because their cost structures do not make them attractive contract partners for agribusiness firms. However, policies that reduce transaction costs through improved transportation and the promotion of organizations for marketing would increase market participation by all farmers. In addition, improving rural infrastructure would facilitate faster delivery of farm produce, especially perishable commodities such as cassava, to urban consumers. An added benefit to increasing a focus on sustainable cassava production is the provision of rural employment opportunities, which will reduce the migration of underemployed rural workers to urban centres. Transaction costs of participation in cassava production could be reduced through improved information, transportation infrastructure and promotion of institutional innovations, such as production and marketing cooperatives.

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APPENDIX 1: SURVEY FORM

CAN CONTRACT FARMING OF CASSAVA CONTRIBUTE TO AMELIONATION OF CLIMATE CHANGE IN THAILAND

Form number: [ ]

Dan Khuntod, Nakhon Ratchasrima

No.	Farmer name:	Phone: (+66) .... Mobile: (+66)	Address: ....
Date of Interview (d/m/y)	_____ / _____/ _____	Village (Code):	
Time interview started	___ ___ : ___ ___ p.m. / a.m.	Time interview completed	___ ___ : ___ ___ p.m. / a.m.
Name of enumerator			

***Village Code*:**

01 = Kud Phiman
02 = Dan Khuntod
03 = Dan Nok
04 = Dan Nai
05 = Tha Kein
06 = Nonmeung Pattana
07 = Ban Kao
08 = Ban Prang
09 = Phan Chana
10 = Sa Jarake
11 = Nong Krad
12 = Nong Sai
13 = Nongbua Takied
14 = Nongbua Lakhon
15 = Huay Bong
16 = Hin Dad

Respondent status: [ ]

1 = Contract farmer
2 = Non-contract farmer

Form number: [ ]

CAN CONTRACT FARMING OF CASSAVA CONTRIBUTE TO AMELIONATION OF CLIMATE CHANGE IN THAILAND

Form number: [ ]

Dan Khuntod, Nakhon Ratchasrima

Household characteristics

We are going to start with basic information concerning the members of the household *(a household member is defined as anyone who has lived in the house for 6 months or more of the previous 12 months)*

Code no.	1. Please list the names of the household members?	2. What is your relationship between the household head and each member of the household? **00 = self** **01 = spouse** **02 = son/daughter** **03 = father/mother** **04 = grandson/ granddaughter** **05 = son-in-law /daughter–in-law** **06 = nephew/niece** **07 = aunt/uncle** **08 = other relative** **09 = non-relative**	3. Gender **01 = male** **02 = female**	4. Age (years)	5. Are you still fulltime at school, college, university etc? **01 = yes** **02 = no**	6. How many years of formal schooling were completed?	7.What is the highest education level completed? **01 = no formal schooling** **02 = Kinergarden** **03 = primary school** **04 = junior high school** **05 = senior high school** **06 = diploma** **07 = university degree** **08 = post-graduate degree**	8. How much time has each household member spent living in the house during the past 12 months? **(months)**
01 (head)								
02								
03								
04								
05								
06								
07								
08								
09								

CAN CONTRACT FARMING OF CASSAVA CONTRIBUTE TO AMELIONATION OF CLIMATE CHANGE IN THAILAND

Form number: ☐

Dan Khuntod, Nakhon Ratchasrima

Complete the table by row not column. Ensure all boxes are filled for each household member

A. Off-farm Income

This table requires information concerning all off-farm income. Off-farm income is any income not earned in farming activities on land owned or managed by members of the household.

1. Did anyone in your household earn income other than that derived from your farming activities during the last 12 months? If yes list the code numbers (see Table A) of those who worked off-farm below, if individuals worked at more than job enter their code number more than once if no go to Table C	2. Within what sectors did household members earn other income? *		3. What form of employment did your labour take? 01 = day labourer 02 = seasonal 03 = other	4. What was the major use for this income? 01 = household consumption 02 = saving/ investment 03 = consumption and investment 04 = don't know
		01 = home industry 02 = labour 03 = local retailing 04 = government 05 = leasing out land 06 = finance 07 = Education scholarship 08 = Pension 09 = Remittances from family members 10 = renting out assets 11 = sharefarming out 12 = Other sources of income		

CAN CONTRACT FARMING OF CASSAVA CONTRIBUTE TO AMELIONATION OF CLIMATE CHANGE IN THAILAND

Form number: [ ]

Dan Khuntod, Nakhon Ratchasrima

B. Family/household assets (farm and non-farm)

This set of questions relates to the type, number and value of your household assets. Complete Q1 for all assets do not leave blank. If money has been borrowed (e.g. from bank or other family member) include that as household assets, questions concerning debt are asked in Table P.

Code No.	Assets	1. Number owned by household members. **If 0 go to Q6, If >0 go to Q2**	2.Are you a joint owner of these assets? **01 = joint owner (go to Q3) 02 = sole owner (go to Q4)**	3. What percentage of these assets do you own? **(%)**	4. What is the approximate value of these assets in todays rupiah **(Baht)**	5. How many of these assets have you bought (or been given) in the last 12 months?	6. How many have you sold (or given away) any of these assets in the last 12 months? **If >0 go to 7 if 0 go to Table D**	7. What was the value of the assets sold or given away? **(Baht)**
01	Car							
02	Motor Bike							
03	Bicycle							
04	Television							
05	Satellite dish							
06	CD and DVD Player							
07	Washing Machine							
08	Refrigerator							
09	Computer							
10	Telephone							
11	Water Pump							
12	Rotary Hoe							
13	Sewing Machine							
14	Motorized cart							
15	Spray equipment							
16	Tractor							
17	Truck							

Form number:

Dan Khuntod, Nakhon Ratchasrima

C. Cassava production

All questions are to be answered with regard to the most recent cassava crops in the last 12 months.

3.1 Present variety of cassava

vaireties	How long have you grown? .... years	Month of planting:	Month of harvesting:	Period of time .... months
[ ] Kasetsart 50				
[ ] Rayong 5				
[ ] Kandang				
[ ] Houy-bong				
[ ] Others				

Season	
[ ] Within raining season March - June	[ ] End of raining season September - December
Root stock preparation	
Age of root stock prior to planting	(weeks)
How many root stocks were used for planting?	(roots/rai)
Size of root stocks	(c.m.)

Form number: ☐

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3.2 Cassava distribution

Plot No.	Products (kg.)	For selling		Root stock (kg.)	Consumed (kg.)	Pay for rental (kg.)	Value by selling (Baht)	Market	
		(kg.)	price (Baht/kg)						
1*									01 = Starch plant 02 = Contractors 03 = Ethanol plant 04 = Others ....
2									
3									
4									
5									

3.3 Cassava root stock preparation

Plot No.	Variety	Plot size (rai)	Tenancy arrangement		How many years has each plot been owned or managed?	Certificate of ownership		Fair rent (Baht/rai)	Source of irrigation water		Approximate value (Baht)
01*				01 = owned 02 = share in 03 = lease			1 = title deed 2 = NS.3 3 = SK.1 4 = PBT.5,6 5 = SPK4-01			01 = tap water 02 = rain 03 = private pond 04 = private groundwater 05 = public pond 06 = public groundwater 07 = river 08 = others	
02											
03											
04											
05											
Total											

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3.4 Inputs information and cropping system

Plot No.1 .... rai					
Cassava production factors	**Quality**	**sources**		**Price (baht/kg./L)**	**Value (Baht)**
		owned	**purchased**		
1. root stock (roots/rai)					
2. chemical fertiliser (.................... kg./bag)					
15-15-15					
46-0-0					
16-8-8					
Others					
3.Manure (.................... kg./bag)					
cow					
chickens					
Others					
4.Bio-fertilizer					
5. herbicide (litre/bottle)					
Glyphosate					
Paraquat					
Grammoczone					
Others					

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3.5 Cost and labour use for cassava production (average purchase for labour .... Baht/day)

Activity	Family labour						Non-family labour						Machinery	Total (Baht)
	Adult male (per)	Adult female (per)	Child (per)	hour /day	days	total	Adult male (per)	Adult female (per)	Chil d (per)	Days	Purchase (Baht/day)	total	Purchase (Baht/rai)	
1. Land preparation														
2. 1st plowing														
3. 2nd plowing														
4. Planting														
5. Fertilising														
6. Weeding														
7. Spraying														
8. Stem cutting														
9. Harvesting														
10. Transport														

CAN CONTRACT FARMING OF CASSAVA CONTRIBUTE TO AMELIONATION OF CLIMATE CHANGE IN THAILAND

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D. Contract

This table is only to be completed by the cassava farmers who are undre contract farming.

1. Have you produced cassava before without a contract? **01 = yes** **02 = no**	2. What year did you first grow cassava under contract	3. How many years since then have you not grown cassava under contract? **If 0 years go to Q5**	4. What were the two major reasons for not growing cassava crops? **01 = contract was not offered** **02 = community chose not to because…** **03 = community chose not to because…** **04 = no** **05 = no market** **06 = other reason**		5. What do you usually do with the cassava residue? **01 = burn** **02 = graze** **03 = graze and burn** **04 = plough** **05 = graze and plough** **06 = cut and plough** **07 = cut and burn** **08 = store** **09 = nothing**	6. What are the potential benefits of contracting this commodity? **(rank the top 3 benefits)** **01 = access to credit** **02 = guaranteed market** **03 = access to high quality inputs** **04 = access to improved technology** **05 = access to training** **06 = increased income** **07 = higher price** **08 = other**			7. What are the potential costs/ risks of contracting this commodity? **(rank the top 3 risks/problems)** **01 = no choice in accessing markets, technology, credit etc** **02 = difficulty in ensuring quality** **03 = difficulty in ensuring quantity** **04 = difficulty in managing credit/ capital that is provided** **05 = decreased income** **06= time consuming meetings/mgt** **07 = lack of understanding/ transparency in contract** **08 = other**			8. When do you receive your income? **01= at harvest** **02 = monthly** **03= annually** **04 = no nparticular time** **05 = other**
						Main benefit	2nd benefit	3rd bene fit	Main problem	2nd problem	3rd problem	

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D (continued)
Please answer these general questions with particular reference to your cassava contract.

9. What is the name of firm you are under contract?

....

....

10. When first considering accepting a contract to grow cassava what were your major concerns?

....

....

....

....

....

11. Would you change the conditions of the contract if you could? (circle) **YES / NO**
(If yes, explain. If no go to question 11)

....

....

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....

....

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....

Form number: ☐

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12. Has the contract changed over the years? (circle) **YES / NO**
(If yes, explain. If no go to question 12)

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....

....

13. Has the introduction of cassava forced you to change other aspects of your farming operations? (circle) **YES / NO**
(If yes, explain. If no go to question 13)

....

....

....

....

....

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....

Form number: ☐

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14. Do you have any other experience with contract farming in the last 5 years? (circle) **YES / NO**
(If no go to Table K, If yes provide details of commodity and contract arrangements go to question 12).

....

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15. Would you enter these types of contract arrangements again if you had the chance?
(Answer yes or no for each commodity discussed in Q.13)

....

....

....

....

....

Form number: [ ]

Dan Khuntod, Nakhon Ratchasrima

E. Multiple crops and tree crops

We need information about all l multiple crops and tree crops costs and income over the last 12 months.

<table>
<tr><th>Plot No.</th><th colspan="2">1. The utilization</th><th>2.Plot size (rai)</th><th colspan="2">3.Tenancy arrangement</th><th colspan="2">4.Certificate of ownership</th><th>5.Fair rent (Baht/rai)</th><th>6.Approximate value (Baht)</th></tr>
<tr><td>1</td><td></td><td rowspan="8">01 = Plot No. 1 – 3: planting (not cassava) …………………
02 = Plot No. 4 – 6: livestock …………………………………
03 = for rent
04 = others ....</td><td></td><td></td><td rowspan="8">01 = owned
02 = share in
03 = lease</td><td></td><td rowspan="8">1 = title deed
2 = น.ส.3
3 = ส.ค.1
4 = ภ.บ.ท.5,6
5 = ส.ป.ก.4-01
อื่นๆ</td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>6</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>7</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>8</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Form number:

Dan Khuntod, Nakhon Ratchasrima

7. Cost and returns of multiple crops and tree crops (not cassava)	**Plot No.1**	**Plot No.2**	**Plot No.3**
Was the crop irrigated?	[ ] yes [ ] no	[ ] yes [ ] no	[ ] yes [ ] no
Month for cropping			
The most important reason for growing crop? 01: household consumption 04: livestock feed 02: consumption and sale 05: sale at market/trader 03: consumption and livestock feed			
Seed cost (Baht)			
Labour purchased (Baht)			
Fertiliser purchased (Baht)			
Manure (Baht)			
Pesticide (Baht)			
Herbicide (Baht)			
Production sold (kg)			
Production not sold (kg)			
Price of product sold (Baht/kg)			
Approximate value of production (Baht)			

CAN CONTRACT FARMING OF CASSAVA CONTRIBUTE TO AMELIONATION OF CLIMATE CHANGE IN THAILAND

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F. Labour use for multiple crops and tree crops

Plot No.1 ....

Activity	Family labour (man/day)						Non-family labour (man/day)						Machinery	Total
	Adult male	Adult female	Child	hour /day	days	total	Adult male	Adult female	Child	Days	Purchase (Baht/day)	total	Purchase (Baht/rai)	(Baht)
1. Land preparation														
2. Planting														
3. Fertilising														
4. Weeding														
5. Spraying														
6. Harvesting														
7. Transport														

Plot No.2 ....

Activity	Family labour (man/day)						Non-family labour (man/day)						Machinery	Total
	Adult male	Adult female	Child	hour /day	days	total	Adult male	Adult female	Child	Days	Purchase (Baht/day)	total	Purchase (Baht/rai)	(Baht)
1. Land preparation														
2. Planting														
3. Fertilising														
4. Weeding														
5. Spraying														
6. Harvesting														
7. Transport														

Form number: ☐

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G. Livestock

We need information about all livestock costs and income over the last 12 months. These questions will be asked with regard to each livestock enterprise. ***Ensure that columns 3 and 4 are completed. This table continues on the next page, ask all questions for one enterprise type before moving to the next line.***

1. Livestock type		2. Average number of animals during the last 12 months?		5. What was the most ususal form of livestock management during the alst 12 months? **1 = stalled** **2 = free grazing** **3 = mix stall and graze**	6. How much money was spent on veterinary costs in the last 12 months? **(Baht)**	7. How much money was spent on purchased feed in the last 12 months? **(Baht)**	8. How much money was spent on other livestock costs in the last 12 months? **(Baht)**
		3. Adult	4. Young				
01	Beef cattle						
02	Dairy cattle						
03	Local chicken						
04	Other ____						

Form number: ______

Dan Khuntod, Nakhon Ratchasrima

G (continued)

1. Livestock type		9. Estimate the number of stock (questions 10-12) and commodities (questions 13 – 15) produced in the last 12 months?						15.Average price/unit **(Baht)**	16. How many animals were purchased in the last 12 months? **If 0 go to next livestock type**	17. What was the total cost of these purchases? **(Baht)**
		10. No. of head sold **if 0 go to Q12**	11. Avge price per head **(Baht)**	12. No. consumed or given away	13. Type of other production		14. Quantity **01 = eggs 02 = litre 03 = kg 04 = other**			
01	Beef cattle					**01 = none (go to Q16) 02 = eggs 03 = milk 04 = skin 05 = meat 06 = other**				
02	Dairy cattle									
03	Local chicken									
04	Other _____									

Form number:

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H. Labour use for livestock

This table requires information concerning the time taken by various houshold members to look after the livestock. The following tables separate animals (beef cattle, dairy cattle etc) from birds (chickens, ducks etc) and also sparates by season if necessary. (Only enter a number if greater than zero)

Livestock

Beef cattle

Activity	**Wet season (code 01)**						**Dry season (code 02)**						**Contract/ season (Baht)**
	Family (hrs/week) (01)			Non-Family (hrs/week) (02)			Family (hrs/week) (01)			Non-Family (hrs/week) (02)			
	male (01)	female (02)	child (03)	male (01)	female (02)	child (03)	male (01)	female (02)	child (03)	male (01)	female (02)	child (03)	
01 Clean stall (hrs/day)													
02 Shepherd (hrs/day)													
03 Feed/water (hrs/day)													
04 Sell (hrs/season)													
05 Other (hrs/day)													

CAN CONTRACT FARMING OF CASSAVA CONTRIBUTE TO AMELIONATION OF CLIMATE CHANGE IN THAILAND

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Dairy cattle

Activity	**Wet season (code 01)**						**Dry season (code 02)**						**Contract/ season (Baht)**
	Family (hrs/week) (01)			Non-Family (hrs/week) (02)			Family (hrs/week) (01)			Non-Family (hrs/week) (02)			
	male (01)	female (02)	child (03)	male (01)	female (02)	child (03)	male (01)	female (02)	child (03)	male (01)	female (02)	child (03)	
01 Clean stall (hrs/day)													
02 Shepherd (hrs/day)													
03 Feed/water (hrs/day)													
04 Sell (hrs/season)													
05 Other (hrs/day)													

Form number:

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H (Continued)

Poultry
Local chicken

Activity	**Wet season (code 01)**						**Dry season (code 02)**						**Contract/season (Baht)**
	Family (hrs/week) (01)			Non-Family (hrs/week) (02)			Family (hrs/week) (01)			Non-Family (hrs/week) (02)			
	male (01)	female (02)	child (03)	male (01)	female (02)	child (03)	male (01)	female (02)	child (03)	male (01)	female (02)	child (03)	
06 All activities – includes cleaning shed, feeding and watering, selling etc (hrs/day)													

CAN CONTRACT FARMING OF CASSAVA CONTRIBUTE TO AMELIONATION OF CLIMATE CHANGE IN THAILAND

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I. Credit

Please complete the following 2 tables which require information about the type and level of household saving.

For each source of credit ensure all boxes in the accompanying row are filled

1. Source of credit		2. For what purpose did you receive this credit?		3. How much did you borrow or what value was the credit/overdraft you obtained? **(Baht)**	4.types of collaterate **1 = individual** **2 = group** **3 = saving**	4. How much collateral or savings were you required to have to obtain this credit? **(Baht)**	5. When did you borrow? **(Mth/yr)**	6. When do you expect to finish repaying? **(Mth/yr)**	7. How much do you still owe? **(Baht)**	8. At what interest rate did you borrow? **(%/mth)**	9. What fees have you or will you have to pay before completion of the credit? **(Baht)**
	01 = commercial bank **02 =** BAAC **03 = farmer/village cooperative** **04 = shop** **05 = moneylender** **06 = neighbours** **07 = family** **08 = other**		**01 = buy/improve land** **02 = buy farming inputs** **03 = buy/repair farm equipment** **04 = rent land** **05 = education fees** **06 = health costs** **07 = basic household needs** **08 = buy/improve house** **09 = family/community ceremony** **10 = buy h'hold assets** **11 = repay debt** **12 = other**								

Form number: ☐

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J. Membership of farmer groups

1. Are you or any members of your household members of any community organizations?

Yes / No

2.List the code numbers (from Tabel A) of the household members who are members of community groups. **(if a h'hold member is a member of more than 1 group, enter the code more than 1 time)**	3. What is the name of the group?	4. How many years has the household member been part of this group?	5.What is the main function of the group (choose max 2 options)? **01 = extension** **02 = training** **03 = credit** **04 = purchase inputs** **05 = social**		6.Has the household member ever held an elected position in this group? **01 = yes** **02 = no**

CAN CONTRACT FARMING OF CASSAVA CONTRIBUTE TO AMELIONATION OF CLIMATE CHANGE IN THAILAND

Form number: [ ]

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K. Community responsibilities

1. Have there been any community or household events (e.g. weddings, funerals, village and religious celebrations) that require significant household inputs (e.g. donation of stock or produce) that may affect the type of production that smallholders are required to produce?

YES / NO

2. Name of community event	**3. How many of these events occured?** Number in the last 12 months	**4.What was the approximate cost of the household participation in this event? (Baht)**
Weddings		
Enter to monkhood		
Funerals		
Traditional celebrations		
Others		

5. Have there been any significant natural occurrences that may have affected rural livelihoods in the last 5 years e.g flood, earthquake, and drought? Please list and discuss the implications of these

....
....
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....
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THANK YOU SO MUCH FOR YOUR KINDLY HELP

APPENDIX 2: STATA SYNTAX AND RESULTS

In this appendix, syntax and results from the estimated methods using Stata version 12 software are presented. The symbols of variables used in the syntax are:

1.	CONTRACT	Contract participation status; 0 = non-contractors, 1 = contractors
2.	HGENDER	Gender of household head; 0 = male, 1 = female
3.	HAGE	Age of household head
4.	PEDU	Education of household head's partner
5.	PLOTSIZE	Size of cassava production area
6.	TFAMLAB	Total family labour
7.	IINPUTS	Input costs
8.	MACHIN	Machinery costs
9.	LABEX	Labour expenses
10.	CREDIT	Access to credit; 0 = not access, 1 = access
11.	GROUPS	Number of agricultural groups
12.	CASSIN	Cassava incomes
13.	GROSS	Farm gross margins
14.	TLAB	Total labour
15.	TNONFAMLAB	Total non-family labour
16.	CHEMUSE	Chemical used
17.	TOTCOST	Total costs
18.	AGASSET	Agricultural asset values
19.	MANURE	Manure used

A. Factors Influencing Contract Participation Using Linear Probability, Probit and Logit Models

Linear Probability Model

```
. xi: reg contract hgender hage pedu plotsize tfamlab inputs machin labex credit groups,
robust

Linear regression                                      Number of obs =     257
                                                       F( 10,   246) =   77.16
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.6220
                                                       Root MSE      =  .31417

------------------------------------------------------------------------------
             |               Robust
    contract |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     hgender |  -.2585846   .0469284    -5.51   0.000    -.3510173   -.1661518
        hage |   .0015797   .0021216     0.74   0.457    -.0025992    .0057585
        pedu |   .0230631   .0097216     2.37   0.018     .0039148    .0422114
    plotsize |   .0008646   .0004599     1.88   0.061    -.0000413    .0017705
     tfamlab |  -.0045186   .0309798    -0.15   0.884    -.0655381    .0565008
      inputs |  -.0001676   .0000366    -4.58   0.000    -.0002396   -.0000956
      machin |   .0001404   .0000273     5.14   0.000     .0000866    .0001941
       labex |  -.0001515   .0000429    -3.53   0.000     -.000236    -.000067
      credit |  -.1399083   .0495492    -2.82   0.005     -.237503   -.0423136
      groups |   .1947475   .0164615    11.83   0.000      .162324    .2271711
       _cons |   .2055513   .1667119     1.23   0.219    -.1228135    .5339162
------------------------------------------------------------------------------

. predict contracthat
(option xb assumed; fitted values)
. gen preddum=1 if contracthat>0.5
(122 missing values generated)
 . replace preddum=0 if contracthat<0.5
(122 real changes made)
. replace preddum=. if contracthat==.
(0 real changes made)
 . tab contract preddum, row col

+-------------------+
| Key               |
|-------------------|
|     frequency     |
|  row percentage   |
| column percentage |
+-------------------+

           |        preddum
  contract |         0          1 |     Total
-----------+----------------------+----------
         0 |       114         16 |       130
           |     87.69      12.31 |    100.00
           |     93.44      11.85 |     50.58
-----------+----------------------+----------
         1 |         8        119 |       127
           |      6.30      93.70 |    100.00
           |      6.56      88.15 |     49.42
-----------+----------------------+----------
     Total |       122        135 |       257
           |     47.47      52.53 |    100.00
           |    100.00     100.00 |    100.00
```

Probit Model

```
. xi: probit contract hgender hage pedu plotsize tfamlab inputs machin labex credit groups,
robust

Iteration 0:   log pseudolikelihood = -178.12132
Iteration 1:   log pseudolikelihood = -64.750322
Iteration 2:   log pseudolikelihood = -61.692018
Iteration 3:   log pseudolikelihood = -61.645448
Iteration 4:   log pseudolikelihood = -61.645428
Iteration 5:   log pseudolikelihood = -61.645428

Probit regression                                 Number of obs   =        257
                                                  Wald chi2(10)   =      80.08
                                                  Prob > chi2     =     0.0000
Log pseudolikelihood = -61.645428                 Pseudo R2       =     0.6539

------------------------------------------------------------------------------
             |               Robust
    contract |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     hgender |  -1.419593   .2897347    -4.90   0.000    -1.987463   -.8517233
        hage |   .0194478   .0143468     1.36   0.175    -.0086713     .047567
        pedu |   .1409822   .0486424     2.90   0.004     .0456448    .2363196
    plotsize |   .0078434   .0030153     2.60   0.009     .0019335    .0137533
     tfamlab |   .1627702   .2452054     0.66   0.507    -.3178236    .6433639
      inputs |  -.0011294   .0003149    -3.59   0.000    -.0017466   -.0005121
      machin |   .0008554   .0002272     3.77   0.000     .0004102    .0013007
       labex |  -.0010141   .0002919    -3.47   0.001    -.0015863    -.000442
      credit |  -.8279742   .2837117    -2.92   0.004    -1.384039   -.2719095
      groups |   1.123863   .1712455     6.56   0.000     .7882278    1.459498
       _cons |  -2.423855   1.136284    -2.13   0.033    -4.650931   -.1967791
------------------------------------------------------------------------------
Note: 1 failure and 0 successes completely determined.
```

```
. predict contractprobithat
(option pr assumed; Pr(contract))
. gen preddumprobit=1 if contractprobithat>0.5
(124 missing values generated)
. replace preddumprobit=0 if contractprobithat<0.5
(124 real changes made)
. replace preddumprobit=. if contractprobithat==.
(0 real changes made)
. tab contract preddumprobit, row col

+-------------------+
| Key               |
|-------------------|
|     frequency     |
|  row percentage   |
| column percentage |
+-------------------+

           |     preddumprobit
  contract |         0          1 |     Total
-----------+----------------------+----------
         0 |       115         15 |       130
           |     88.46      11.54 |    100.00
           |     92.74      11.28 |     50.58
-----------+----------------------+----------
         1 |         9        118 |       127
           |      7.09      92.91 |    100.00
           |      7.26      88.72 |     49.42
-----------+----------------------+----------
     Total |       124        133 |       257
           |     48.25      51.75 |    100.00
           |    100.00     100.00 |    100.00
```

Logit Model

```
. xi: logit contract hgender hage pedu plotsize tfamlab inputs machin labex credit groups,
robust

Iteration 0:   log pseudolikelihood = -178.12132
Iteration 1:   log pseudolikelihood = -65.360579
Iteration 2:   log pseudolikelihood = -62.058282
Iteration 3:   log pseudolikelihood = -61.552131
Iteration 4:   log pseudolikelihood = -61.551515
Iteration 5:   log pseudolikelihood = -61.551515

Logistic regression                               Number of obs   =        257
                                                  Wald chi2(10)   =      66.71
                                                  Prob > chi2     =     0.0000
Log pseudolikelihood = -61.551515                 Pseudo R2       =     0.6544

------------------------------------------------------------------------------
             |               Robust
    contract |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     hgender |  -2.470749   .5412525    -4.56   0.000    -3.531584   -1.409913
        hage |    .035418   .0274637     1.29   0.197      -.01841    .0892459
        pedu |   .2499007   .0908738     2.75   0.006     .0717913    .4280101
    plotsize |    .014595   .0052803     2.76   0.006     .0042459    .0249442
     tfamlab |   .3293428   .5433971     0.61   0.544    -.7356959    1.394381
      inputs |  -.0019485   .0006542    -2.98   0.003    -.0032308   -.0006663
      machin |   .0016162   .0004539     3.56   0.000     .0007267    .0025057
       labex |  -.0019159   .0005478    -3.50   0.000    -.0029896   -.0008423
      credit |   -1.43776   .5206205    -2.76   0.006    -2.458157   -.4173622
      groups |   2.061368    .340794     6.05   0.000     1.393424    2.729311
       _cons |  -4.657778    2.24577    -2.07   0.038    -9.059406   -.2561504
------------------------------------------------------------------------------

. predict contractlogithat
(option pr assumed; Pr(contract))
. gen preddumlogit=1 if contractlogithat>0.5
(124 missing values generated)
. replace preddumlogit=0 if contractlogithat<0.5
(124 real changes made)
. replace preddumlogit=. if contractlogithat==.
(0 real changes made)
. tab contract preddumlogit, row col

+-------------------+
| Key               |
|-------------------|
|     frequency     |
|  row percentage   |
| column percentage |
+-------------------+

           |     preddumlogit
  contract |         0          1 |     Total
-----------+----------------------+----------
         0 |       115         15 |       130
           |     88.46      11.54 |    100.00
           |     92.74      11.28 |     50.58
-----------+----------------------+----------
         1 |         9        118 |       127
           |      7.09      92.91 |    100.00
           |      7.26      88.72 |     49.42
-----------+----------------------+----------
     Total |       124        133 |       257
           |     48.25      51.75 |    100.00
           |    100.00     100.00 |    100.00
```

B. Effects of Contract Participation on Total Costs

```
. xi: reg totcost contract agasset plotsize tlab tnonfamlab chemuse manure , robust

Linear regression                                      Number of obs =     257
                                                       F(  7,   249) =   13.90
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.2820
                                                       Root MSE      =  909.22

------------------------------------------------------------------------------
             |               Robust
     totcost |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    contract |  -344.3893   125.6069    -2.74   0.007    -591.7767   -97.00194
     agasset |  -.0012792   .0002615    -4.89   0.000    -.0017943    -.000764
    plotsize |  -3.791876   2.424544    -1.56   0.119    -8.567104    .9833523
        tlab |  -273.1742   131.6746    -2.07   0.039    -532.5121   -13.83624
  tnonfamlab |   395.3619   131.5476     3.01   0.003     136.2742    654.4497
     chemuse |   10.37516   2.820652     3.68   0.000     4.819781    15.93054
      manure |   1.370609   .3993612     3.43   0.001     .5840519    2.157165
       _cons |    3166.74   177.7163    17.82   0.000     2816.721    3516.759
------------------------------------------------------------------------------

.
. global tcvar "agasset plotsize tlab tnonfamlab chemuse manure"

.
. global ivcvar "pedu credit"

. ivregress 2sls totcost $tcvar (contract=$ivcvar)

Instrumental variables (2SLS) regression               Number of obs =     257
                                                       Wald chi2(6)  =   80.40
                                                       Prob > chi2   =  0.0000
                                                       R-squared     =  0.2448
                                                       Root MSE      =  917.81

------------------------------------------------------------------------------
     totcost |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    contract |  -99.13786   462.1064    -0.21   0.830     -1004.85     806.574
     agasset |  -.0012426   .0002734    -4.55   0.000    -.0017784   -.0007068
    plotsize |  -3.965803   1.737326    -2.28   0.022      -7.3709   -.5607065
        tlab |   48.80721   60.97008     0.80   0.423    -70.69196    168.3064
     chemuse |   10.38272   2.581201     4.02   0.000     5.323658    15.44178
      manure |   1.347994    .358199     3.76   0.000      .645937    2.050051
       _cons |    3045.23    325.305     9.36   0.000     2407.644    3682.817
------------------------------------------------------------------------------
Instrumented:  contract
Instruments:   agasset plotsize tlab chemuse manure pedu credit

. estat endogenous

  Tests of endogeneity
  Ho: variables are exogenous

  Durbin (score) chi2(1)          =  .140047  (p = 0.7082)
  Wu-Hausman F(1,249)             =  .135762  (p = 0.7128)

. estat overid

  Tests of overidentifying restrictions:

  Sargan (score) chi2(1) =  4.02428  (p = 0.0448)
  Basmann chi2(1)        =  3.96103  (p = 0.0466)
```

C. Effects of Contract Participation on Income

```
. xi: reg cassin contract hage hedu plotsize chemuse totcost, robust

Linear regression                                      Number of obs =     257
                                                       F(  6,   250) =   18.67
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.2419
                                                       Root MSE      =  3049.5

------------------------------------------------------------------------------
             |               Robust
      cassin |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    contract |   1996.258    418.472     4.77   0.000     1172.078    2820.438
        hage |   42.27613   21.73336     1.95   0.053    -.5276913    85.07995
        hedu |   136.5399   71.46686     1.91   0.057    -4.213935    277.2938
    plotsize |   19.06081   3.093405     6.16   0.000     12.96835    25.15326
     chemuse |  -28.98923   7.950705    -3.65   0.000    -44.64813   -13.33033
     totcost |   .7427973   .2114769     3.51   0.001     .3262939    1.159301
       _cons |   4993.038    1558.07     3.20   0.002     1924.421    8061.655
------------------------------------------------------------------------------

.
. global ivar "hage hedu plotsize chemuse totcost"

. global ivcvar "pedu groups"
.
. ivregress 2sls cassin $ivar (contract=$ivcvar)

Instrumental variables (2SLS) regression               Number of obs =     257
                                                       Wald chi2(6)  =   67.61
                                                       Prob > chi2   =  0.0000
                                                       R-squared     =  0.2416
                                                       Root MSE      =  3008.3

------------------------------------------------------------------------------
      cassin |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    contract |   2125.439   642.4855     3.31   0.001     866.1902    3384.687
        hage |    41.9753   19.84796     2.11   0.034     3.074002    80.87659
        hedu |   133.6023   65.16578     2.05   0.040     5.879668    261.3248
    plotsize |   18.85602   4.866743     3.87   0.000     9.317374    28.39466
     chemuse |  -28.55563   6.948114    -4.11   0.000    -42.17368   -14.93758
     totcost |   .7509255   .1936249     3.88   0.000     .3714275    1.130423
       _cons |   4929.146   1404.163     3.51   0.000     2177.038    7681.254
------------------------------------------------------------------------------
Instrumented:  contract
Instruments:   hage hedu plotsize chemuse totcost pedu groups

. estat endogenous

  Tests of endogeneity
  Ho: variables are exogenous

  Durbin (score) chi2(1)          =  .065383  (p = 0.7982)
  Wu-Hausman F(1,249)             =  .063364  (p = 0.8015)

. estat overid

  Tests of overidentifying restrictions:

  Sargan (score) chi2(1) =  1.95499  (p = 0.1621)
  Basmann chi2(1)        =  1.90865  (p = 0.1671)
```

D. Effects of Contract Participation on Farm Gross Margins

```
. xi: reg gross contract hage hedu plotsize chemuse totcost, robust

Linear regression                                      Number of obs =     257
                                                       F(  6,   250) =   12.33
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.1674
                                                       Root MSE      =  3455.3

------------------------------------------------------------------------------
             |               Robust
       gross |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    contract |   917.5577   473.4059     1.94   0.054    -14.81449     1849.93
        hage |    59.2826   23.56398     2.52   0.013     12.87338    105.6918
        hedu |   168.2911   77.72951     2.17   0.031     15.20297    321.3792
    plotsize |   20.25762    3.26981     6.20   0.000     13.81773     26.6975
     chemuse |  -33.48779   8.091173    -4.14   0.000    -49.42335   -17.55224
     totcost |   .1978651   .2282995     0.87   0.387    -.2517704    .6475006
       _cons |   4596.518   1602.712     2.87   0.004     1439.979    7753.056
------------------------------------------------------------------------------

.
. global gvar "hage hedu plotsize chemuse totcost"

.
. global ivcvar "pedu groups"

.
. ivregress 2sls gross $gvar (contract=$ivcvar)

Instrumental variables (2SLS) regression               Number of obs =     257
                                                       Wald chi2(6)  =   51.99
                                                       Prob > chi2   =  0.0000
                                                       R-squared     =  0.1594
                                                       Root MSE      =  3424.2

------------------------------------------------------------------------------
       gross |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    contract |   1624.029   731.3185     2.22   0.026     190.6707    3057.386
        hage |   57.63737   22.59223     2.55   0.011     13.35741    101.9173
        hedu |   152.2254    74.1759     2.05   0.040     6.843338    297.6075
    plotsize |   19.13764   5.539642     3.45   0.001     8.280141    29.99514
     chemuse |  -31.11652   7.908792    -3.93   0.000    -46.61746   -15.61557
     totcost |   .2423167   .2203964     1.10   0.272    -.1896523    .6742858
       _cons |   4247.101   1598.309     2.66   0.008     1114.474    7379.728
------------------------------------------------------------------------------
Instrumented:  contract
Instruments:   hage hedu plotsize chemuse totcost pedu groups

.
. estat endogenous

  Tests of endogeneity
  Ho: variables are exogenous

  Durbin (score) chi2(1)          =  1.52315  (p = 0.2171)
  Wu-Hausman F(1,249)             =  1.48454  (p = 0.2242)

.
. estat overid

  Tests of overidentifying restrictions:

  Sargan (score) chi2(1) =  3.03615  (p = 0.0814)
  Basmann chi2(1)        =  2.97681  (p = 0.0845)
```

E. Effects of Contract Participation on Employment

Effects of Contract Participation on Total Labour

```
. xi: reg tlab contract agasset plotsize machin  groups, robust

Linear regression                                      Number of obs =     257
                                                       F(  5,   251) =   14.27
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.2636
                                                       Root MSE      =  .98758

------------------------------------------------------------------------------
             |               Robust
        tlab |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    contract |   .2302707   .1916843     1.20   0.231    -.1472439    .6077853
     agasset |  -8.05e-07   2.51e-07    -3.20   0.002    -1.30e-06   -3.10e-07
    plotsize |  -.0095138   .0023295    -4.08   0.000    -.0141015    -.004926
      machin |  -.0005651   .0000847    -6.68   0.000    -.0007319   -.0003984
      groups |  -.2405947   .0874581    -2.75   0.006    -.4128399   -.0683496
       _cons |   2.715393    .211734    12.82   0.000     2.298391    3.132394
------------------------------------------------------------------------------

.
. global lvar "agasset plotsize machin groups"

.
. global ivcvarlab "pedu hgender"

.
. ivregress 2sls tlab $lvar (contract=$ivcvarlab)

Instrumental variables (2SLS) regression               Number of obs =     257
                                                       Wald chi2(5)  =   90.50
                                                       Prob > chi2   =  0.0000
                                                       R-squared     =  0.2574
                                                       Root MSE      =   .9801

------------------------------------------------------------------------------
        tlab |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    contract |   .4736418   .4332028     1.09   0.274      -.37542    1.322704
     agasset |  -8.17e-07   2.95e-07    -2.77   0.006    -1.40e-06   -2.38e-07
    plotsize |  -.0098182   .0016984    -5.78   0.000    -.0131469   -.0064895
      machin |  -.0006102   .0001167    -5.23   0.000    -.0008389   -.0003815
      groups |  -.3027049   .1223356    -2.47   0.013    -.5424782   -.0629316
       _cons |   2.767524   .1987876    13.92   0.000     2.377908    3.157141
------------------------------------------------------------------------------
Instrumented:  contract
Instruments:   agasset plotsize machin groups pedu hgender

.
. estat endogenous

  Tests of endogeneity
  Ho: variables are exogenous

  Durbin (score) chi2(1)          =  .372874  (p = 0.5414)
  Wu-Hausman F(1,250)             =  .363245  (p = 0.5473)

.
. estat overid

  Tests of overidentifying restrictions:

  Sargan (score) chi2(1) =  .355685  (p = 0.5509)
  Basmann chi2(1)        =  .346477  (p = 0.5561)
```

F. Effects of Contract Participation on Outcomes using Propensity Score Matching

```
. psmatch2 contract hgender hage pedu plotsize tfamlab inputs machin labex credit groups,
outcome(totcost) logit neighbor(1)
>  ate common

Logistic regression                               Number of obs   =        257
                                                  LR chi2(10)     =     233.14
                                                  Prob > chi2     =     0.0000
Log likelihood = -61.551515                       Pseudo R2       =     0.6544

==============================================================================
    contract |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     hgender |  -2.470749   .6000042    -4.12   0.000    -3.646736   -1.294762
        hage |    .035418   .0246319     1.44   0.150    -.0128596    .0836955
        pedu |   .2499007    .096445     2.59   0.010      .060872    .4389294
    plotsize |    .014595   .0077607     1.88   0.060    -.0006157    .0298058
     tfamlab |   .3293428   .6115449     0.54   0.590    -.8692632    1.527949
      inputs |  -.0019485   .0005734    -3.40   0.001    -.0030724   -.0008246
      machin |   .0016162   .0004189     3.86   0.000     .0007952    .0024373
       labex |  -.0019159   .0006226    -3.08   0.002    -.0031362   -.0006957
      credit |   -1.43776   .5953221    -2.42   0.016     -2.60457   -.2709497
      groups |   2.061368    .340781     6.05   0.000     1.393449    2.729286
       _cons |  -4.657778   2.010428    -2.32   0.021    -8.598146   -.7174109
------------------------------------------------------------------------------
---------------------------------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
----------------------------+----------------------------------------------------------
         totcost  Unmatched | 3063.92961   3487.52869  -423.599083    129.59968    -3.27
                        ATT | 3136.94682   3028.89681   108.050013   372.390854     0.29
                        ATU | 3121.66475   3132.23166   10.5669085            .        .
                        ATE |                          68.1408224            .        .
----------------------------+----------------------------------------------------------
Note: S.E. does not take into account that the propensity score is estimated.

 psmatch2: |   psmatch2: Common
 Treatment |        support
assignment | Off suppo  On suppor |     Total
-----------+----------------------+----------
 Untreated |        69         61 |       130
   Treated |        39         88 |       127
-----------+----------------------+----------
     Total |       108        149 |       257
```

Effects of Contract Participation on Non-Family Labour

```
. xi: reg tnonfamlab contract agasset plotsize machin  groups, robust

Linear regression                                      Number of obs =     257
                                                       F(  5,   251) =   16.09
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.1461
                                                       Root MSE      =  .93211

------------------------------------------------------------------------------
             |               Robust
  tnonfamlab |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    contract |   .3666458   .1824832     2.01   0.046     .0072524    .7260393
     agasset |  -4.95e-07   2.19e-07    -2.26   0.025    -9.26e-07   -6.37e-08
    plotsize |  -.0068517   .0015502    -4.42   0.000    -.0099048   -.0037986
      machin |  -.0003229   .0000745    -4.33   0.000    -.0004697   -.0001761
      groups |  -.2010337   .0840053    -2.39   0.017    -.3664788   -.0355886
       _cons |   1.877431   .1894758     9.91   0.000     1.504266    2.250596
------------------------------------------------------------------------------

.
. global nflabvar "agasset plotsize machin groups"

.
. global ivcvarnflab "pedu hgender"

.
. ivregress 2sls tnonfamlab $nflabvar (contract=$ivcvarnflab)

Instrumental variables (2SLS) regression               Number of obs =     257
                                                       Wald chi2(5)  =   40.72
                                                       Prob > chi2   =  0.0000
                                                       R-squared     =  0.1292
                                                       Root MSE      =  .93021

==============================================================================
  tnonfamlab |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    contract |   .7174607   .4111494     1.75   0.081    -.0883772    1.523299
     agasset |  -5.12e-07   2.80e-07    -1.83   0.068    -1.06e-06    3.74e-08
    plotsize |  -.0072905   .0016119    -4.52   0.000    -.0104498   -.0041313
      machin |  -.0003879   .0001107    -3.50   0.000    -.0006049   -.0001708
      groups |  -.2905644   .1161077    -2.50   0.012    -.5181314   -.0629974
       _cons |   1.952579   .1886677    10.35   0.000     1.582797     2.32236
------------------------------------------------------------------------------
Instrumented:  contract
Instruments:   agasset plotsize machin groups pedu hgender

.
. estat endogenous

  Tests of endogeneity
  Ho: variables are exogenous

  Durbin (score) chi2(1)          =  .869743  (p = 0.3510)
  Wu-Hausman F(1,250)             =  .848926  (p = 0.3577)

.
. estat overid

  Tests of overidentifying restrictions:

  Sargan (score) chi2(1) =  1.24344  (p = 0.2648)
  Basmann chi2(1)        =  1.21545  (p = 0.2703)
```

F. Effects of Contract Participation on Outcomes using Propensity Score Matching

```
. psmatch2 contract hgender hage pedu plotsize tfamlab inputs machin labex credit groups,
outcome(totcost) logit neighbor(1)
>  ate common

Logistic regression                               Number of obs   =        257
                                                  LR chi2(10)     =     233.14
                                                  Prob > chi2     =     0.0000
Log likelihood = -61.551515                       Pseudo R2       =     0.6544

------------------------------------------------------------------------------
    contract |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     hgender |  -2.470749   .6000042    -4.12   0.000    -3.646736   -1.294762
        hage |    .035418   .0246319     1.44   0.150    -.0128596    .0836955
        pedu |   .2499007    .096445     2.59   0.010      .060872    .4389294
    plotsize |    .014595   .0077607     1.88   0.060    -.0006157    .0298058
     tfamlab |   .3293428   .6115449     0.54   0.590    -.8692632    1.527949
      inputs |  -.0019485   .0005734    -3.40   0.001    -.0030724   -.0008246
      machin |   .0016162   .0004189     3.86   0.000     .0007952    .0024373
       labex |  -.0019159   .0006226    -3.08   0.002    -.0031362   -.0006957
      credit |   -1.43776   .5953221    -2.42   0.016     -2.60457   -.2709497
      groups |   2.061368    .340781     6.05   0.000     1.393449    2.729286
       _cons |  -4.657778   2.010428    -2.32   0.021    -8.598146   -.7174109
------------------------------------------------------------------------------
----------------------------------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
----------------------------+-----------------------------------------------------------
         totcost  Unmatched | 3063.92961   3487.52869  -423.599083    129.59968    -3.27
                        ATT | 3136.94682   3028.89681   108.050013   372.390854     0.29
                        ATU | 3121.66475   3132.23166   10.5669085            .        .
                        ATE |                           68.1408224            .        .
----------------------------+-----------------------------------------------------------
Note: S.E. does not take into account that the propensity score is estimated.

 psmatch2: |   psmatch2: Common
 Treatment |        support
assignment | Off suppo  On suppor |     Total
-----------+----------------------+----------
 Untreated |        69         61 |       130
   Treated |        39         88 |       127
-----------+----------------------+----------
     Total |       108        149 |       257
```

```
. psmatch2 contract hgender hage pedu plotsize tfamlab inputs machin labex credit groups,
outcome(totcost) logit kernel kern
> eltype(epan) ate common

Logistic regression                               Number of obs   =        257
                                                  LR chi2(10)     =     233.14
                                                  Prob > chi2     =     0.0000
Log likelihood = -61.551515                       Pseudo R2       =     0.6544

------------------------------------------------------------------------------
    contract |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     hgender |  -2.470749   .6000042    -4.12   0.000    -3.646736   -1.294762
        hage |    .035418   .0246319     1.44   0.150    -.0128596    .0836955
        pedu |   .2499007    .096445     2.59   0.010      .060872    .4389294
    plotsize |    .014595   .0077607     1.88   0.060    -.0006157    .0298058
     tfamlab |   .3293428   .6115449     0.54   0.590    -.8692632    1.527949
      inputs |  -.0019485   .0005734    -3.40   0.001    -.0030724   -.0008246
      machin |   .0016162   .0004189     3.86   0.000     .0007952    .0024373
       labex |  -.0019159   .0006226    -3.08   0.002    -.0031362   -.0006957
      credit |   -1.43776   .5953221    -2.42   0.016     -2.60457   -.2709497
      groups |   2.061368    .340781     6.05   0.000     1.393449    2.729286
       _cons |  -4.657778   2.010428    -2.32   0.021    -8.598146   -.7174109
------------------------------------------------------------------------------
----------------------------------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
----------------------------+-----------------------------------------------------------
         totcost  Unmatched | 3063.92961   3487.52869 -423.599083    129.59968    -3.27
                        ATT | 3136.94682   3143.53909 -6.59227208    309.601194    -0.02
                        ATU | 3101.67789   3101.96928   .2913873             .        .
                        ATE |                         -3.88628184             .        .
----------------------------+-----------------------------------------------------------
Note: S.E. does not take into account that the propensity score is estimated.

 psmatch2: |   psmatch2: Common
 Treatment |        support
assignment | Off suppo  On suppor |     Total
-----------+----------------------+----------
 Untreated |        73         57 |       130
   Treated |        39         88 |       127
-----------+----------------------+----------
     Total |       112        145 |       257
```

```
. psmatch2 contract hgender hage pedu plotsize tfamlab inputs machin labex credit groups,
outcome(cassin) logit neighbor(1)
> ate common

Logistic regression                               Number of obs   =        257
                                                  LR chi2(10)     =     233.14
                                                  Prob > chi2     =     0.0000
Log likelihood = -61.551515                       Pseudo R2       =     0.6544

------------------------------------------------------------------------------
    contract |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     hgender |  -2.470749   .6000042    -4.12   0.000    -3.646736   -1.294762
        hage |    .035418   .0246319     1.44   0.150    -.0128596    .0836955
        pedu |   .2499007    .096445     2.59   0.010      .060872    .4389294
    plotsize |    .014595   .0077607     1.88   0.060    -.0006157    .0298058
     tfamlab |   .3293428   .6115449     0.54   0.590    -.8692632    1.527949
      inputs |  -.0019485   .0005734    -3.40   0.001    -.0030724   -.0008246
      machin |   .0016162   .0004189     3.86   0.000     .0007952    .0024373
       labex |  -.0019159   .0006226    -3.08   0.002    -.0031362   -.0006957
      credit |   -1.43776   .5953221    -2.42   0.016     -2.60457   -.2709497
      groups |   2.061368    .340781     6.05   0.000     1.393449    2.729286
       _cons |  -4.657778   2.010428    -2.32   0.021    -8.598146   -.7174109
------------------------------------------------------------------------------
----------------------------------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
----------------------------+-----------------------------------------------------------
          cassin  Unmatched | 12230.8268   9860.40831   2370.41846   406.408136     5.83
                        ATT | 12071.1648   8132.44955   3938.71523   1338.98999     2.94
                        ATU | 10568.9939   11506.3934   937.399502            .        .
                        ATE |                           2709.98865            .        .
----------------------------+-----------------------------------------------------------
Note: S.E. does not take into account that the propensity score is estimated.

 psmatch2: |   psmatch2: Common
 Treatment |        support
assignment | Off suppo  On suppor |     Total
-----------+----------------------+----------
 Untreated |        69         61 |       130
   Treated |        39         88 |       127
-----------+----------------------+----------
     Total |       108        149 |       257
```

```
. psmatch2 contract hgender hage pedu plotsize tfamlab inputs machin labex credit groups,
outcome(cassin) logit kernel kerne
> ltype(epan) ate common

Logistic regression                               Number of obs   =        257
                                                  LR chi2(10)     =     233.14
                                                  Prob > chi2     =     0.0000
Log likelihood = -61.551515                       Pseudo R2       =     0.6544

------------------------------------------------------------------------------
    contract |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     hgender |  -2.470749   .6000042    -4.12   0.000    -3.646736   -1.294762
        hage |    .035418   .0246319     1.44   0.150    -.0128596    .0836955
        pedu |   .2499007    .096445     2.59   0.010      .060872    .4389294
    plotsize |    .014595   .0077607     1.88   0.060    -.0006157    .0298058
     tfamlab |   .3293428   .6115449     0.54   0.590    -.8692632    1.527949
      inputs |  -.0019485   .0005734    -3.40   0.001    -.0030724   -.0008246
      machin |   .0016162   .0004189     3.86   0.000     .0007952    .0024373
       labex |  -.0019159   .0006226    -3.08   0.002    -.0031362   -.0006957
      credit |   -1.43776   .5953221    -2.42   0.016     -2.60457   -.2709497
      groups |   2.061368    .340781     6.05   0.000     1.393449    2.729286
       _cons |  -4.657778   2.010428    -2.32   0.021    -8.598146   -.7174109
------------------------------------------------------------------------------
----------------------------------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
----------------------------+-----------------------------------------------------------
          cassin  Unmatched | 12230.8268   9860.40831   2370.41846   406.408136     5.83
                        ATT | 12071.1648   8072.24987   3998.91491   1358.44735     2.94
                        ATU |  10548.397   11239.7237   691.326671            .        .
                        ATE |                           2698.69057            .        .
----------------------------+-----------------------------------------------------------
Note: S.E. does not take into account that the propensity score is estimated.

 psmatch2: |   psmatch2: Common
 Treatment |        support
assignment | Off suppo  On suppor |     Total
-----------+----------------------+----------
 Untreated |        73         57 |       130
   Treated |        39         88 |       127
-----------+----------------------+----------
     Total |       112        145 |       257
```

```
. psmatch2 contract hgender hage pedu plotsize tfamlab inputs machin labex credit groups,
outcome(gross) logit neighbor(1) a
> te common

Logistic regression                               Number of obs   =        257
                                                  LR chi2(10)     =     233.14
                                                  Prob > chi2     =     0.0000
Log likelihood = -61.551515                       Pseudo R2       =     0.6544

------------------------------------------------------------------------------
    contract |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     hgender |  -2.470749   .6000042    -4.12   0.000    -3.646736   -1.294762
        hage |    .035418   .0246319     1.44   0.150    -.0128596    .0836955
        pedu |   .2499007    .096445     2.59   0.010      .060872    .4389294
    plotsize |    .014595   .0077607     1.88   0.060    -.0006157    .0298058
     tfamlab |   .3293428   .6115449     0.54   0.590    -.8692632    1.527949
      inputs |  -.0019485   .0005734    -3.40   0.001    -.0030724   -.0008246
      machin |   .0016162   .0004189     3.86   0.000     .0007952    .0024373
       labex |  -.0019159   .0006226    -3.08   0.002    -.0031362   -.0006957
      credit |   -1.43776   .5953221    -2.42   0.016     -2.60457   -.2709497
      groups |   2.061368    .340781     6.05   0.000     1.393449    2.729286
       _cons |  -4.657778   2.010428    -2.32   0.021    -8.598146   -.7174109
------------------------------------------------------------------------------
----------------------------------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
----------------------------+-----------------------------------------------------------
           gross  Unmatched | 10068.5032   8453.33448   1615.16873   456.735556     3.54
                        ATT | 9874.75283   6805.21636   3069.53647   1759.00459     1.75
                        ATU | 9742.83063   9432.52039  -310.310239            .        .
                        ATE |                           1685.84084            .        .
----------------------------+-----------------------------------------------------------
Note: S.E. does not take into account that the propensity score is estimated.

 psmatch2: |   psmatch2: Common
 Treatment |        support
assignment | Off suppo  On suppor |     Total
-----------+----------------------+----------
 Untreated |        69         61 |       130
   Treated |        39         88 |       127
-----------+----------------------+----------
     Total |       108        149 |       257
```

```
. psmatch2 contract hgender hage pedu plotsize tfamlab inputs machin labex credit groups,
outcome(gross) logit kernel kernel
> type(epan) ate common

Logistic regression                               Number of obs   =        257
                                                  LR chi2(10)     =     233.14
                                                  Prob > chi2     =     0.0000
Log likelihood = -61.551515                       Pseudo R2       =     0.6544

------------------------------------------------------------------------------
    contract |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     hgender |  -2.470749   .6000042    -4.12   0.000    -3.646736   -1.294762
        hage |    .035418   .0246319     1.44   0.150    -.0128596    .0836955
        pedu |   .2499007    .096445     2.59   0.010      .060872    .4389294
    plotsize |    .014595   .0077607     1.88   0.060    -.0006157    .0298058
     tfamlab |   .3293428   .6115449     0.54   0.590    -.8692632    1.527949
      inputs |  -.0019485   .0005734    -3.40   0.001    -.0030724   -.0008246
      machin |   .0016162   .0004189     3.86   0.000     .0007952    .0024373
       labex |  -.0019159   .0006226    -3.08   0.002    -.0031362   -.0006957
      credit |   -1.43776   .5953221    -2.42   0.016     -2.60457   -.2709497
      groups |   2.061368    .340781     6.05   0.000     1.393449    2.729286
       _cons |  -4.657778   2.010428    -2.32   0.021    -8.598146   -.7174109
------------------------------------------------------------------------------
----------------------------------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
----------------------------+-----------------------------------------------------------
           gross  Unmatched | 10068.5032   8453.33448   1615.16873   456.735556     3.54
                        ATT | 9874.75283   7038.41913    2836.3337   1590.25086     1.78
                        ATU | 9793.03189   9134.01187  -659.020016            .        .
                        ATE |                            1462.2981            .        .
----------------------------+-----------------------------------------------------------
Note: S.E. does not take into account that the propensity score is estimated.

 psmatch2: |   psmatch2: Common
 Treatment |        support
assignment | Off suppo  On suppor |     Total
-----------+----------------------+----------
 Untreated |        73         57 |       130
   Treated |        39         88 |       127
-----------+----------------------+----------
     Total |       112        145 |       257
```

```
. psmatch2 contract hgender hage pedu plotsize tfamlab inputs machin labex credit groups,
outcome(tlab) logit neighbor(1) at
> e common

Logistic regression                               Number of obs   =        257
                                                  LR chi2(10)     =     233.14
                                                  Prob > chi2     =     0.0000
Log likelihood = -61.551515                       Pseudo R2       =     0.6544

------------------------------------------------------------------------------
    contract |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     hgender |  -2.470749   .6000042    -4.12   0.000    -3.646736   -1.294762
        hage |    .035418   .0246319     1.44   0.150    -.0128596    .0836955
        pedu |   .2499007    .096445     2.59   0.010      .060872    .4389294
    plotsize |    .014595   .0077607     1.88   0.060    -.0006157    .0298058
     tfamlab |   .3293428   .6115449     0.54   0.590    -.8692632    1.527949
      inputs |  -.0019485   .0005734    -3.40   0.001    -.0030724   -.0008246
      machin |   .0016162   .0004189     3.86   0.000     .0007952    .0024373
       labex |  -.0019159   .0006226    -3.08   0.002    -.0031362   -.0006957
      credit |   -1.43776   .5953221    -2.42   0.016     -2.60457   -.2709497
      groups |   2.061368    .340781     6.05   0.000     1.393449    2.729286
       _cons |  -4.657778   2.010428    -2.32   0.021    -8.598146   -.7174109
------------------------------------------------------------------------------
----------------------------------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
----------------------------+-----------------------------------------------------------
            tlab  Unmatched | 1.03582677   1.47007693  -.434250156   .139835966    -3.11
                        ATT | 1.10704545   .195113634   .911931821   .259455193     3.51
                        ATU | .993278685    1.7167213   .723442611            .        .
                        ATE |                           .834765097            .        .
----------------------------+-----------------------------------------------------------
Note: S.E. does not take into account that the propensity score is estimated.

 psmatch2: |   psmatch2: Common
 Treatment |        support
assignment | Off suppo  On suppor |     Total
-----------+----------------------+----------
 Untreated |        69         61 |       130
   Treated |        39         88 |       127
-----------+----------------------+----------
     Total |       108        149 |       257
```

```
. psmatch2 contract hgender hage pedu plotsize tfamlab inputs machin labex credit groups,
outcome(tlab) logit kernel kernelt
> ype(epan) ate common

Logistic regression                               Number of obs   =        257
                                                  LR chi2(10)     =     233.14
                                                  Prob > chi2     =     0.0000
Log likelihood = -61.551515                       Pseudo R2       =     0.6544

------------------------------------------------------------------------------
    contract |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     hgender |  -2.470749   .6000042    -4.12   0.000    -3.646736   -1.294762
        hage |    .035418   .0246319     1.44   0.150    -.0128596    .0836955
        pedu |   .2499007    .096445     2.59   0.010      .060872    .4389294
    plotsize |    .014595   .0077607     1.88   0.060    -.0006157    .0298058
     tfamlab |   .3293428   .6115449     0.54   0.590    -.8692632    1.527949
      inputs |  -.0019485   .0005734    -3.40   0.001    -.0030724   -.0008246
      machin |   .0016162   .0004189     3.86   0.000     .0007952    .0024373
       labex |  -.0019159   .0006226    -3.08   0.002    -.0031362   -.0006957
      credit |   -1.43776   .5953221    -2.42   0.016     -2.60457   -.2709497
      groups |   2.061368    .340781     6.05   0.000     1.393449    2.729286
       _cons |  -4.657778   2.010428    -2.32   0.021    -8.598146   -.7174109
------------------------------------------------------------------------------
----------------------------------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
----------------------------+-----------------------------------------------------------
            tlab  Unmatched | 1.03582677   1.47007693  -.434250156   .139835966    -3.11
                        ATT | 1.10704545   .220734749   .886310706   .453330341     1.96
                        ATU | 1.03614035   1.61246208   .576321732            .        .
                        ATE |                           .764452972            .        .
----------------------------+-----------------------------------------------------------
Note: S.E. does not take into account that the propensity score is estimated.

 psmatch2: |   psmatch2: Common
 Treatment |        support
assignment | Off suppo  On suppor |     Total
-----------+----------------------+----------
 Untreated |        73         57 |       130
   Treated |        39         88 |       127
-----------+----------------------+----------
     Total |       112        145 |       257

.
```

```
. psmatch2 contract hgender hage pedu plotsize tfamlab inputs machin labex credit groups,
outcome(tnonfamlab) logit neighbor
> (1) ate common

Logistic regression                               Number of obs   =        257
                                                  LR chi2(10)     =     233.14
                                                  Prob > chi2     =     0.0000
Log likelihood = -61.551515                       Pseudo R2       =     0.6544

------------------------------------------------------------------------------
    contract |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     hgender |  -2.470749   .6000042    -4.12   0.000    -3.646736   -1.294762
        hage |    .035418   .0246319     1.44   0.150    -.0128596    .0836955
        pedu |   .2499007    .096445     2.59   0.010      .060872    .4389294
    plotsize |    .014595   .0077607     1.88   0.060    -.0006157    .0298058
     tfamlab |   .3293428   .6115449     0.54   0.590    -.8692632    1.527949
      inputs |  -.0019485   .0005734    -3.40   0.001    -.0030724   -.0008246
      machin |   .0016162   .0004189     3.86   0.000     .0007952    .0024373
       labex |  -.0019159   .0006226    -3.08   0.002    -.0031362   -.0006957
      credit |   -1.43776   .5953221    -2.42   0.016     -2.60457   -.2709497
      groups |   2.061368    .340781     6.05   0.000     1.393449    2.729286
       _cons |  -4.657778   2.010428    -2.32   0.021    -8.598146   -.7174109
------------------------------------------------------------------------------
----------------------------------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
----------------------------+-----------------------------------------------------------
      tnonfamlab  Unmatched | .951653544   1.07392308   -.12226954   .124622969    -0.98
                        ATT | .993181818   .056931818       .93625     .2284744     4.10
                        ATU | .647540985   1.47475409   .827213107            .        .
                        ATE |                           .891610735            .        .
----------------------------+-----------------------------------------------------------
Note: S.E. does not take into account that the propensity score is estimated.

 psmatch2: |   psmatch2: Common
 Treatment |        support
assignment | Off suppo  On suppor |     Total
-----------+----------------------+----------
 Untreated |        69         61 |       130
   Treated |        39         88 |       127
-----------+----------------------+----------
     Total |       108        149 |       257
```

```
. psmatch2 contract hgender hage pedu plotsize tfamlab inputs machin labex credit groups,
outcome(tnonfamlab) logit kernel k
> erneltype(epan) ate common

Logistic regression                               Number of obs   =        257
                                                  LR chi2(10)     =     233.14
                                                  Prob > chi2     =     0.0000
Log likelihood = -61.551515                       Pseudo R2       =     0.6544

------------------------------------------------------------------------------
    contract |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     hgender |  -2.470749   .6000042    -4.12   0.000    -3.646736   -1.294762
        hage |    .035418   .0246319     1.44   0.150    -.0128596    .0836955
        pedu |   .2499007    .096445     2.59   0.010      .060872    .4389294
    plotsize |    .014595   .0077607     1.88   0.060    -.0006157    .0298058
     tfamlab |   .3293428   .6115449     0.54   0.590    -.8692632    1.527949
      inputs |  -.0019485   .0005734    -3.40   0.001    -.0030724   -.0008246
      machin |   .0016162   .0004189     3.86   0.000     .0007952    .0024373
       labex |  -.0019159   .0006226    -3.08   0.002    -.0031362   -.0006957
      credit |   -1.43776   .5953221    -2.42   0.016     -2.60457   -.2709497
      groups |   2.061368    .340781     6.05   0.000     1.393449    2.729286
       _cons |  -4.657778   2.010428    -2.32   0.021    -8.598146   -.7174109
------------------------------------------------------------------------------
----------------------------------------------------------------------------------------
        Variable     Sample |    Treated     Controls   Difference         S.E.   T-stat
----------------------------+-----------------------------------------------------------
      tnonfamlab  Unmatched | .951653544   1.07392308   -.12226954   .124622969    -0.98
                        ATT | .993181818   .108635012   .884546806   .375782059     2.35
                        ATU | .671052633    1.2823249   .611272269            .        .
                        ATE |                           .777121643            .        .
----------------------------+-----------------------------------------------------------
Note: S.E. does not take into account that the propensity score is estimated.

 psmatch2: |   psmatch2: Common
 Treatment |        support
assignment | Off suppo  On suppor |     Total
-----------+----------------------+----------
 Untreated |        73         57 |       130
   Treated |        39         88 |       127
-----------+----------------------+----------
     Total |       112        145 |       257
```