CHAPTER 9

R&D and Performance of the Thai Agriculture and Food Processing Industry: The Role of Government, Agribusiness Firms, and Farmers

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1. Introduction

Thailand is the world's thirteenth-largest exporter of agricultural products and food, with a market share of 2.2 percent of world food exports (**figure 1.1**). It is the largest exporter of rice, rubber, cassava, shrimp, and canned tuna. It is also one of the major exporters of sugar, canned pineapple, chicken, fruits and vegetables, and animal feeds. Between 1988 and 2010, the annual growth rates of agricultural and food exports were impressive, averaging 10.5 percent, and 12.2 percent, respectively. There is no doubt that this high export growth is due to Thailand's huge comparative advantage in agriculture. There are also other important factors on the demand and supply sides that affect export growth. This paper will emphasize one of the most important supply side factors—technology—because it is the most significant source of long-term growth in output, which does not only contribute to export growth but also to the low cost of living.

The Thai agriculture and food processing industry has undergone rapid transformation and modernization in the last three decades. The exhaustion of the land frontier in the 1980s, the labor shortage, and the overvaluation of the Thai baht caused by the industrial and financial booms in the 1986—96 periods used to be the major concerns of economists and policy

makers. Yet Thai agriculture has, time and again, escaped malaise and managed to stay resilient and grow quite well. Farmers and agribusiness firms have responded to the opportunities and shocks that caused changes in relative output and input prices in several ways. The government has also changed its policies in response to the malaise in the agriculture sector. In fact, during the period of rapid economic growth in 1980—95, agriculture was the only sector that posted positive growth in total factor productivity (TFP). As a result, the annual growth rate of agricultural GDP averaged 3.4 percent between 1960 and 2009. This study will explain the sources of productivity growth in Thai agriculture, emphasizing the role of public research and technology.

Food manufacturers and exporters have also played important roles behind the structural transformation. Thai food exporters began experiencing a series of crises in the early 1990s, starting with the increase in nontariff barriers imposed by developed and developing countries; the depletion of fish stocks in the Gulf of Siam; environmental degradation, particularly water pollution and the destruction of mangrove forests; and the bird flu outbreak. Most agribusiness firms, with government support, successfully adjusted their production and marketing strategies towards food safety. As a result, Thailand has been able to maintain its position as one of the world's largest exporters of agricultural products and food for decades. This study wants to explain the performance of the Thai food processing, its sources of growth, and the role of agribusiness firms in research and development (R&D).

However, both the agricultural and food processing sectors are now facing a new set of internal constraints and external challenges, one of which is the decline in investment in agricultural R&D that started in the mid-1990s. In response to this, several public agencies that focus on funding agricultural research have begun to commission policy research to tackle the problems. This study will identify a few major challenging issues in public research and discuss some implications for R&D policy.

After a brief discussion of the performance of Thai agriculture and the food processing industry, the paper will explain the importance of technology in this industry, the trend in agricultural R&D as well as the role of the government, farmers, and agribusiness firms in R&D. Some critical problems in agricultural R&D investments will then be analyzed.

Finally, the paper will discuss some major challenges facing the Thai agriculture and food processing industry as well as some policy implications of investment in R&D.

2. Performance, Structural Change, and Modernization of the Thai Agriculture and Food Processing Industry

Thai agriculture grew at moderate to high rates of 3.4 percent per year over the last fifty-three years (**table 2.1**) despite the agricultural malaise that caused the boom-bust cycles. Exports of agricultural products and food also grew impressively as has already been mentioned. This part will explain the performance, structural change, and modernization of the Thai agriculture and food processing industry, emphasizing the investment and technology in the industry.

2.1 Growth and Structural Change of Thai Agriculture

There are two important growth trends in Thai agriculture. The first is that the growth rate in agricultural value added is declining (except for the crop subsector). The second is that Thai agriculture has exhibited a boom-and-bust pattern (**table 2.1 and figure 2.1**). The decline began in the mid-1980s and continued in the early 1990s when the Thai economy experienced an industrial boom followed by the asset-price bubble. When the economic crisis broke out in 1998, the gross domestic product (GDP) for the agriculture sector suffered negative growth due to the sharp fall in the world prices of agricultural products and the drought, which more than offset the gains from the currency depreciation. After the crisis, agricultural output rebounded and grew impressively, thanks to the low exchange rates and the higher world prices of food starting 2006. Over the 1998—2009 period, the real value added for fishery grew at 3.54 percent per annum, livestock at 3.1 percent per annum, and crops at 2.8 percent per annum.

The decline in agricultural growth rates together with the faster growth of the nonagricultural sector resulted in the declining share of agriculture in real GDP. However, the recent boom in world commodity prices has stimulated the growth of agricultural output relative to that of

the nonagricultural output. As a consequence, the share of agriculture in GDP has stabilized at 10 percent to 11 percent.

The structural change in Thai agriculture can be discerned from the changes in the share of agricultural subsectors (i.e., crops, livestock, fishery, and forestry) and the share of products within each subsector. As shown in **figure 2.2**, the share of crops in agricultural value added dropped by almost 10 percent between the 1970s and the early 1990s. Since the economic crisis in 1997—98, its share has increased, thanks to the baht depreciation and the increasing demand for agricultural products from China. The share of fisheries in agricultural value added increased rapidly in the 1980s and the 1990s (**figure 2.2**). After that, its share sharply declined due to the overexploitation of natural resources and the environmental impact of shrimp and fish farming. Shrimp exports declined sharply for a few years in the early 1990s due to a chemical residue found in the exported shrimp product and the shortage of brood stocks for black tiger shrimp. However, Thai agribusiness managed to regain its position as the world's largest exporter of shrimps. The share of livestock value added increased in the 1970s and 1980s, but fell in the 1990s (figure 2.2). It then increased slightly before Thailand was hit hard by an outbreak of the avian flu in late 2003. The outbreak wiped out more than two-thirds of chicken exports. Although the industry successfully switched to the export of cooked chicken, the total export value of chicken substantially declined. Consequently, the share of livestock in agricultural value added has also been on the decline. Finally, the share of forestry in agricultural value added has steadily dropped to the level that it no longer plays any significant role in Thai agriculture.

The changes in the composition of agricultural products can be described in another way using the concept of traded and nontraded goods. Table 2.2 classifies agricultural products according to their trade orientation. Over the period 1980—85, traded crops, traded livestock, and fishery products had the fastest growth rate, thanks to Thailand's abundant land and cheap supply of labor. Between 1985—90 and 1990—96, the nontraded and noncompeting products had the highest growth rates. These were the periods of industrial boom in the mid-1980s, followed by the asset-price bubble in the early 1990s, which resulted in the Dutch disease effect. As resources were drawn away from the agricultural sector to the nontraded and booming manufacturing sectors, the growth of the nontraded products increased relative to that of traded products. The growth of import-competing products can be explained by the

high wall of tariff and increasing per capita income. During the period 1996—98 (the crisis years), both nontraded crops and import-competing products suffered negative growth because of the fall in real GDP and the sharp depreciation of the baht. As a result, exports of traded products expanded.[1] After the economic recovery, the growth rate of nontraded and import-competing products rebounded. Only chicken products, which are traded goods, still had the highest growth rate among the livestock subsectors, thanks to the bovine spongiform encephalopathy (BSE) disease. However, the avian influenza outbreak in the 2003 seriously affected the chicken industry. The higher prices of food on the world market which began in 2006 also had a positive effect on the growth of exportable products in the crop and fishery subsectors.

2.2 A Brief History of Thai Agricultural Growth

Before discussing a brief history of agricultural growth in Thailand, it is worth noting that the main source of comparative advantage of Thai agriculture is abundant land. In 1995, the agricultural land per worker was 3.31 rais, compared to 1.88 rais in Myanmar, 1.25 rais in the Philippines, and 0.75 rais in Viet Nam. The high land-labor ratio was the consequence of agricultural expansion into forests. Then the exhaustion of forest land and increasing population pressure caused the land-labor ratio to decline after the mid-1980s. The exodus of the young population from agriculture in the period 1990—2000 has reversed the trend of declining land labor ratio (**figure 2.3**).

As a consequence, Thailand has comparative advantage in land-intensive crops (e.g., rice, some field crops and permanent trees, particularly rubber) as evidenced by the pattern of land uses shown in **table 2.3.** According to table 2.3, paddy lands still account for the largest share of agricultural land despite the fact that their share has steadily declined over the last five decades. Rice is grown in every region, with the northeast having the largest areas (most of which are rain-fed). Most of the irrigated lands in the Central Plains and in the north are used for growing rice and vegetables. Most upland areas in all regions are suitable for field crops, especially cassava and sugar cane. Southern Thailand is dominated by rubber trees, oil palm, and, to a lesser extent, fruit trees. Recently, farmers in the northeast have begun growing

[1] The low growth rate of traded crops was the result of drought and the financial crisis, which spread to other Asian countries.

rubber, thanks to the higher prices of rubber and the government subsidy. Eastern Thailand specializes in fruit trees. The fact that only a small but increasing share of agricultural land is devoted to oil crops (e.g., oil palm, soybean, and coconut) indicates that Thailand does not have much comparative advantage in these protein-based crops, mainly because of the agronomic constraints.

Thailand's agricultural transformation can be divided into four periods: the golden growth period of 1960—85, the period of declining comparative advantage in 1985—96, the crisis in 1997—98, and the growth revival period in the 2000s. It can be argued that, in addition to the increase in export demand, long-term agricultural growth has been made possible by investment and technology.

During the 1960—85 period, agriculture was the engine of Thailand's economic growth. At that time, it was not only the largest economic sector but it also enjoyed the highest GDP growth, thanks to the abundance of land, sound macroeconomic management policy, and public investment in infrastructure. The conservative fiscal policy and disciplined monetary policy resulted in price stability. Public investment in irrigation which began in the late 1950s, rural roads in the 1970s, and rural electrification in the 1980s, made it possible for farmers to expand and sell their output at higher farm gate prices while compulsory primary education contributed to the higher productivity of commercial farms. In 1966, the Bank for Agriculture and Agricultural Cooperatives was established. Its mission was to provide credit to farm households. Thanks to its innovative lending approach of group-guarantee lending, more than 90 percent of farm households now have access to the bank's credit, which, in turn, allows farmers to increase their agricultural investment.

The expansion of land for traditional crops (e.g., rice, rubber) and upland crops (e.g., jute, maize, cassava, and sugar cane) resulted in the rapid increase in commodity exports.

After 1970, Thailand began to export high-value agricultural products, especially chicken, canned tuna, frozen shrimp, and high-value vegetables to Europe and Japan. The emergence of export markets for high-value products is attributed to several factors. On the demand side, the 1973 commodity boom and the increased demand in developed countries provided an export opportunity for local agribusiness firms. But without imported technology, it would

not have been possible for these firms to exploit such an opportunity. To capture the external benefits arising from the use of new technologies in poultry farming (particularly new breeds, feeds, and modern farming practices), Charoen Phokaphan (CP) introduced the American contract farming system to its farmer-contract growers. After that, an American agribusiness company introduced contract farming to tomato farmers in the irrigated area of one northeastern province. Since then, contract farming has become a popular business model for agribusiness companies exporting high-value agricultural products to Japan and Europe.

In the mid-1980s, Thai agriculture began to lose its comparative advantage due to dwindling land frontier and increasing agricultural real wages resulting from massive rural-urban migration. In addition, world prices of agricultural products declined drastically as a result of the expansion of global food production and the protectionist policies of developed countries. Consequently, the growth rate in agricultural GDP slowed down from 4.1 percent in 1960—80 to 2.45 percent in 1981—85 before slightly increasing to 3.5 percent in 1985—96. The asset-price bubble in the early 1990s also had a serious negative effect on agriculture as the prices of traded agricultural products declined sharply relative to the prices of nontraded agricultural products. In response to the malaise, farmers began to hire illegal migrants and mechanize their farm operations. As a result, investment in farm machines increased dramatically (see **figure 2.4**). In fact, there is evidence that farmers in the irrigated areas of the Central Plains began to mechanize land-preparation tasks in the late 1970s. Meanwhile, some farmers have also begun to produce organic or safe products by adopting Good Agricultural Practices (GAP) while others have adopted integrated farming methods, which helped reduce the price and output risks of the mono-cropping approach.

After the economic crisis of 1997—98 and the ensuing El Niño-induced drought, agricultural growth rebounded, thanks to the depreciation of the baht. In response to the problems caused by the chemical residues found in chicken and shrimp exports, the government and the private sector jointly tackled food safety problems in the supply chain. The increases in the prices of agricultural products and food, which began in 2006, also stimulated the growth of Thai agriculture.

The preceding discussion shows that agricultural growth in Thailand can be attributed to several factors—namely, land expansion, labor, investment in infrastructure, capital

investment by farmers, and technology. Part 3 will provide measures on the relative importance of these factors using the growth accounting method.

2.3 Modernization of Thai Agriculture

The malaise that threatened the agricultural sector also stimulated it to undergo a transformation and modernization process. Many farm tasks are now mechanized in response to the labor shortage, resulting in larger farm sizes. Meanwhile, professional farmers have adopted modern farm-management methods to reduce cost, increase productivity, and produce safer food. They now employ modern and more efficient logistic and marketing systems. To address the problem of food safety and to guard against the possibility of exporting unsafe agricultural products and food, farmers and agribusiness firms have had to adopt GAP and new farming technologies (e.g., biosafety farms). Perhaps the most modern farms can be found in the livestock subsector. When domestic and foreign demand for chicken meat began to rise in the 1970s, one agribusiness firm began to introduce new production technologies and modern farm management to farmers. The swine industry experienced a similar scaling-up transformation, thanks to the growth of domestic demand and a university's research and extension efforts. As a result, poultry and swine production in Thailand is now more like an industry than traditional agriculture.

Malaise-inducing events in the late 1990s and early 2000s (i.e., the nitrofuran residue found in chicken meat and shrimp exports, the bird flu outbreak) prompted farmers to reduce the use of antibiotics and replace their open farms with the closed-farm system, resulting in larger farm sizes. Food processing firms were also forced to produce cooked chicken meat and ready-to-eat products. The swine industry likewise rapidly modernized and adopted sanitation measures in response to the growing need to tackle water pollution and the foul odor that usually emanates from a swine farm. These air and water pollution issues caused conflicts between farm owners and their neighbors since most swine farms in Thailand are located in densely populated suburbs. A large number of swine farms are also located near rivers. Due to advancements in technology and the labor shortage, Thai swine farms are large in scale and are as advanced as farms in more developed countries.

2.4 Pattern and Structural Change in the Food Processing Industry

Thailand is a major food-exporting country. Its food and beverages subsector is one of the largest subsectors in the country's manufacturing sector. In 2009, the share of this subsector in the value added of the manufacturing sector was 18.4 percent; in 1985, its share peaked at 24 percent. If other agriculture-related manufacturing products (e.g., leather, pulp) are included, this share will increase to 25 percent. The food subsector is also the largest employer in the manufacturing sector, employing 1.7 million workers in 2009, or about 13 percent of manufacturing workforce.

The Structure and Pattern of the Food Industry

Among the three subsectors (i.e., food, beverages, and simple agricultural processed products), beverages is the largest, accounting for 27 percent of food value added in 2005, according to the 2005 input output table. It is followed by food and then by simple agricultural processed products, the shares of which have both declined (table 2.1). Unfortunately, there is no data on simple agricultural processed products after 2001.

It is possible to measure the relative size of the industries from the input-output table. Within the food subsector, the largest industries are, in descending order, rice milling and flour products, sugar and confectionery, slaughtering and preserving meat, and canning and preserving of fish and seafood. Together, these industries accounted for 34.2 percent of food value added in 2005 (see **table 2.4**).

The pattern of food exports is slightly different from the pattern of value added. The largest food exports are seafood, sugar, fruits and vegetables, animal feed, and rice and flour products (**table 2.5**). The difference reflects the differential pattern of domestic and foreign demand.

The input-output table also reveals some interesting characteristics of the food industry. First, contrary to general belief, the current share of value added in the output of the food industries is not much higher than the output of the other manufacturing sectors. The industries with the

highest share of value added in output are beverages, sugar, dairy products, meat products, and seafood (**table 2.4**). However, the wage share in the industry value added is the lowest in beverages and highest in rice products, meat products, fruits and vegetables, and seafood (**table 2.4**). The share of operating surplus in food value added, which averages at 50 percent, is higher than that of the other manufacturing products (47 percent). The profit share is highest in fishmeal and feed, oil products, and meat products and lowest in beverages (**table 2.4**). Finally, the use of imported raw materials in the food industry has increased over the 1980—2005 period, reflecting either the depletion of domestic raw materials or the increasing sophistication of the demand for food products.

According to the Ministry of Industry, there were 7,094 food and beverage factories in 2009, an increase from the 6,812 factories in 1997. There were another 43,348 basic agro-processing factories, the largest number among all the manufacturing factories. The industries with the largest number of factories are, in a descending order, ice making, flour mills canning and preserving of fruits and vegetables, meat canning, food ingredients (e.g., fish sauce, soy sauce), and tea and coffee (**table 2.6**).

The size distribution of the food industry has barely changed. According to factory registration data, the food industry is dominated by small factories that employ more than fifty employees. These small factories account for 90 percent of all new food factories. The share has either remained almost constant or slightly declined between 1980—85 and 2000—09 (**table 2.7**). The share of medium-scale factories employing 51 to 200 employees has stayed constant. The share of large-scale factories has increased slightly from 1 percent to 4 percent in 1980—85 to 2 percent to 4 percent in 2009.

There is no official information on the ownership of food factories. Casual observation suggests that the food industry is dominated by large-scale Thai companies, especially in poultry products, seafood, rice export, canned fruits and vegetables, dry grocery products, sugar, etc. Multinational companies (MNCs) play an important role in a few sectors but they usually dominate their respective product niches (i.e., soft drinks, coffee, imported whisky, ice cream, health food, soup mixes like chicken soup and bird nest soup). The industries with a relatively high concentration of Thai firms are poultry products, canned and frozen seafood, canned and preserved fruits and vegetables, sugar, dairy products, and beer. A few firms in

some of these industries have a vertically integrated structure. For example, there are at least three vertically integrated companies in the broiler industry. Their operations cover research on genetic improvement, breeding of grandparent and parent stock, hatcheries, contract farms for growing broilers, production of animal feeds, production of drugs and premixes, slaughterhouses and meat-processing plants, restaurants, and exports. A few companies in the seafood industry also have a vertically integrated structure, that is, these companies have their own fishing boats, cold storage, processing plants, retail outlets, and export arms. One of the companies owns a well-known American brand of canned tuna.

Some food industries that produce high-quality food products have to have some form of contract farming to ensure a stable supply of quality raw materials or products. These include the poultry industry, the canned pineapple industry, exporters of fresh vegetables, sugar factories, the dairy processors, and even the exporters of quality Jasmine rice.

Structural Changes in the Agribusiness Sector

The Thai food processing industry has come a long way from producing simple processed foods to producing high-quality and sophisticated foods and from exporting resource-intensive foods to high-value foods over the last four decades. **Table 2.5** shows that between 1980 and 2010, exports of some food items increased by 43 to 104 times. These items include preserved and canned fruits (104 times); preserved and canned seafood (42.8 times); fresh and frozen vegetables (58.7 times); fresh, chilled, and cooked poultry products (79.6 times); and fresh and frozen fruits (47.8 times). This section will explain the factors underlying the structural changes in the agribusiness sector.

There are at least six major trends underlying the structural changes in the agribusiness sector: a shift from resource-intensive and labor-intensive products towards high-value products; a shift from domestic resources towards imported raw materials; the increase in the domestic demand for safe food; emergence of national brands and the growth of the large-scale distributors; the rapid rise of foreign retailers; increasing intra-ASEAN trade in food; the development of contract farming and the vertical integration of food producers. This paper postulates that the structural changes in agribusiness are the result of over half a

century of industrialization, which, in turn, is influenced by certain important economic forces. Before explaining those forces, the seven trends will be briefly explained.

First, one important structural shift in the process of Thai industrialization is the shift from resource- and labor-intensive industries towards skill- and knowledge-intensive industries (Poapongsakorn et al. 2004). There have been two types of shifts in the food industry, in particular: (1) a shift from the use of domestic, resource-dependent materials to imported, resource-oriented materials and (2) a shift towards high-value products.

The food industry experienced rapid growth in the 1980s due partly to rapid industrialization and rising per capita income. It resulted in a shortage of raw materials for some agro-business industries, especially the seafood and the livestock industries. The expansion of the poultry industry for the export and domestic markets turned Thailand from being a net exporter of maize to being a net importer of both maize and soybean. The growth in seafood exports forced manufacturers to import more fish and shrimp. They, therefore, lobbied the government to abolish import duties and other import restrictions in the 1980s. The fishing industry also asked the government to negotiate fishing rights in the territorial waters of neighboring countries such as Myanmar, Indonesia, and India.

In response to higher labor costs in the 1990s and the increasing scarcity of raw materials, food exporters and manufacturers had to improve efficiency and produce higher-value products. Factories producing canned fruits and pineapple have improved logistics and the transportation of raw materials, which allows them to increase the yield from each ton of raw materials. Chicken exporters who used to export labor-intensive frozen chicken breast diversified into cooked and ready-to-eat chicken and other processed chicken products because of increased labor costs and the avian flu problem.

The second trend is that food products have increasingly higher value, better quality, more varieties, and are safer. As per capita income increases, consumers will demand higher-quality and safer products. For example, increases in the domestic demand for fruit juices and better-tasting beverages have resulted in the expansion of the modified starch industry which produces fructose and glucose. Modified starch is one of the cassava-derived products with the fastest growth rate in the last decade (Poapongsakorn et al. 2007). There are now more

varieties of dry grocery goods, such as sauces and noodles, than the simple products available in the old days. The types and supplies of ready-to-eat foods have dramatically increased as working, married women do not have time to cook. Diets have also shifted towards more processed meat, dairy products, bakery products, and other Western types of food.

One of the consequences of increased demand for food safety is the development of private and public standards for food safety in the domestic market. Thai food manufacturers and exporters of frozen foods (e.g., chicken, seafood, vegetables and fruits) have successfully exported safe and organic foods to markets in developed countries for more than 10 to 15 years. In the past, however, Thai consumers did not benefit from such standards because the local demand for safe food was low. Thanks to increasing health consciousness, increasing awareness of the risks of food hazards, and the growth of modern supermarkets, foods that are sold in the supermarkets must now adhere to certain safety and quality standards.

The third trend is that the industrial organization of some food industries has significantly changed in the last twenty-five years. There have been three types of organizational and structural changes in the food industry: (1) the emergence of contract farming which has already been discussed; (2) the vertical integration of agribusiness companies; and (3) the increasing concentration of the agribusiness market and the retail market.

One of the unique characteristics of the organization in the agribusiness sector is the vertical integration of companies in the poultry and seafood business. In poultry, most large-scale agribusiness firms are vertically integrated. Their business covers genetic research, breeding farms to produce the grandparent and parent stock, hatcheries, contract farms, feed factories, drug companies, slaughterhouses and meat-processing plants, restaurants, and exports. In the early years, CP established the Bangkok Livestock Trading Company as a vertically integrated entity. In recent years, however, with the rapid expansion of its agribusiness interests worldwide, the holding company CP Group (CPG) reorganized its business into four major companies and a number of smaller companies. CPG has four major companies in the food business, including CPF, which deals with livestock, shrimp, and fishery; CP All, which runs the 7-Eleven convenient stores; and CP Inter Trade, which is involved in rice trading. In addition, CPG also owns CP Seeds, a small company in the business of corn seeds, rubber seedlings, etc. It should be noted that the Chiarawanond family, which is the major

shareholder of CPG, also controls Chia Tai Company, which is the family's first agribusiness firm. Chia Tai Company produces vegetable seeds, fertilizers, and drugs.

A few large-scale companies in the seafood industry have adopted the vertically integrated structure, the notable ones being CP, Surapon Seafood, and Union Frozen. These companies have their own farms or contract farms, cold storage, production plants. They handle their own marketing, research, and export. Some companies have their own farms while others depend on contract farms or maintain a close and long-term relationship with wholesalers who supply the required raw materials.

There are a few important reasons for vertical integration. In the early period of the industrialization of the broiler, frozen shrimp, and canned seafood businesses, the companies may have dealt with the uncertainty and risks involved in depending on the market for supplies of raw materials. After the bird flu outbreak and the discovery of chemical residues on chicken and shrimp bound for export, many companies reacted by investing in the closed-farm system for broilers. CP is now experimenting on an ambitious closed-farm system for shrimp production. The rationale for such an integration effort is traceability and biosafety. The transaction costs of enforcing safety standards and traceability with smallholders are still too high. The second reason is that a vertically integrated structure allows firms to exploit tax laws so that the tax burden is reduced. In addition, vertical integration also helps reduce transaction costs when there are a large number of activities that need to be efficiently coordinated.

The agribusiness industry has also become more concentrated. In poultry, CP is the dominant oligopolist, followed by Betagro and Saha Farm. The bird flu outbreak pushed many companies to bankruptcy, which left only a few integrated firms standing. The shrimp and seafood business has more large-scale companies than the poultry industry. The leading firms in the shrimp and seafood business are CP, Union Frozen, Surapon Seafood, and Pran Tha-le. Other highly concentrated industries are fertilizers (dominated by four companies, most of which are MNCs), drugs (also dominated by a few MNCs), rice export (dominated by five Thai exporters), and seeds (dominated by a few MNCs and CP).

The fourth trend, which began in the late 1980s, is the development of national brands of dry grocery products. In the past, there were a variety of local brands of grocery products such as fish sauce, chili sauce, soy sauce, and dried egg noodles. These products were usually available in markets in the urban areas that were too far from Bangkok for Bangkok products to compete with, thanks to high distribution costs. However, due to the increased demand for food in the 1980s, producers in Bangkok began to enjoy economies of scale. In addition, the distribution system began to change. The old distribution system in which small wholesalers who bought products from factories in Bangkok and then sold them to small retailers in other provinces was rapidly replaced by the modern distribution system of large-scale distributors in Bangkok. These distributors have lower average transaction costs than the traditional wholesalers and the manufacturers. In addition, the distributors and the manufacturers also advertised their branded products. As a result, branded food products from Bangkok replaced the local brands.

The fifth trend is the emergence of foreign supermarkets that introduced a modern procurement system, private labels, and strict product standards. These supermarkets rapidly increased in number during the economic crisis of 1998—99 because the asset-price deflation allowed them to acquire prime locations for their branches. Consequently, they enjoyed economies of scale in purchasing and distribution as well as increased bargaining power with suppliers. This, in turn, allowed them to pass on part of the cost savings to the consumers. The emergence of foreign supermarkets had a tsunami-like effect on retail and wholesale markets. First, their rapid expansion and low-price strategy caused a large number of traditional grocery stores to go bankrupt. Other grocery stores had to restructure their business in order to survive. Second, hypermarkets began asking their suppliers to produce some products bearing the hypermarkets' private labels. The suppliers, including those of private-label goods, have to comply with the standards imposed by the hypermarkets. Such practice has enabled foreign retailers to export goods to (or import goods from) their branches in other countries, resulting in a global or regional sourcing network. Finally, some supermarkets have begun to source directly from farmers' associations. This issue will be discussed later.

The final trend is that the establishment of ASEAN Free Trade Area (AFTA), the ASEAN+3, and other bilateral free trade agreements (FTAs) has begun to have an impact on intra-

ASEAN trade and trade among FTA partners. The market-access agreements have enabled some multinational food companies to establish regional production centers in one country and export the products to other ASEAN countries, thus enjoying economies of scale.

There are a number of factors that influenced these trends. This study postulates the five factors that influenced the industrialization process of the agrifood sector.

First, as the food industry started to expand rapidly in the 1980—90 period, supplies of domestic raw materials were insufficient to meet the demand. This resulted in a shortage of raw materials, particularly fish, maize, and soybean. The government responded to complaints from the private sector by reducing import tariffs and surcharges and by relaxing import restrictions. The industries also responded to the shortage by sourcing more raw materials from neighboring countries and reducing loss and waste in the production process.

The rapid industrialization that happened in 1985—96 also resulted in a labor shortage and higher real wage rates. The response of labor-intensive industries, particularly the small- and medium-scale seafood factories, was to hire illegal foreign migrants from neighboring countries. In the early 2000s, the government finally agreed to allow employers to hire foreign workers by issuing temporary permits to workers who registered with the Ministry of Labor.

The second factor, which was a direct consequence of industrialization, was the increasing per capita income and the shift in the lifestyle of the middle class toward the Western way of life. As their per capita income increased, Thais began to switch from their main staple diets, which have low or negative income elasticity of demand (see part 3), to goods and services with high income elasticity. They demanded not only high-quality foods but also safe foods and foods that are readily edible such as ready-to-eat dinner packages and instant noodles. This was because the time cost is more expensive. Since information cost is always high, consumers tend to make buying decisions based on the brand names of products.

Third, firms began to master tacit knowledge as they grew during the different stages of industrialization. In the beginning, Thai entrepreneurs learned and absorbed the technology of foreign companies either as joint-venture partners or as former employees. In the 1960s and

1970s, many of the canned-seafood companies in Thailand were foreign firms that received investment privileges. The industry is now dominated by Thai entrepreneurs who were able to absorb tacit knowledge and to develop their own technology. Many Thai companies are now able to export high-quality foods that meet the stringent sanitary and phytosanitary (SPS) standards of the European Union (EU), the United States, and Japan, thanks to the skills and knowledge transferred by these companies' Japanese partners.

Fourth, the rapid growth of the food industry can be partly attributed to the industrialization policy. In the first four national economic development plans, the industrialization strategy was to promote import-substituting industries. The fifth national plan (1982—86) marked the first time that the government began to promote export-oriented industries. Agro-business industries had 1,021 projects with investments amounting to THB 1.49 billion that received tax and nontax incentives from the Board of Investment, Thailand's most important agency in industrial development. The number of promoted projects declined to 975 (with investments worth THB 0.89 billion) in the sixth plan and 235 projects (worth THB 0.22 billion) in the seventh plan. The projects included large plantations, cattle farms, frozen and canned seafood, frozen chicken, canned pineapple, and canned fruits and vegetables.

In 1995, the government also approved policy measures and development plans to promote twelve groups of agro-business industries, including canned and preserved foods, fresh and frozen foods, modified starches, animal feeds, dry grocery products, and ready-to-eat food. The policy measures included tariff exemptions for imported raw materials, improved procedures for claiming tax rebates, tariff reforms (which were carried out in 1990 and 1999), promotional and assistance measures for export goods, registration of foreign migrant workers, and trade negotiation for market access with important trading partners (TDRI 1998). As has been previously discussed, Thailand has, since 2003, signed FTAs with many trading partners. These FTAs have already increased trade volume for both Thailand and its partners. The tariff reforms have reduced the average tariffs for manufactured products from 42.7 percent in 1989 to 20.4 percent in 1994 and then to 9.9 percent in 2006. These also almost eliminated the negative bias against some food-exporting industries such as rice milling, starch factories, canned food, and monosodium glutamate (TDRI 1998; Poapongsakorn et al. 2007). The study finds that the number of food industries that used to be penalized by the tariff system (i.e., industries with negative effective rate of protection) was

reduced from sixteen industries in 1995 to thirteen industries in 2006 (Poapongsakorn et al. 2007).

Other important policies include the provision of cheap credit for food industries through the Industrial Finance Corporation of Thailand (IFCT), the Small Industry Finance Corporation, and farm credit from the Bank for Agriculture and Agricultural Cooperatives (BAAC) as well as the promotion of eleven contract-farming projects in 1987—92 and new contract-farming projects in 1993—96 (see further discussion below).

2.5 Growth of the Food Industry and Food Export

The growth of food value added—6.7 percent per year during the 1970—2009 period—is quite impressive compared to the growth of manufacturing value added of 16.33 percent. Except for the periods 1980—85 and 1996—98, the growth of the food sector was slower than that of manufacturing value added (see **table 2.1**). This is not surprising because the income elasticity of demand for food is lower than one while many manufactured products have higher income elasticity. Nevertheless, the food sector grew almost as fast as real GDP.

The food sector grew fastest in 1985—96, which were the years of the industrial boom and the financial bubble. During these periods, beverage value added had the highest growth rate among the three subsectors in **table 2.4**. The food sector (excluding beverages) registered negative growth during the crisis years of 1997—98. After the crisis, its growth slowed down to only 3.56 percent per year (**table 2.4**).

It is possible to identify the growth performance of twenty-one food subsectors using the input-output tables for 1980—2005. The largest subsectors were canned and preserved seafood, rice milling, slaughtering, breweries, sugar refinery, soft drinks, and canned and preserved fruits and vegetables (see table 2.4). The subsectors that experienced increasing share in manufacturing GDP were canned and preserved fruits, vegetables, and seafood; breweries; canned and preserved meat; dairy products; palm oil; confectionery and snacks; and coffee. These are mostly products with high income elasticities of demand and health foods. The industries with declining share in manufacturing value added produced products

with low income elasticity of demand (e.g., rice milling, flour and tapioca milling, sugar refinery, distilling of low-grade spirits, bakery, animal feeds, and ice).

The growth performance of the food industries reflects the comparative advantage of each subsector, which can be measured by an index of domestic resource cost (DRC). The DRC is the social cost of domestic resources that are used to earn (or to save) one unit of foreign currency. The social costs of domestic resources are measured at world prices (i.e., all of the distortions created by the policies are eliminated from the costs). The industries are competitive if the DRC is less than one. **Table 2.8** shows the DRC of the food industries that are export-oriented (i.e., export is higher than import) and import-substituted. The results confirm that Thailand has high comparative advantage in the production of flour, leather products, rubber products, monosodium glutamate, seafood, and canned fruits and vegetables, among other commodities.

Performance of Thai Food Exports

Food exports grew by more than 6 percent per year during the 1988—2010 period.[2] Exports of agro-industrial products grew the fastest while agricultural exports had the lowest growth rate (**table 2.5**). These differential growth rates changed the pattern of food exports. Though exports are still dominated by agricultural products, their importance declined from almost 63 percent in 1988 to about 52 percent in 2005. The share of agro-industrial exports increased by ten percentage points to almost 35 percent in 2010. Livestock exports also enjoyed a slightly high share despite the avian flu outbreak in 2003. The share of fishery exports declined, reflecting the fact that fish and shrimp culture and the marine fishing industry are not environmentally sustainable.

Exports of traditional crops such as rice, rubber, and cassava have remained robust. These three commodities have remained the most important exports of Thailand for the past few

[2] Note that during the 1988—96 period of asset-price bubble, food exports grew at impressive annual rates, even reaching 8.5 percent. Then growth surged to 33.5 percent when the Thai baht was depreciated from THB 25 to a US dollar to THB 52 in the early 1998. After that, export growth slowed down but was still higher than it was during the 1988—96 period (**table 2.5**). As a result, Thailand's share of the world agricultural and food export increased from about 1.2 percent in the early 1960s to more than 2 percent in 2006 (**figure 1.1**).

decades for the following reasons. First, the share of consumption in total production is low (i.e., 20 percent for rubber, 30 percent for cassava, 42 percent for rice). Second, Thailand has abundant land. Therefore, any increase in planted areas or farm productivity would certainly boost Thai exports. Thailand has also maintained its position as one of the top four exporters of canned pineapple, sugar, canned tuna, and frozen shrimps for the same reasons.

Compared to other developing countries, Thailand has undisputedly high comparative advantage in many processed foods. The revealed comparative advantage indices for five groups of processed foods are high compared to other developing countries. Viet Nam and Bangladesh have higher RCA than Thailand for low-value products, that is, for more labor-intensive and simple processed products such as frozen shrimp. However, Thailand has higher comparative advantage in high-value products such as canned tuna and canned fruits. There are varieties of these ready-to-eat foods that can meet the demand of different consumer groups. **Table 2.10**, however, shows a worrisome sign—a declining trend in the RCAs for all four products.

Chutikul (2006) analyzed the weaknesses and strengths of two product groups--fresh food and processed food. First, although Thailand's market share in both products ranked 11th out of 173 exporting countries in 2003, exports had concentrated markets as measured by their rank in market spread and market diversification. Their ranks for product spreads are in the top twenty out of 173 countries. Second, the performance of both products between 1999 and 2003 worsened because their market shares declined relative to the market shares of other countries. The decline in market share was due to reduced competitiveness and changes in geographic specialization. Adaptation capability, however, improved.

The strength of Thai exports is in its adaptability. When food export data are disaggregated and analyzed, one will find that the share of the top eighteen agricultural exports declined from 11.8 percent in 1990—94 to 9.96 percent in 2000—05 (Poapongsakorn 2006). This implies that some of the less important products registered higher export shares.

The export destinations of agricultural products differ from that of processed foods. The largest markets for traditional agricultural exports are mostly developing countries, especially Asian countries. For example, four of the top five largest markets for Thai rice are China,

Iran, Iraq, and Benin. The largest markets for cassava are China, Japan, Indonesia, and Taiwan. All of the top six destinations for Thai maize and palm oil are Asian countries. The only exception is rubber, which is used as the raw material for the rubber product industries in developed countries. In Asia, China is the largest market for Thailand's rubber while the other top destinations are developed countries.

The main destinations for processed-food exports are mainly developed countries. The largest export markets are the United States, Japan, and the EU. The demand for processed foods is income elastic; hence, the main demand for these products come from consumers in rich countries.

Table 2.9 decomposes the sources of the value-added growth in the food sector. The result shows that domestic demand is the largest source of growth, followed by exports. Export growth is the largest source of value-added growth in fruits and vegetables, fish and seafood, rice and flour, and sugar. It is not surprising that private consumption plays a major role in the value-added growth of oil products, meat products, and dairy products because these are import-competing industries. Part 3.2 will discuss the role of technology as the source of growth.

3. Technology and R&D in Agriculture and in the Food Processing Industry

Aside from infrastructural investment and capital investment, technology also determines agricultural growth. Unlike investment in capital, which is subject to the law of diminishing returns, the returns on investment in technology and knowledge are not subject to such a law, according to the endogenous growth theory. This part will explain the role of technology as a major source of economic growth and investment in R&D.

3.1 Sources of Agricultural Growth: Technology and Rates of Return to R&D[3]

To measure the relative importance of each factor, particularly the role of technology, this study will decompose the sources of agricultural growth. Using Solow's growth accounting model, Poapongsakorn and Anuchitworawong (2006) estimated the growth in total factor productivity (TFP) of three agricultural subsectors in 1980 and 2003—crops, livestock, and fishery (**table 3.1**). Waleerat (2009) also provided similar estimates for 1980—2006. The paper will then provide an estimate of the impact of R&D on TFP and the rates of return on investment in R&D.

During the 1980—95 period, the agricultural sector was the only sector with positive TFP growth (Tinnakorn and Sussangkarn 1998). The estimates made by Poapongsakorn and Anuchitworawong (2006) for the 1981—2003 period show that the growth rate in agricultural TFP was higher than the 1980—95 estimates obtained by Tinakorn and Sussangkarn (1998). The estimates for the 1981—2003 period also confirmed the previous findings that TFP is the second-largest source of agricultural growth after capital expansion (**table 3.1**). The decomposition of the sources of growth of the three agricultural subsectors shows interesting results. TFP was found to be the largest source of growth of crop value added, accounting for 75 percent of agricultural growth (3.57 percent per annum) in 1981—2003. In livestock, labor was the most important growth contributor (almost 74 percent), followed by TFP (34.6 percent). This finding is consistent with the fact that there have been increasing numbers of highly educated labor in the poultry and swine sectors, which are dominated by large commercial farms run with modern management methods. The increasing growth in TFP between 1985—96 and 1996—98 can be explained by the scaling-up effect (due to the adoption of evaporative housing), improved nutrition feeds, and better farm management.

The most interesting finding was that TFP was negative in fishery and that the most important source of growth in this sector was capital. This is not surprising because fishermen have been overexploiting natural resources for years, resulting in a sharp decline in output from 2.752 million tons in 1993 to 2.164 million tons in 2010. The catch per unit of fishing effort drastically declined from 131.8 kg in 1966 to 22.1 tons in 2002. Tokrisna

[3] This section draws heavily from the author's previous work (Poapongsakorn and Anuchitworawong 2006).

(2009) found that the actual catch of surface-water fish (0.39 million tons in 2008) in the Gulf of Siam is already lower than the maximum potential catch (0.4 million tons), an evidence of overfishing.

The third decomposition using similar method and data was that of Waleerat (2009). The results are similar, that is, TFP was the second most important source of growth for the agriculture and livestock subsectors. While capital growth was the most important factor behind agricultural growth, labor played the most important role for the growth of the livestock subsector. The only difference was that capital was the most important source of the growth for the crop subsector, followed by TFP. This is plausible given the increasing mechanization in the 2000s in response to labor shortage.

Since TFP is the proxy of technological change, it is interesting to measure the impact of research and extension (which create technology) on TFP. Waleerat (2009) found that a one percent increase in crop research will increase the TFP of crops by 0.15 percent (**table 3.2**). In addition, the elasticity of private research was estimated at 0.10 while the spillover of the research done by the Consultative Group on International Agricultural Research (CGIAR) had a TFP elasticity of 0.15 (**table 3.2**). Waleerat (2009) also estimated the TFP elasticity of extension (**table 3.2**). The last finding confirmed the importance of the technological spillover effect.

The final question is whether or not agricultural research pays off. There are some studies that provide estimates of the rates of return on investment in agriculture. Most estimates peg the rates of return at about 40 percent (**table 3.3**). The latest estimates by Waleerat (2009) showed that the rate of return is 29.5 percent for crops and 104 percent to 144 percent for livestock. A study on the return on investment for research on disease-tolerant Chainart HV is 200 percent (Orachos 2010) while the return for the Kor Kor-6 sticky rice is 47 percent to 57 percent (Warin 2009). Finally, a study on the benefit of organic fertilizer management for corn revealed that the benefit is 19.4 times higher than the cost.

Since Thailand has established several research departments and invested in agricultural research since the late 1950s, it has developed many innovations and new technologies. Part 3.3 will describe those technologies as well as the technology developed by agribusiness

firms and farmers, followed by an analysis of public investment in agricultural research and research intensity. Before that, however, the following section (3.2) will discuss the sources of growth in the food industry.

3.2 Sources of Growth and Role of Technology in the Food Industry

The discussion on the structure and growth of the food sector in parts 2.4—2.5 reveals that domestic consumption is the sector's main source of growth. Export demand is an important source of growth for a few subsectors (e.g., fruits and vegetables and rice and flour products). A more interesting question, however, is the contribution of the key structural factors, particularly technology, on sectoral growth. This study will report the results of the decomposition exercise in a study done by Chedtha (2010). The method of decomposition used was the historical/decomposition simulation technique, which is typically used to sort out the effects of each of the categories of structural changes. The CAMGEM-H model (a genre of computable general equilibrium or CGE) was used to compute the necessary changes in the structural parameters and to decompose the sources of growth. The data used came from the 2000 and 2005 input-output tables.

The result shows that technology and trade were the most important sources of growth, contributing 43.1 percent and 27.3 percent, respectively, to GDP growth between 2000 and 2005. The sectoral decomposition in **table 3.4** confirms that technology and trade are indeed the two most important sources of growth in most manufacturing sectors, including food and agriculture. According to estimates of the impact of the four different types of technological changes, increased efficiency in using primary inputs (land, labor, and capital) contributed the most to the growth of all sectors, including agriculture and food. The small negative contribution of intermediate input-saving technology for food and agriculture should be interpreted cautiously, that is, that said technology probably had no significant impact. On the other hand, the estimates incorrectly showed that food and agriculture suffered a decline in labor-saving technology given the fact that these sectors experienced a 5.6 percent and 6.8 percent respective increase in labor requirement per unit of output. The estimates are contrary to the fact that in response to the labor shortage, Thai farmers widely adopted labor-saving technologies. The problem with the estimates is that the input-output table only reports the wage bill, with no information on labor units.

3.3 Agricultural technology

Previous research shows that TFP has been the second most important factor explaining the growth of agricultural output; the major factor explaining TFP growth is R&D. The question is, what kinds of technology and innovation make up the output of agricultural R&D? Who invests in the technology?

Table 3.5 lists the technologies used in Thai agriculture according to their objectives (e.g., genetic improvement to enhance yield, impart biotic and abiotic tolerance, save labor, etc.). A few main observations can be drawn from the table. First, the most important agricultural technology is yield-enhancing genetic improvement. A large number of high-yield varieties (HYVs) have been successfully developed for all major crops in Thai agriculture. For example, the Department of Rice and other public research agencies have been able to develop many HYVs for rice including RD6, RD15, RD21, RD25, Supan Buri 60, Chainat 1, and others. There are at least thirty-two varieties for sugar cane, more than eight varieties for cassava, and twenty-three varieties for rubber. In fisheries, the most important technologies involve reproduction and cultivation methods. The Department of Fishery, in cooperation with an international research agency, also successfully bred many high-yielding varieties of fish (e.g., tilapia). Thailand depends heavily on imported breeds in the livestock sector. The parent stocks of chicken, for example, are imported to produce day-old chicks. Some companies also import grandparent stocks for their parent stock farms. Pure lines of swine and cows are imported for reproduction and adaptation to heat. Some imported pure lines of swine and cows are crossed with native breeds to produce the appropriate breed for local conditions (e.g., heat-tolerant swine). In addition, appropriate feed formulae have been developed so that the feed-meat conversion ratio can be reduced.

Thai plant breeders have also attempted to breed varieties that produce high-quality plants. In the beginning, when the local breeders cross-bred the IR variety with the native variety to achieve higher yield, the resulting new rice varieties (RD1, RD2, RD3, and RD4) were not popular among Thai consumers. They had to improve the cooking quality of the rice and, at the same time, breed the varieties that produce long-grain rice with a minimum length of 7 millimeters. Examples of these improved varieties are RD23 (which was the result of

multiple crossings of IR 8 with the native variety Hleung Thong Na Prang, IR 32, and RD7), RD11, and RD21. Consequently, Thai rice commands a relatively higher price in the world market, thanks to its quality. The Pathum Thani 1 variety, which has similar characteristics as the high-value jasmine or Dok Mali rice but has higher yield, has also been developed.

Later on, research on genetic improvement began to shift towards the development of heat-tolerant breeds that also resistant to diseases and floods. For example, the Chainat and IR-6 are disease resistant while the Cholasit breed can withstand floods for up to twenty-one days.

As a result of the development of HYVs, the productivity of crops, livestock, and fisheries increased significantly (see **table 3.6**), benefiting millions of farmers and consumers. For example, the development of the Chainat rice reduced production cost for several million farmers, with a rate of return of 200 percent (**table 3.3**).

The most important livestock technologies include improved feeds and new hybrid breeds with a shorter raising period and lower feed-conversion ratio. In the 1990s, evaporative housing, which was modified from the expensive imported system, was introduced. This housing helps increase the number of chickens per farm unit and enhances the productivity of chicken farms. In response to the avian flu outbreak, agribusiness companies adopted the closed chicken farm system (the so-called compartmentalization). An agribusiness company has been experimenting with an environment-friendly closed shrimp farm system. A large number of shrimp farms have also adopted the biosafety farming method that eliminates the use of antibiotic drugs.

Perhaps the second most important agricultural technology is farm mechanization. It began with the use of the small hand tractor to replace buffaloes in the 1970s. Since then, all land-preparation and harvesting tasks have been mechanized due to the labor shortage that began in the early 1990s. The combined harvesters are now widely used for rice harvesting throughout Thailand. In some large-scale farms, the owners have begun to mechanize the task of planting rice seedlings. In sugar cane harvesting, sugar mills have imported large cane-cutting machines. These machines, however, are so large that they are not economical and need further modification.

In addition to the hardware technology, Thai farmers have also actively embraced the so-called “software” technology. Modern farm management methods, such as the GAP, are an example of this software technology. The GAP makes it possible to adopt the traceability system. New organization systems, which include contract farming and the central procurement system, are another example of software technology. The central procurement system was introduced by modern supermarkets in the late 1990s so that these supermarkets can impose standards on the agricultural products that they procure either directly or indirectly from the farmers. The product standards, which cover quality, safety, service level, and the like, are demanded by consumers. Farmers able to produce products adhering to the required standards can command higher prices. At the same time, the standards enable the supermarkets and the suppliers to achieve economies of scale in their procurement.

Contract farming was adopted as a means for agribusiness firms to introduce new technologies to farmers and allow them to internalize the external benefits of these technologies. Since Thailand is one of the first among developing countries to successfully adopt the contract farming system, the case of contract farming in Thailand is worth analyzing.

Contract farming was successfully developed starting in the 1970s for chicken and tomato farms. Since then, it has been widely applied to a large number of high-value crops and livestock. The success cases include the contracts to produce vegetables (e.g., baby corn, tomato seeds, potato, asparagus, okra, peas) and organic vegetables for export. There are also other forms of contract farming in which the contractor will provide credit to the farmers. Most sugar mills provide such credit to ensure that they will secure an adequate supply of sugar cane during the four-month production period. There are also many cases of failed contract farms (e.g., the contracts to grow Indica rice, Japonica and Basmati rice and raise swine).

As already mentioned, the first group of contract farms consisted of the modern broiler farms introduced by CP in the 1970s, thanks to the export opportunity in the Japanese market. Contract farming is a means for agribusiness companies to introduce new technologies to farmers and to capture some benefit from the farmers by tying the production contract to the sale of the required inputs. Before 1970, most chicken farms employed traditional

technology. The new technology includes new breeds with low feed-conversion ratio and high-nutrition feeds. It also requires modern farm management methods, including investing in a modern chicken house, good sanitation, and ventilation. Since new technology represents an uncertain prospect to farmers, agribusiness firms have to offer a contract to buy their products at the minimum guaranteed prices, which are generally higher than the prices in the spot market. There are two types of contracts: the guaranteed-price contract and the wage (or hired labor) contract. The former eliminates the price risk for farmers but they have to bear the output risks. Under the wage contract, most risks are transferred to the contractor but the farmers still have to be accountable for some of the loss. The contractor also helps the farmers secure the large loan contract required for investment in a modernized farm. In the early years, the guaranteed-price contracts were the most popular contracts. But as chicken markets rapidly expanded, the market for contracts had to give way to the wage contract (or hire for a fixed fee) due to the contestability in the contract market (Poapongsakorn et al. 2003).

What factors can explain the success of contract farming in Thailand? The first is the high net income earned from contract farms. Some studies show that the net income gained by contract farmers is significantly higher than the net income of farmers who grow the same products but sell their produce in the spot market (see **table 3.7**). In addition to the higher yield and lower loss (e.g., lower mortality rate) generated by the new technology, the products of the contract farms are of higher quality and safer. Their products are sold at very high prices in high-income countries. Part of the high income is the return on the farmers' effort because contract farming is care- and time-intensive. Second, the contract market in Thailand has been contestable because of minimum government regulations. Thus, contractors have to compete with one other to offer the best possible deals to farmers. There are, however, many cases of failure as either side try to cheat each other by not complying with the contractual terms (TDRI 1996). Some agribusiness firms have also tried to introduce contract farming in a number of agricultural products but failed because the contractual arrangement for many products do not result in higher net income for both parties. Contract farming involves high transaction costs for both sides. Most of the success cases are where the contractors put serious effort in screening the farmers.

Despite its popularity, the 2003 Agricultural Census found only 260,330 farms (about 4.5 percent of farm households) with some form of contractual arrangement. However, this number decreased to 165,000 in 2008. To date, no research has been done to explain the cause of the decline. One hypothesis is that there was a shortage of family labor (contract farming is very labor-intensive). In recent years, there have been studies showing that many farmers have complained about the unfairness of contracts. For example, many farmers were required to unfairly bear the risk of disease outbreak and that some contractors did not allow the farmers to keep a copy of the contract (Portphant 2009).

Technology is not manna from the sky. It is the output of R&D, which is actively carried out by the government, the farmers, and the private sector. To understand the issues related to who undertakes research activities, it might help to divide the factors that influence technology into three categories: genetic base, resource base and environment (research on the relationship between the plant and its resource base), and support (fertilizers and pesticides) and postharvest inputs (storage, transport, and processing). The classification of livestock production has to be expanded to include the fields of animal nutrition and health (Siamwalla 2001).

It is clear that the private sector plays an important role in the third category of technology because this sector can capture the entire benefit (either through patents or trade secrets) from its investment in research. The technology referred to in the second category is mostly the work of scientists in the academe. MNCs in developed countries have also recently become involved in such research, thanks to intellectual property laws. Research on animal nutrition is mostly the effort of large-scale farmers and agribusiness firms. In Thailand, the academe has also been actively involved in such research because most farmers are smallholders with no incentive to do this kind of research. Research on animal health is done mostly by multinational drug companies.

Traditionally, agricultural research, particularly genetic improvement, has been the domain of the public sector due to two reasons: economies of scale in gene banks and research being a public good. But some of the research in genetic improvement is also carried out by the private sector (or farmers) because they can benefit from their research effort. Siamwalla (2001) lists three categories of genetic-improvement research according to the ability of the

private sector and farmers to capture the benefits. The first category is research on self-pollinating crops (e.g., rice) and crops that undergo vegetative propagation (e.g., cassava and sugar cane). This type of research is usually done by the public sector since the private sector cannot recover the research cost due to the fact that the farmers who obtain the improved germplasm can simply use the seeds from the harvested grain for future crops.

The second category in genetic-improvement research includes cross-pollinating crops (e.g., hybrid maize and sorghum) and small animals like chicken and swine. Crops that propagate themselves by cross-pollination have a high rate of outcrossing. The quality of seeds from experiment stations can rapidly degrade in succeeding generations. Because of this, a private commercial maize seed industry arose to supply farmers' needs. Private companies can benefit from their research from the sale of seeds. In Thailand, there are a few MNCs and Thai firms that do research and supply the maize seeds to farmers and export the seeds as well. Interestingly, the private maize-seed industry came about after a public university successfully developed a new variety, Suwan, which was resistant to downy mildew. The research on hybrid rice in Thailand was also done first by the public sector. It took decades, however, before a private company began to sell hybrid rice seed in 2009.

The poultry breeding industry is organized somewhat similarly to the hybrid maize seed industry, with a few MNCs dominating the industry. In Thailand, it was CP that introduced imported chicken breeds together with the contract farming system in the 1970s. Since then, the poultry-raising industry has become industrialized. CP also entered the swine-raising industry in the 1980s using a similar but unsuccessful business model. Although CP has a large market share in the pig-feed industry and operates its own pig farms and slaughterhouse, the swine industry is still dominated by a large number of medium- and large-scale pig farms, thanks to the research on heat-tolerant breeds and improved pig feeds done by a public university and the Department of Livestock Development.

The third category of genetic-improvement research deals with tree crops (e.g., rubber) and large animals (e.g., cows). Since the generation length of these crops and animals is counted in years, it is very costly to crossbreed on a trial-and-error basis. As a result, the private sector has less incentive to do research. Thus, most crossbreeding activities are done by farmers and

public research agencies. The role of private firms, however, will increase with the advent of modern cloning technologies.

3.4 Technology in the Food Processing Industry: The Role of Agribusiness Firms

Most of the technologies used in the food processing industry have been introduced or adapted by agribusiness firms. Since food processing includes activities like product grading, handling and transportation, processing, stocking, distribution and marketing, the type of technologies required should incorporate those activities as well. These technologies include (1) genetic improvement (e.g., production of hybrid seeds, disease-tolerant seeds, etc.) and farm machinery; (2) postharvest technologies (e.g., product-grading machines, grading stations, and mechanization of handling tasks); (3) processing technologies involving new, automatic machines and more efficient use of raw materials and energy; (4) management methods and other software technology (e.g., Good Manufacturing Practices or GMP, Hazard Analysis and Critical Control Points or HACCP, Total Quality Control or TQC) and new organizational techniques to improve the efficiency of doing business such as contract farming and, more recently, central procurement and the implementation of private product standards developed by the modern supermarkets, which has already been discussed in section 3.3; (5) logistics, which involves storage and transportation (e.g., refrigerated trucks); and (6) product development. These technologies can be grouped into two broad categories—hardware and software technologies. **Table 3.8** lists some of the key technologies. It should be noted that, unlike agribusiness firms in developed countries, most Thai firms tend to adopt the last four types of technologies, particularly the ones considered software technologies. Although some companies have been active in R&D on hybrid seeds, most of the hybrid breeds used in Thailand are imported and adapted to the local environment (e.g., white shrimp and hybrid broilers). In general, Thai companies have not had adequate resources to develop their research capability, given their business scale. When business expands, they will have to use other strategies to quickly obtain critical technology. CP, for example, decided to take over an American research company that controls the chicken-breeding technology, but it did this only after it successfully expanded its poultry business in China, which is the world largest market for chicken.

After describing the technology-upgrading activities of the food-processing industry, the factors affecting the firms' decision to adopt such technologies will be analyzed.

Technology Upgrading

In response to the changes in the relative prices of inputs and output as well as external shocks, firms have to adopt and adapt new technologies, change their marketing strategy, and sometimes reorganize their organizations. There are four important strategies employed by agro-business companies: technology, management, organization, and marketing strategies.

There have been a few studies (Archanun 2006; Bhanupong 2007; Phatarapong 2010; and Poapongsakorn et al. 2010) analyzing the technology-improvement and technology-upgrading activities of agribusiness companies in some food industries. Some of these activities also involve technological improvements in the agricultural sector. Some of the findings of these studies are as follows.

First, agribusiness companies in all food sectors have adopted some kind of technology improvement. Contrary to the popular argument in the literature (e.g., Doner 2008) that most Thai companies are good at diversification but not at technology upgrading, a few studies (Archanun 2006; Phatarapong 2010; Poapongsakorn et al. 2010) found that some large-scale food companies have actively engaged in technology improvement, if not upgrading. It is the large-scale firms that have a long-term strategy on research and have put serious effort and large investments in R&D. For example, CP (the animal group) invests more than one billion baht per year on R&D. It hires several hundred researchers, many of whom are poached from university and public research centers. Although there are only a few firms that adopt and adapt new technologies in each subsector of the food industry, one can argue that the fact that each industry has a few leaders who put in serious effort in technology improvement means that, sooner or later, there will be a spillover effect as other firms begin to copy and adapt the new ideas. Though most small- and medium-scale firms are still not investing in R&D (Phatarapong 2010), these same firms are quick copycats.

Second, the comparative advantage of Thai food exports does not only depend on the availability of domestic raw materials produced by the agriculture sector but also on other,

more important factors, especially the companies' ability to constantly add value and improve the quality of their products so that they can overcome the pressure resulting from the increasing scarcity of raw materials and labor shortage. A few examples should be sufficient to illustrate the point.

CP, the largest agribusiness company in Thailand, has successfully exported frozen chicken since 1970s and frozen shrimp since 1980s to markets in developed countries (i.e., Japan, the EU, and the United States). As labor cost became more expensive, it gradually switched to the higher-value, ready-to-eat chicken products and new product varieties. In the past, its export success was attributed to cheap labor and its ability to exploit market opportunities in Japan by seeking investment privileges to establish a modern slaughterhouse, introduce new chicken-raising technologies, and engage in contract farming as discussed in part 1. Later on, it successfully adopted new technologies for food processing, which enabled it to improve its food-safety standards in response to the stringent demand of consumers in the developed world. When the chicken industry was almost brought to its knees by the bird flu outbreak in the early 2000s, CP was able to quickly shift from exporting frozen and fresh chicken to cooked chicken meat and ready-to-eat products, thanks to its prior investment in new processing factories. Its partnership and coordination with Japanese importers also provided CP with the necessary information on the types of products and food safety standards that are required in the world market. More recently, its partnership with Tesco in the Tesco-Lotus supermarket in Thailand has enabled CP to gain access to the British retail market for its ready-to-eat chicken products. This access is made possible by its ability to satisfy the complex requirements of England's strict animal welfare standards.

Other chicken exporters were also able to quickly respond to the export opportunity for safe food. When South Korea abandoned its import quotas on chicken in 2001 and reduced import tariffs, Thai exports of processed chicken wings to South Korea significantly increased after thirty-three Thai factories successfully obtained food safety certificates (Nidhiprabha and Chamchan 2005). CP was one of those exporters.

A second example is that of Chor Heng, a large-scale flour producer and the first Thai exporter to successfully export rice flour to the United States despite the stringent standards imposed by the U.S. Food and Drug Administration (FDA). These examples show that Thai

exporters have been more than able to meet the food safety standards for high-end markets and that they were able to develop this capability ahead of other developing countries (Nidhiprabha and Chamchan 2005).

The third example focuses on exporters of canned tuna. Thailand is the largest exporter of canned tuna in the world. Its success implies efficient scale of production, high quality standards, and well-known brand names. Some Thai companies have already established their brand names as premium quality products (e.g., Nautilus brand of Pattaya Food Industry; Sealect brand of Thai Union Manufacturing Co., more recently known as TUF). The product range has also been expanded from the original product range of tuna in oil or tuna in springwater to value-added products such as spicy tuna and mayonnaise tuna spread. But perhaps the most important factor is that majority (94 percent) of the Thai seafood-processing companies have obtained at least one quality standard certification, either ISO 9000 or HACCP, or even both certifications (ibid.). This clearly shows that most Thai companies are aware of the need to comply with SPS norms. Their effort to have their brand names identified with products meeting high food safety standards has become the industry norm in Thailand (ibid.).

Thailand is also one of the leading exporters of canned pineapples with exports of more than 358 million tons, accounting for more than 80 percent of total production in 2002. The exports have encountered significant trade barriers. Being the largest exporter of this commodity, Thailand has been accused of dumping by producers in the United States. It also has to compete with African and Caribbean products, which are given preferential tariff treatment by major importers. A sharp decline in Thai pineapple exports from 500 million to 700 million tons in the early 1990s to less than 400 million tons in the early 2000s can be partly attributed to those factors. But Thai exports have remained competitive, thanks to manufacturers' continuous effort to upgrade product quality standards in order to meet the requirements of international customers. Some companies (e.g., Dole Thailand) have minimized the use of pesticides though integrated pest management (IPM). This has been made possible by adopting the vertically integrated structure, which combines plantation, processing, canning, shipping, and market operations (Nidhiprabha and Chamchan 2005).

Finally, the food export industry has shown its willingness to invest in a public good to help solve problems in the export market. In response to the nitrofuran incident in 2002, which involved eighty-five cases of Thai exports of chicken and shrimps, the private sector acted swiftly by pooling resources to buy chemical-residue testing devices (Elisa test kits) worth THB 5 million. The private sector thus effectively worked around the delay in the approval of the government budget, which would have funded the purchase of the testing devices. The testing devices were deployed to wholesale seafood markets in Samut Sakorn and Nakorn Srithammarat. It should also be noted that the nitrofuran incident helped speed up the establishment of the Bureau of Agricultural Commodity and Food Standards (ACFS) in 2002. The main responsibility of this bureau is to establish and enforce food safety standards, build cooperation among concerned entities or agencies, and negotiate on issues relating to international standards setting, which affects international trade. Realizing the export benefits of having standards in agricultural production, the food industry supported the ACFS in establishing national standards (GAP) for poultry and dairy farms and the Agricultural Standards Act was quickly legislated.

How and Why Firms Acquire and Upgrade Technology

Most Thai firms acquired technological capability through four channels (Archanun 2006; Phatarapong 2010). The first channel is through MNCs who are the buyers (MNE buyers). Their products have to comply with the food safety regulations of the importing countries. MNE buyers play critical role not only in providing information on required regulations but also in giving technical advice on how to comply with the new regulations. Another important role of the MNE buyers, particularly the Japanese MNEs, involves product development. The MNE buyers constantly carry out market research on the new food products their customers demand. They will thus ask their suppliers to produce the new products by providing details on formula and required ingredients. After successful production, some Thai suppliers begin experimenting with cheaper ingredients. In the process, Thai suppliers acquire the capability to develop new products. As a result, these companies (e.g., CP, Betagro, TUF) will establish a research unit in their company. CP, for example, does not only put billions of baht in R&D but is now also hiring hundreds of researchers in diverse fields. These researchers include food scientists, food engineers, home economics graduates, restaurant management graduates, animal scientists, plant breeders, and

veterinarians. Thus, R&D activities have gradually become an important channel through which a few large-scale firms have been able to develop their technological capability and upgrade their technology.

The third channel is labor mobility. Hiring skilled labor from other companies is the most important means by which small and medium enterprises (SMEs) can acquire technology. The last channel is the copying and demonstration effect. When new food products have become popular, other firms—large and small—begin to imitate the originator of the product. The Thai food market has experienced such phenomena in recent years. As a result of the competition among food companies, consumers have benefited from lower food prices and more choices in food products.

Agribusiness firms, in general, decide to adopt new technologies or upgrade their existing technologies for four reasons: higher revenues, cost reduction, response to increasing pressure for food safety by the consumers, and, last but not the least, market opportunity and threats. Agribusiness firms invest in breeding technologies and improved animal feeds because these result in higher production and higher revenues. Examples include new chicken breeds and improved shrimp larvae. Firms also adopt various technologies to reduce production and logistic costs (e.g., grading machines, waste-management technologies, energy-saving devices, truck-handling stations, GPS units and truck-fleet monitoring devices, truck queueing-in for the sugar mills, among others). In response to the demand for safe food and adherence to food safety regulations, firms have adopted a number of management processes and standards (e.g., HACCP, GMP, GAP, traceability, and other international standards). The last reason is market opportunity and threats. The increase in consumers' income and changing consumption behavior have encouraged many firms to introduce new high-value products such as ready-to-eat and ready-to-cook products, organic products, hydroponic vegetables, and biodegradable products. CP's chicken products comply with the strict animal welfare requirements of the United Kingdom (UK). Some canned-seafood firms have bought international brands (e.g., Bumble Bee and Star Kist). Other food companies pack their products in retort pouch packages so that the product will taste better than canned food.

4. Some Problems of Public Research in Agriculture

This part will describe the pattern and trend of R&D expenditure in Thai agriculture and food processing industry followed by a discussion of some critical problems in agricultural R&D of the public sector.

The Thai government has always played the biggest role in agricultural research. Research efforts began a century ago when the government sent students to study agricultural science abroad. One of the graduates began to collect the best native rice breeds, and one of these breeds won a competition in Canada. Major effort was expended on the training of hundreds of plant breeders after the Second World War. In the late 1960s, hundreds of agricultural students received scholarships to study abroad. The formal organization of public research in agriculture began in the late 1950s and early 1960s when the government established important research departments in the Ministry of Agriculture (MOAC)--the Department of Rice, Department of Agriculture, Department of Fishery, and Department of Livestock. The research system of these departments consists of national research centers that are responsible for specific product groups (e.g., the Rubber Institute, Field Crops Institute, etc.), regional research centers, research stations, and disciplinary research in the national centers (e.g., plant protection, biotechnology, postharvest, etc.). In addition, public universities, particularly Kasetsart University, also play an active role in research. In 1983, the National Center for Genetic Engineering and Biotechnology was established. In 1991, it was merged with the independent National Sciences and Technology Development Agency (NSTDA). Its scientists conduct agricultural research with emphasis on biotechnology. A few private agribusiness firms are active in research on livestock, fishery, and seeds while farmers usually carry out their own R&D on fruit trees, orchids, flowers, and fisheries.

There are five public funding agencies: the National Research Council (NRC), NSTDA, the Thai Research Fund (TRF), the Agricultural Research Development Agency (ARDA), and Thailand Tapioca Development Institute (TTDI). While the NRC is a government agency, the other three (NSTDA, TRF, and ARDA) are independent public agencies. TTDI is a foundation. The NRC is also responsible for the approval of research proposals submitted by all government agencies, including public universities. The TRF funds applied research that is mostly carried out by university professors and graduate students. The last two funding

agencies finance agricultural research. The ARDA finances commercially feasible agricultural research while the TTDI takes charge of cassava research.

The first three agencies source their funds from the fiscal budget. The ARDA is funded by a loan from the ADB while the TTDI has an endowment fund from the proceeds of the cassava auctions in the early 1990s.

The budget for agricultural research at the MOAC began to increase from THB 78.3 million in 1961 until it peaked at THB 10,872 million in 1997. After declining for a few years, the budget began to increase again in 2003, reaching THB 12,509.1 million in 2009. If the budgets of the other public funding agencies are included, the total expenditure for agricultural research amounted to THB 13,736.3 million in 2009 (**table 4.1**). In 1988 prices, the real research expenditure peaked in 1977. Although it increased in recent years, the real expenditure in 2009 was still lower than that in 1977. It should also be noted that the research budget is prone to cuts during economic crises, such as what happened in 1998 and 2008 (**table 4.1**).

The private sector recently increased its role in agricultural research. Casual observation suggests that private research in agriculture has increased in the fields of hybrid seeds (e.g., baby corn, vegetable seeds, hybrid rice, etc.), genetic improvement of rubber trees, cultural practices, and postharvest technology. A survey by the NECTECH found that a few agribusiness firms spent THB 869.71 million on agricultural research in 2007, which is about 30 percent of all agricultural research expenditure. This is much higher than the 13 percent estimated by Fuglie (2001).

In recent years, many policy makers (especially those in funding agencies) and scientists have raised their concerns about a decline in Thailand's competitiveness. One of their main concern is that Thailand's investment in research is very small, compared to other countries. Public research in agriculture has also experienced similar financing problems in addition to other problems.

The first problem is that agricultural research intensity, measured by the ratio of the MOAC's research budget to agricultural GDP, peaked at 0.92 percent in 1993 and never recovered. It was only 0.37 percent in 2009 (**figure 4.1**).

Second, agricultural research has always been less important than extension services. Ever since its establishment, the Department of Agricultural Extension's (DOAE) budget has always increased faster than the research budget until it reached its highest level in 1998 (see **figure 4.2**). The extension budget was as high as 62 percent of the total research budget in 1996—97. After 2005, the research budget began to increase at a faster rate. However, this is misleading. Bureaucrats and politicians have managed to increase the extension budget and hide this increase in the research departments. Interviews with senior officers in all research departments of the MOAC show that the bulk of the research budgets of the research departments have been diverted to "development" activities under the guise of R&D. In fact, the budget is used for extension activities because such activities have immediate political impact. One reason for the ease with which this move has been carried out is that there is no clear distinction between "development" and "extension." Interviews with officers at some research departments reveal that about 80 percent to 90 percent of their R&D budget is used for the "D" activities.

Third, the allocation of the research budget has been without a clear direction, which results in inefficient allocation (**table 4.2**). One cannot immediately identify the objectives or the criteria for budget allocation. The research intensities (measured by ratio of research expenditure to output value) for crops, animals, and fish vary widely. Rice and rubber, which are the two largest crops, have a research intensity of only 0.05 percent and 0.037 percent, respectively. Orchids and oil palm, which account for less than 0.6 percent of agricultural output, have a research intensity of 0.32 percent and 0.35 percent, respectively. It should also be noted that many research projects that should be carried out by private companies (e.g., orchids and swine) received more budget than the crops whose research should be funded by public funds (e.g., cassava). The problems of research-budget allocation are not caused by the lack of a national research strategy. Rather, the problem is caused by the fact that each research agency has its own research agenda determined by the department heads, the researchers, and their minister. For example, the Department of Livestock Development (DLD) has to give the highest priority to R&D programs on goats because of the conflicts in

the four southern provinces in recent years. There is no systematic process of taking into account the changes in the demand and markets in the process of budget consideration (see further discussion on the role of funding agencies below).

Fourth, the research budget is fragmented. Since there were 4,020 projects between 2007 and 2010, the average budget for each project works out to only about THB 0.98 million. The problem is caused by the fact that there are too many research funding agencies, each with its own mission. Moreover, these agencies are subject to the "divide and rule strategy" of the budget bureau because they have to negotiate their budget requests with this powerful body.

Fifth, since the allocation of the budget is also on an annual basis, many medium- and long-term research projects may not receive enough budget in some years. Thus, researchers are forced to downsize their research, affecting research output and the effectiveness of the projects. Given the fact that agricultural technology usually takes five to eight years to develop, the yearly budget allocation process is not an efficient way of investing. In fact, the four public funding agencies have begun to finance some projects on a four- to five-year basis. Nevertheless, some problems remain when their budget request is cut by the budget bureau. In addition, the long lag in the budget consideration process also means that it takes two years for the research proposal to be funded.

Sixth, most research and extension programs are bureaucratically and politically driven. This is because the board members of the public funding agencies who make decisions on budget allocation are dominated by senior government officials. About 40 percent to 74 percent of the board members on the board of directors of four funding agencies consists of senior government officials. Members belonging to the private sector are in the minority, accounting for 0 percent to 15 percent of the board of directors. The only agency with 44 percent of its board of directors coming from the private sector is the NSTDA.

Finally, Thailand has begun to experience a shortage of high-caliber agricultural researchers. Although there are more researchers in agriculture than in other sciences, there is a smaller number of agricultural researchers with PhDs (**figure 4.3**). Moreover, a number of senior researchers (some with PhDs) have already retired and more will retire within the next few years. It will be difficult to replace these senior researchers because of the low government

salary and lack of attractive incentives. In the last five years, eleven rice researchers retired with no replacement. Within the next seven years, sixty-four rice researchers will retire, seven of whom have PhDs. The number of research staff at the Department of Agriculture also dropped by 6 percent between 1994 and 1998. In addition, Thailand now has smaller number of agricultural researchers than Viet Nam, the Philippines, and Indonesia (**figure 4.4**).

5. Conclusion and Some Challenging Issues

This study explained the sources of growth of Thai agriculture and the food processing industry. Besides land abundance and good macroeconomic policies, the critical factors are public investment in infrastructure and education; the investment made by farmers, which has been made possible by the establishment of the BAAC; and the investment made by agribusiness firms. Although the growth of TFP came behind capital as the most important source of growth, TFP growth resulted in the sustainable, long-term growth of Thai agriculture. The long-term growth of agricultural productivity makes it possible for food exports to grow rapidly and keep Thailand as one of the world's largest exporters of food. Since investment in agricultural R&D is the major factor explaining productivity growth, the rate of return on investment in agricultural research is very high.

The impressive growth of the food industry is also mainly attributed to technology. Unlike in agriculture where research is mainly carried out by the public sector, it is the private sector that takes the lead role in food research in the food industry. Moreover, in recent years, a few large-scale agribusiness companies have begun to carry out their own research in agriculture. Some of the innovations and technologies that have been successfully developed are sold to farmers while others are freely distributed by the firms.

That the rate of return on agricultural research is very high (i.e., more than 30 percent to 40 percent) means that the government underinvests in R&D. In the past, the Thai government used to invest heavily both in agricultural research and in the training of researchers, particularly plant breeders. Recently, however, research intensity has declined drastically to a level (0.37 percent of agricultural GDP) that is lower than the research intensity of some

ASEAN countries. There are also many problems in the allocation of the research budget, which results in the inefficient use of said budget.

The rest of this chapter will briefly identify some important challenges—internal and external—facing Thai agriculture as well as some opportunities. Some policy implications will also be discussed.

Challenging issues

Thai agriculture is at a crossroads. It is facing several internal and external challenging issues. The internal constraints include labor shortage, increasing water scarcity, water and soil pollution caused by intensive agriculture, resource degradation, and increasing incidence of pest infestation and disease outbreaks. Labor shortage is one of the most serious problems not only because of the higher wage rate for hired labor (which can be partially mitigated by mechanization) but also because of the massive migration of young people out of agriculture (estimated at four million workers aged 15--34 years between 1991 and 2010). As a result, there is now a greater number of older farmers, with the average age of 52 years old and about 18 percent of whom are older than 60 years old. The problem is that as these elderly farmers retire, they are unlikely to be replaced by their sons and daughters who are now living in the cities. Those who wish to rent out their land will find that the legal regulations are biased in favor of the tenants (i.e., the rental contract has to be at least six years and if the landlord wants to sell his/her land, he/she has to give the tenant the right to buy before other potential buyers). If the law is not repealed, it is possible that a large number of lands will be left idle, affecting agricultural production.

The external challenges include climate change, widespread trade protection policies, and the increasing demand for safe food and foods that are produced and marketed in a socially responsible manner. Some studies predict that climate change will have serious impact on irrigated rice in the Central Plains within the next twenty to thirty years. (Rerkasem 2010; IFPRI 2008). It may, however, have a positive impact on some crops such as sugar cane while other crops, such as cassava, may not be affected (Rerkasem 2010).

Nevertheless, the future for Thai agriculture is still promising, given the increasing prices of food on the world market (IFPRI 2009; FAO 2009).[6] In addition, higher per capita income in the emerging economies of the world should result in increasing demand for high-value agricultural products in which Thailand has acquired comparative advantage.

Policy Implications

Thailand will be able to exploit such export opportunities only if it can tackle the constraints previously discussed. This requires changes in some key policies. As has already been mentioned, the agricultural tenant law has to be repealed so that it can provide balanced protection of rights to both the land owners and the tenants. The cumbersome legal process to evict tenants who refuse to move out after the contract has expired has to be streamlined. These constraints seriously affect the efficiency of the land-rental markets.

The second policy concerns the water demand-management policy. In response to increasing demand for water from the agricultural and nonagricultural sectors, the government has invested heavily in irrigation (especially in small and medium irrigation systems) in the last two decades. Despite this, the policy has not been effective in mitigating water-scarcity problems for several reasons such as the limited supply of surface water and the lack of investment coordination among a few dozen government agencies, among others (TDRI Report 2002). There has been a recent attempt to revise the demand management policy by drafting a new water law. The government, however, still controls property rights over water and still wants to impose a water-management system at the large river basin level. Still, water conflicts (most of which break out between the upstream and downstream farmers) arise at the small tributary of the river basin. Some studies found some success cases in water management organized at the local community level. The policy implication, therefore, is that a water management system can be effectively implemented if the local people are allowed to

[6] There are several reasons for the increase in world food prices (e.g., the pressure from biofuel policies in many developed countries; the slower growth of agricultural production due to the decline in public investment in agriculture and agricultural research; the increase in population and higher per capita income in the emerging countries). The World Bank (2008), however, argues that the demand for food in the emerging economies may increase only slowly in the future. Moreover, if new technologies for alternative energy can be commercially developed, there will less pressure on the future prices of commodities.

organize the system and if they are granted the right to manage water utilization at the small tributary of the river basin (Mingsarn 2011).

Finally, the most important policy would be the reform of agricultural research and extension policies. Without new technologies to cope with resource constraints and rapidly increasing production cost, Thai agricultural exports will quickly lose their competitiveness. Moreover, technologies will enable Thai farmers and agribusiness firms to move away from the production of low-value and labor-intensive agricultural products and to exploit the opportunity presented by increasing demand for high-value and safe food products. Higher-value products include health foods, organic foods, foods that are produced in an environment friendly and socially responsible manner as well as foods with therapeutic or medicinal value. At the top of the research agenda is the immediate need for the government to increase the research intensity for public research to 0.7 percent of agricultural GDP within the next few years and then to gradually increase it further to 1 percent in the coming decade. Public research should be financed by general revenues, a special levy on exports for exportable crops, and a research levy for import-substituting crops that are cash crops. The research levy will result in a steady research budget, thus allowing funding agencies to finance medium- and long-term R&D projects lasting at least five to eight years before the new technology can be fine-tuned and disseminated.

Another important policy change involves putting in place an objective mechanism for effective budget allocation. The current decision-making process on allocation is dominated by bureaucrats and politicians and needs to be more market-driven. The composition of the NRC has to be changed (e.g., reducing the number of senior bureaucrats and retired bureaucrats). After the NRC identifies the research objectives, the funding agencies should jointly commission a research study on the priority setting of the research budget using an approach similar to economic surplus. The decision process should also involve all the stakeholders in agricultural research and business.

The incentives for researchers also need to be overhauled. The promotion system and career path for researchers who are civil servants have to be different from that of other civil servants. The evaluation of the academic performance of university professors also needs to be changed so that it provides incentives for researchers to work on medium-term projects

and to work as a team because agricultural R&D involves scientists from many disciplines. The government should also provide more scholarships for PhD students. Universities should be allocated more funds to finance the research projects of PhD students and postgraduate students who will have to work with their professors.

The Thai government has already provided generous income tax incentives for private firms that invest in R&D. However, the government should allow agribusiness firms to submit research proposals and to bid for theme research financed by public money. This will not only increase competition in research but will also enable researchers in agribusiness firms to work with public sector researchers. Of course, certain rules on intellectual property rights have to be established in a transparent and accountable manner.

Last but not least, the extension services provided by central government agencies need to be restructured. Even though the government has spent more on extension services than on research, farmers are not satisfied with the service. There are a number of success cases in the provision of extension service in many developing countries involving the decentralization of extension services to the local government and the participation of nongovernment organizations (NGOs) and university professors in extension services (World Bank 2008). The government should, therefore, begin to restructure extension services by carrying out several pilot projects and evaluating the effectiveness of new approaches.

References

Achanun Kohpaiboon. 2006. "International Trade: From Multilateralism to Bilateralism." Paper presented at *the Faculty of Economics 26th Symposium*, Thammasat University, Bangkok, July 2006.

Chedtha Intaravitak. 2010. "Decomposing Growth: A Historical/Decomposition Simulation of Thailand Sectoral Growth." *TDRI Quarterly Review* 25, no. 4, 8--16.

Chutikul, Sirilaksana. 2006. "Thailand's Trade Strategy under the Changing Global Socio-Economic Environment: A Case of Non-tariff Measures". In *The Processing of the 2006 Annual Seminar on Thai Economy under the Changing Global Socio-Economic Environment*. Faculty of Economics, Thammasat University, Bangkok.

FAO. 2009. *The State of Food and Agriculture 2009: Livestock in the Balance*. Rome: The Food and Agriculture Organization of the United Nations.

IFPRI. 2008. "Global Food Crises: Monitoring and Assessing Impact to Inform Policy Responses." *IFPRI Issue Brief* No. 55, International Food Policy Research Institute, Washington D.C.

———. 2009. *Climate Change Impact on Agriculture and Costs of Adaptation*. Washington D.C.: International Food Policy Research Institute.

Mingsarn Kaosa-ard. 2011. "Reform in Thailand: Reforms in Water Management." Paper presented at a seminar organized by the National Assemblies Reform Committee, Rama Gardens Hotel, Bangkok, January 21.

Nidhiprabha, Bhanupong and Chalermpol Chamchan. 2005. "SPS and Thailand's Exports of Processed Food." In *Food Safety Regulation Concerns and Trade—A Developing Country Perspective*, edited by Rajesh Mehta and J. George. Delhi: Macmillan India Ltd.

Orachos Napasintuwong Artachinda. 2010. "Economic Impact of Research Rice Varieties: Chainart." Paper presented at the First National Rice Research Conference, Kasetsart University, Bang Khen, December 16.

Patarapong Intarakumnerd. 2010. "Seven Habits of Thailand's Highly Ineffective Technology and Innovation Policies." College of Innovation, Thammasat University.

Poapongsakorn, Nipon and Chaiyasit Anuchitworawong. 2006. "The Decline and Recovery of Thai Agriculture: Causes, Responses, Prospects and Challenges." In *Rapid Growth of Selected Asian Economies: Lessons and Implications for Agriculture and Food Security; Republic of Korea, Thailand, and Viet Nam.* FAO Policy Assistance Series 1/3, Bangkok: FAO.

Poapongsakorn, Nipon, Nessara Sukpanit, and Nipa Srianan. 2007. "The Current Situation and Government Policy in the Cassava Industry." Paper prepared for the Thailand Tapioca Development Institute.

Poapongsakorn, Nipon, Viroj Na Ranong, Christopher L. Delgado, and Clare A. Narrod. 2003. "Policy, Technical, and Environmental Determinants and Implications of the Scaling-Up of Swine, Broiler, Layer and Milk Production in Thailand." *Livestock Industrialization Project: Phase II*. Prepared for FAO and IFPRI. Bangkok: Thailand Development Research Institute.

Porphant Ouyyanont et. al. 2010. *Contract Farming: Return Risks and Fairly*. Bangkok: Thailand Research Fund (TRF).

Rerkasem, Benjavan. 2009. "R&D Strategy for Climate Change." Thai Health Promotion Foundation.

TDRI Report. 2002. Water Management Policy for Thailand. *TDRI Report* Vol.33. Bangkok: Thailand Development Research Institute.

TDRI. 1996. "The Potential for the Development of Contract Farming: The Case of Cotton Production in Thailand." Prepared for Monsanto Thailand Limited. Bangkok: Thailand Development Research Institute.

Tinakorn, Pranee and Chalongphob Sussangkarn. 1998. *Total Factor Productivity Growth in Thailand: 1980--1995*. Bangkok: Thailand Development Research Institute.

Wacharin, Meerod. 2010. "Economic Impact of Research Rice Varieties: RD6 Blast Resistance." Paper presented at the First National Rice Research Conference, Kasetsart University, Bang Khen, December 16.

Waleerat, Suphannachart. 2009. "Research and Productivity in Thai Agriculture." Departmental Working Paper 2009-11, Arndt-Corden Department of Economics, Australian National University.

World Bank, The. 2008. *World Development Report 2008: Agriculture for Development*. Washington D.C.: The World Bank.

Tables and Figures

Table 2.1. Value Added Share and Annual Growth Rate of Agricultural Subsectors

Subsectors	1960-85	1985-96	1996-98	1998-2009	1960-2009
Agricultural (share of agricultural GDP)					
- Crops	65.49	64.86	64.27	64	66.41
- Livestock	10.62	10.68	10.74	10.69	9.06
- Fisheries	6.7	6.9	7.18	7.49	13.88
- Forestry	6.11	6.05	5.98	5.79	1.98
- Agricultural services	3.55	3.68	3.77	3.81	2.32
Agricultural (share of GDP)					
- Crops	14.54	13.9	13.32	12.88	7.96
- Livestock	2.36	2.29	2.23	2.15	1.09
- Fisheries	1.49	1.48	1.49	1.51	1.66
- Forestry	1.36	1.3	1.24	1.17	0.24
- Agricultural services	0.79	0.79	0.78	0.77	0.28
Growth rate of agricultural					
- Crops	3.98	2.63	-0.64	2.8	3.37
- Livestock	4.37	3.82	-3.26	3.1	3.8
- Fisheries	7.35	9.29	-1	3.54	5.38
- Forestry	0.62	-11.12	-6	-1.64	-3.38
- Agricultural services	4.4	-0.81	-8.54	-0.36	0.54
Food and beverages (share of GDP)	2.86	3.09	3.25	3.44	5.52
	1980-85	**1985-96**	**1996-98**	**1998-2009**	**1980-2009**
Food and beverages					
- Share of manufacturing GDP	13.78	14.62	15.08	15.61	17.72
- Growth of manufacturing GDP	6.75	10.84	0.49	3.83	6.67
	1970-85	**1985-96**	**1996-98**	**1998-2010**	**1970-2010**
Simple agricultural processing					
- Share of manufacturing GDP	8.05	7.92	7.76	7.50	2.45
- Growth of manufacturing GDP	5.09	6.97	-1.79	2.15	5.47
		1988-96	**1996-98**	**1998-2010**	**1988-2010**
Share of agricultural export		100	100	100	100
- Crops		92.0	92.6	95.6	94.8
- Livestock		9.1	11.9	12.3	11.7
- Fisheries		43.0	45.0	26.7	30.4
Share of food processing export		100	100	100	100
- Crops product		12.4	8.6	11.2	11.3
- Livestock product		1.6	3.6	2.6	2.5
- Fisheries product		32.2	33.9	35.7	35.0
- Beverage		1.7	2.3	3.2	2.9
Growth of agricultural export		508.3	10.0	10.7	8.2
- Crops		5.3	9.9	11.1	8.5
- Livestock		8.9	34.5	5.5	9.8
- Fisheries		15.0	17.1	0.0	4.7
Growth of food processing export		7.1	17.8	6.8	8.5
- Crops product		9.3	1.3	8.8	8.3
- Livestock product		40.4	46.7	5.7	16.3
- Fisheries product		8.9	31.3	4.8	9.0

- Beverage		21.8	2.4	12.7	14.5

***Source*:** Calculated from NESDB, National Income

Table 2.2. Growth Rates of Output Classified by Traded and Nontraded Products

Items	**Growth (% p.a.)**				
	1980-1985	**1985-1990**	**1990-1996**	**1996-1998**	**1998-2004**
Traded Crops	5.84	2.34	2.00	0.52	2.96
Import Competing Crops	2.95	10.17	4.77	-9.09	4.39
Nontraded Crops	2.37	5.46	3.59	-5.72	6.96
Traded Livestock Products					
- Hens	7.08	7.67	4.42	10.44	9.73
Import Competing Livestock Products	4.23	5.66	4.74	-18.27	6.61
Nontraded Livestock Products	0.34	6.58	0.18	-4.41	4.90
Traded Fishery					
- Marine Fish	4.26	8.70	7.93	-0.85	0.45
Nontraded Fishery					
- Freshwater Fish	0.36	2.23	10.64	-2.02	4.64

***Source*:** Calculated from NESDB, National Income

***Note*:** (1) Exportable crops include paddy, cassava, kapok, tobacco, sugar cane, maize, sorghum, mungbean, sesame, black pepper, pineapple, rubber, and orchids. (2) Import-competing crops are cotton, kenaf, jute, soybean, garlic, shallots, oil palm, cocoa, coffee and tea. (3) Nontraded crops consist of native tobacco, castor bean, groundnut, chili, bird pepper, vegetables, fruits (except pineapple), coconut, flowers (other than orchids), and other crops. (4) Traded livestock = import-competing livestock = dairy products and cattle. (5) Nontraded livestock = buffaloes, swine, ducks, chicken, and duck eggs.

Table 2.3 Share of Land Holding by Crop (%)

Crops	1993	1998	2003	2008
Paddy Rice	55.4	56.1	52.3	50.6
Field crop	21.3	18.8	19.1	19.7
Vegetable/flower and ornamental plant	0.9	1.4	1.2	1.2
Permanent crop	9.6	10.6	11.7	10.5
Para rubber	8.0	9.4	8.6	12.1
Total area of holding	100.0	100.0	100.0	100.0

Source: NSO, Agricultural Census and Inter Census

Table 2.4. Value Added of Food Subsectors and Performance Ratios in 2005

	Food	Beverage	Rice Products	Sugar	Maize	Seafood	Coffee	Dairy	Meat	Fruits
Share of food value added	100	27.0	11.7	8.6	7.9	6.0	6.0	4.5	7.9	4.0
- rank	-	1	2	3	4	6	7	7	5	8
Export share	100	4.7	8.4	17.8	2.5		7.4	8.4		14.5
- rank	-	6	4	2	8		10	10		3
Key performance ratio										
VA/Output	26.5	52.8	16.5	40.9	18.8	18.8	36.1	30.2	18.8	21.8
Export/Output	32.4	3.6	36.5	36.7	18.8	95.4	51.8	17.3	18.8	59.6
Wages/VA	26.7	12.2	36.8	25.3	33.2	31.0	30.8	25.7	33.2	30.1
Profit/VA	50.2	28.2	52.0	52.9	58.5	59.1	53.5	42.6	58.5	52.6
Imported inputs/Intermediate	17.5	25.2	7.0	6.3	1.6	33.2	18.0	16.5	1.6	14.4
Sources of growth 2000--2005										
- Private consumption (%)	54.7	52.1	26.4	-531.3	86.6	-14.8	87.9	87.9	68.6	63.8
- Export (%)	24.8	-2.6	39.2	-2,450	24.2	-121.6	16.5	16.5	34.2	43.3

***Source*:** Calculated from NESDB, *Input-Output Table*
***Note*:** Meat Product = Slaughtering + Canning and Preserving of Meat
Dairy Product = Dairy Product
Fruit and Vegetables = Canning and Preserving of Fruit and Vegetables
Fish and Seafood = Canning and Preserving of Fish and Seafood
Oil Product = Coconut and Palm Oil + Other Vegetables and Animal Oil
Rice and Flour Product = Rice Milling +Flour and Sagu Mild Products and Tapioca Milling + Grinding Corn + Flour and Other Grain Milling +Bakery and Other + Noodle and Similar Products
Sugar and Confectionery = Sugar Refineries +Confectionery and Snack + Monosodium Glutamate
Coffee = Coffee and Cocoa and Tea Processing +Other Food Products
Fish Meal and Animal Feed = Fish Meal and Animal Feed
Beverage = Ice + Distilling and Blending of Spirits +Breweries +Soft Drinks and Carbonated Water
Tobacco = Tobacco Processing + Tobacco Products

Table 2.5 Pattern of Food Export by Products (billion baht)

	1988	1993	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1. Agricultural products	97.78	96.06	186.28	161.18	171.88	181.64	193.68	246.8	318.25	309.72	384.5	402.5	518.85	419.19	530.25
(Share)	12.1%	10.2%	8.3%	7.3%	6.2%	6.3%	6.6%	7.4%	8.2%	7.0%	7.8%	7.6%	8.9%	8.1%	8.6%
1.1 Rice	34.68	32.96	86.8	73.81	65.56	70.1	70	75.73	108.29	92.92	97.54	119.22	203.22	172.21	168.19
1.1.1 White rice		23.36	65.72	48.23	42.78	38.1	27.02	25.62	44.77	29.51	30.62	41.4	71.41	34.42	45.84
1.1.2 Jasmine rice						2.08	15.17	24.42	26.24	26.19	30.94	34.78	46.53	55.13	53.09
1.1.3 Other rice				25.59	22.77	29.92	27.82	25.69	37.28	37.21	35.98	43.04	85.28	82.66	69.26
1.2 Maize	3.81	0.68	0.62	0.28	0.11	2.22	1.18	1.5	5.62	1.1	2.6	3.54	7.2	8.21	4.52
1.3 Tapioca and products	21.8	21.74	22.08	23	20.28	25.57	22.69	27.11	34.59	34.02	42.97	48.55	47.76	51.6	68.59
1.3.1 Cassava pellet		17	10.87	11.81	7.61	8.97	4.13	5.1	6.39	0.84	1.39	7.2	8.68	1.46	0.78
1.3.2 Cassava sliced		0.11	0.55	0.6	0.09	2.67	4.08	5.35	8.64	11.94	15.78	12.11	7.19	19	25.21
1.3.3 Cassava flour		4.53	5.2	4.82	6.17	6.3	6.44	7.51	8.29	9.47	13.68	14.01	15.01	16.66	24.59
1.4 Fresh and frozen fruits	0.76	1.76	3.99	5.51	8.99	8.4	8.96	9.1	9.79	11.82	12.2	13.2	13.58	17.96	17.23
1.4.1 Longans		0.41	0.17	1.19	2.13	1.97	1.99	1.68	2.19	2.17	2.14	2.43	2.61	3.63	3.51
1.4.2 Durian		0.55	2.61	2.72	2.25	2.64	2.32	2	2.22	2.65	3.19	2.57	3.13	4.11	3.69
1.5 Fresh and frozen vegetables	0.38	1.7	3.17	3.27	3.65	4.58	4.96	5.42	7.04	7.39	7.16	6.87	6.89	6.7	6.58
1.6 Rubber	27.19	29.18	55.41	43.94	60.71	58.71	74.6	115.8	137.47	148.68	205.37	194.34	223.63	146.19	249.26
1.6.1 Rubber smoked sheets		20.29	31.62	24.69	29.56	25.68	33.74	49.83	53.12	52.86	72.65	68.82	78.01	46.24	78.98
1.6.2 Block rubber		4.61	14.49	12.37	21.53	21.01	25.88	41.65	53.12	62.65	82.84	6.27	3.05	1.41	2.08
1.6.3 Rubber concentrated latex		3.97	8.94	6.61	9.36	11.66	13.8	22.61	28.65	30.39	46.3	43.67	46.16	40.62	59.41
1.7 Oil seeds and oleaginous fruits			0.49	0.61	0.33	0.39	0.38	0.47	2.45	0.77	1.59	0.71	0.45	0.52	0.44
1.7.1 Palm nuts and kernels					0.01	0.04	0.03	0.03	0.03	0.02	0.02	0.04	0.09	0.11	0.15
1.7.2 Other oil seeds					0.33	0.35	0.35	0.44	2.41	0.75	1.58	0.68	0.36	0.41	0.29
2. Fishery products	20.83	55.8	90.05	80.65	92.77	91.4	71.15	73.61	72.04	78.4	77.47	84.08	86.72	85	91.5
(Share)	2.6%	5.9%	4.0%	3.6%	3.4%	3.2%	2.4%	2.2%	1.9%	1.8%	1.6%	1.6%	1.5%	1.6%	1.5%
2.1 Fresh, chilled, and cooked shrimps	9.97	38.62	58.81	48.7	60.2	55.13	34.51	36.05	32.69	37.89	37.98	43.08	43.12	46.42	53.33

2.2 Fresh, chilled fish	4.54	9.01	16.19	16.31	16.59	18.61	18.91	19.32	19.01	21.54	20.98	22.38	26.6	23.33	22.8
3. Livestock	5.92	10.18	28.1	24.81	27.29	39.49	40.6	44.63	24.36	29.97	31.64	35.95	56.67	55.27	57.98
(Share)	0.7%	1.1%	1.2%	1.1%	1.0%	1.4%	1.4%	1.3%	0.6%	0.7%	0.6%	0.7%	1.0%	1.1%	0.9%
3.1 Fresh,chilled poultry cuts	4.9	8.89	16.64	15.26	15.69	23.93	22.96	24.77	1.75	0.54	0.6	1.05	1.34	1.58	1.88
3.2 Prepared poultry			8.66	5.94	8.75	11.55	13.15	15.7	20.85	27.34	28.84	31.98	50.28	47.26	50.35
4. Agro-industrial products	95.18	83.07	202.6	204.6	187.7	213.49	218.94	247.59	255.84	280.21	299.6	327.3	385.77	384.3	419.32
(Share)	11.8%	8.8%	9.0%	9.2%	6.8%	7.4%	7.5%	7.4%	6.6%	6.3%	6.1%	6.2%	6.6%	7.4%	6.8%
4.1 Preserved and canned seafood	20.94	30.04	76.45	75.22	82.84	89.38	86.5	88.79	90.71	100.29	109.28	109.02	128.92	126.69	130.09
4.2 Preserved and canned fruits	6.64	13.13	15.45	21.76	18.35	21.22	24.59	29.52	31.37	34.53	37.97	38.32	44.79	41.76	44.93
4.3 Preserved and canned vegetables		3.36	6.35	5.87	6.28	6.82	6.91	7.62	8.44	9.03	10.86	9.99	9.67	9.81	9.81
4.4 Cane sugar and molasses	10.23	12.74	28.05	21.68	27.03	33.28	32.04	40.36	34.12	30.7	29.37	45.06	49.34	63.02	70.29
Total Agricultural export	219.71	245.1	507.02	471.24	479.64	526.02	524.36	612.62	670.49	698.3	793.21	849.83	1,048.00	943.76	1,099.00
Total Export	**807.14**	**940.86**	**2,248.09**	**2,214.25**	**2,768.06**	**2,884.70**	**2,923.94**	**3,325.63**	**3,874.82**	**4,439.31**	**4,938.51**	**5,302.12**	**5,851.37**	**5,194.59**	**6,176.42**

***Source*:** Ministry of Commerce

Note: Annual growth rate are

1) Agricultural products = 12%
2) Fishery products = 4%
3) Livestock = 11%
4) Agro-industrial products = 10%
5) Total Export = 13%

Table 2.6. Number of Factories by Food Subsectors.

Types	1997		2002		2007		2009	
	Number	*%*	**Number**	*%*	**Number**	*%*	**Number**	*%*
Basic agro industry	***48,936***		***46,774***		***43,998***		***43,348***	
tea and tobacco preservation	280	*0.5*	209	*0.4*	83	*0.2*	82	*0.2*
other agriculture produce	878	*1.6*	1,117	*2.1*	1,401	*2.8*	1,493	*3.0*
plant seeds or plant bulbs	47,778	*85.7*	45,448	*84.5*	42,514	*83.5*	41,773	*82.8*
food	***6,437***		***6,616***		***6,503***		***6,631***	
animals other than aquatic animals	619	*1.1*	646	*1.2*	942	*1.8*	989	*2.0*
milk and dairy products	102	*0.2*	194	*0.4*	174	*0.3*	182	*0.4*
aquatic animals	549	*1.0*	569	*1.1*	668	*1.3*	666	*1.3*
oil from plants or animals or animal fats	297	*0.5*	315	*0.6*	299	*0.6*	334	*0.7*
vegetables, plant and fruits	587	*1.1*	627	*1.2*	615	*1.2*	622	*1.2*
food from flour	1,643	*2.9*	1,642	*3.1*	1,258	*2.5*	1,248	*2.5*
related to sugar	192	*0.3*	192	*0.4*	130	*0.3*	123	*0.2*
tea, coffee, cocoa, chocolate or sweets	556	*1.0*	498	*0.9*	492	*1.0*	495	*1.0*
food ingredients	469	*0.8*	479	*0.9*	452	*0.9*	455	*0.9*
ice making	1,423	*2.6*	1,454	*2.7*	1,473	*2.9*	1,517	*3.0*
beverage	***375***		***402***		***444***		***463***	
liquor	80	*0.1*	97	*0.2*	104	*0.2*	118	*0.2*
nonalcohol	295	*0.5*	305	*0.6*	340	*0.7*	345	*0.7*
Total	**55,748**	*100.0*	**53,792**	*100.0*	**50,945**	*100.0*	**50,442**	*100.0*

Source: Department of Industrial Works, Ministry of Industry

Table 2.7. Number of New Food Factories by Employment Size

Year	Small	Medium	Large
1980	91	7	2
1981	91	6	3
1982	93	3	4
1983	91	8	1
1984	91	6	3
1985	90	6	4
1986	91	5	4
1987	92	5	3
1988	95	3	2
1989	87	8	5
1990	86	8	6
1991	83	9	9
1992	87	9	4
1993	85	10	5
1994	85	9	6
1995	89	7	4
1996	84	11	5
1997	90	7	3
1998	93	5	2
1999	93	6	1
2000	95	4	1
2001	92	6	2
2002	92	6	2
2003	91	6	3
2004	89	8	3
2005	90	8	2
2006	89	8	3

***Source*:** Department of Industrial Works

***Note*:** Small = less than 50 workers; Medium= 50-300 workers; Large = more than 300 workers

Table 2.8. Domestic Resource Cost of the Agricultural and Food Industries, 1997

(1) Export-oriented industries		(2) Import-substituted industries	
IO	**DRC**	**IO**	**DRC**
Wood products	0.58	Coffee and tea	2.83
Flour	0.66	Leather tanning	2.44
Furniture	0.7	Confectionery	1.94
Leather products	0.74	Tobacco	1.91
Rubber tire	0.75	Liquor distilling	1.6
Monosodium glutamate	0.77	Dairy products	1.24
Other rubber products	0.77	Saw milling	1.17
Other food products	0.82	Paper pulp	1.06
Animal feeds	0.82	Fertilizers and pesticides	1.05
Canned and preserved seafood	0.82	Vegetables and animal oil	0.9
Canned fruits and vegetables	0.82		
Cassava starch	0.83		
Rice milling	0.83		
Jute products	0.84		
Crepe rubber	0.84		
Slaughtering	0.85		
Sugar	1.02		

***Source*:** TDRI (1998).

Table 2.9. Decomposition of Sources of Growth in the Food Subsectors

	C (%)	**X (%)**	**X/output (%)**
Food		55.0	25.0
Beverages	52.0	-2.6	4.7
Rice product	26.0	39.0	8.4
Sugar	-531.0	-2,450.0	18.0
Meat	87.0	24.0	2.5
Dairy	88.0	17.0	8.4
Fruits and vegetables	64.0	43.0	15.0

***Source*:** NESDB, Input Output Table 2005

Table 3.1-a. Growth Accounting in Agricultural Subsectors

	Labor	**Land**	**Capital**	**TFP**
Agricultural	18.79	6.13	54.73	20.35
Crop	7.6	7.63	63.95	20.82
Livestock	78.35	-0.38	4.53	17.49

***Source*:** Waleerat (2009).

Table 3.1-b. Growth Accounting for Growth in the Agricultural Subsectors

	GDP growth	**Labor adjusted for quality and working hours**	**Land**	**Capital**	**TFP**
a) All sectors					
1981--1985	5.45	1.51	0.07	2.35	1.52
1985--1996	8.78	1.61	0.02	4.88	2.27
1996--1998	-1.99	0.63	0.01	3.3	-5.94
1998--2003	2.18	0.69	0.01	0.66	0.81
1981--2003	6.07	1.47	0.03	3.28	1.29
% of growth	100	24.24	0.46	54.00	21.30
b) Agriculture					
1981--1985	4.26	0.40	0.36	0.84	2.65
1985--1996	3.54	-0.43	0.12	2.62	1.24
1996--1998	0.57	-0.32	0.07	3.04	-2.22
1998--2003	3.43	-1.33	0.12	1.45	3.20
1981--2003	3.43	-0.28	0.16	2.06	1.50
% of growth	100	-8.09	4.64	59.90	43.55
c) Crops					
1981--1985	5.26	0.22	0.47	2.46	2.11
1985--1996	2.96	-0.79	0.18	0.91	2.66
1996--1998	2.30	-0.75	0.18	1.97	0.90
1998--2003	4.20	-2.43	0.17	0.99	5.47
1981--2003	3.57	-0.70	0.23	1.35	2.68
% of growth	100	-19.64	6.52	37.86	75.27
d) Livestock					
1981--1985	1.82	3.06	0.16	3.55	-4.95
1985--1996	4.14	1.36	0	0.33	2.45
1996--1998	-0.89	-0.02	-0.46	-6.75	6.34
1998--2003	4.10	5.85	0	-2.28	0.53
1981--2003	3.59	2.65	-0.02	-0.28	1.24
% of growth	100	73.73	-0.42	-7.89	34.59
e) Fisheries					
1981--1985	4.74	6.17	0.03	2.36	-3.82
1985--1996	7.97	2.44	0.02	4.22	1.30
1996--1998	-1.43	1.64	0.02	6.16	-9.25
1998--2003	1.24	0.78	0.03	4.82	-4.38
1981--2003	5.36	1.99	0.02	3.96	-0.61
% of growth	100	37.03	0.42	73.9	-11.35

***Source*:** Nipon and Chaiyasit (2005).

Table 3.2. TFP Elasticity vis-a-vis Research Expenditure

Type of research	Agricultural	Crop	Livestock
Government	0.05	0.15	0.12-0.17
CGIAR	0.12	0.10	n.a.
Private	n.a.	0.15	0.25-0.32

***Source*:** Waleerat (2009).

Table 3.3. Rates of Return on Investment in Agricultural Research

	Percentage	Source
Agricultural	42--45.0	Setboonsrang and Evenson (1991)
Agricultural	44.95	Pochanakul (1992)
Crop	17--29.5	Waleerat (2009)
Livestock	104--144	Waleerat (2009)
Rice (Chainart)	200	Orachos (2009)
Rice (RD. 6 Blast Resistance)	47--57	Watcharin (2009)
Rice	BC ratio 16	(2005)
Nutrient management in maize (4 site-specific)	BC ratio 19.4	Suwanna and Somporn (2010)

Table 3.4. Source of Growth of the Food Industry

Industry	Technology					Trade	Taste	Investment	General macro	Total impact
	Primary factors (saving)	Intermediate input usage for production	Intermediate input usage for capital creation	Labor saving	Total					
Agriculture	4.8	–0.6	–0.6	–1.9	1.7	1.3	1.1	0.6	0.5	5.3
Food	5.0	–0.3	–0.5	–2.0	2.2	1.2	–0.7	0.8	0.5	4.0
Textiles	5.4	0.5	–0.5	–2.1	3.2	1.1	–0.6	0.9	0.5	5.1
Jewelry	3.7	4.2	–0.4	1.4	8.9	–0.5	1.1	0.6	0.3	10.4
Electronics	3.3	10.9	–0.3	1.3	15.2	1.4	0	0.8	0.3	17.6
Vehicles	4.2	1.7	2.6	1.5	10.0	4.0	0.5	1.7	0.4	16.7
Services	4.9	0.1	–1.0	–2.0	2.0	0.8	–0.7	0.4	0.7	3.3
Others	4.6	–1.3	–0.6	–1.9	0.9	0.6	–0.2	0.8	0.5	2.5

***Source*:** Chedtha Intaravitak (2010).

Table 3.5. Agricultural Technology

Impact	Technology	Product/Type	Researcher
I. Yield Improvement			
Breeding		RD. rice, etc.	Government
		Hybrid rice	Private (CP), Government
		Tapioca	Government, Kasetsart University, Thai Tapioca Development Institute
		Para rubber	Government
		Sugar cane	Government, Private
		Maize (Suwan 1-2)	Government
		Maize (hybrid)	Private
		Baby corn	Private
		Vegetables (kale, cauliflower, morning glory)	Private
Breeding and Raise		Tilapia nilotica	Government
		Sea bass	Government
		Shrimp (Vannamei)	Private
Selection / Breeding / Artificial insemination		Swine (land race)	Government, Kasetsart University
		Swine (European)	Private
		Beef cattle	Government, Private
		Dairy cattle	Government, Private
II. Value added			
Breeding		Rice (Pathumthani)	Government
		Rice (size 7 mm./ cooked quality)	Government
		Tilapia (Red, Ruby)	Private
		Fruit (Shogun orange, mango Mahachanok)	Farmer
		Swine (Kurobuta or Berkshire)	Private
		Chicken (native)	Government
		Beef (Ponyangkham brand)	Farmer
III. Health / Safety			
Breeding	Healthy food	Rice (Sinlek, Sangyod, Vitamin A rice)	Farmer
Process	Food safety/ healthy	Organic rice	Farmer Private
		Organic	Private, Farmer
		Egg (iodine)	Government
		Chicken (closed system)	Private
		Shrimp (closed system)	Private (trials)

Impact	Technology	Product/Type	Researcher
IV. Environment: Resistance to Droughts, Floods, and Pests			
Breeding	Pest resistance	Rice RD.6, Chainat1 (Blast resistance)	Government
		Maize (Suwan 1-2) Antimildew	Government
	Drought resistance	Rice (Khao Dawk Mali 105) drought resistance	NSTDA
	Flood resistance	Rice (Hom Cholasit) Flood resistance	NSTDA
	Thermo tolerance	Swine, cattle	Private, Government
IPM	Pest resistance	Parasite of pink mealybug in cassava	Thai Tapioca Development Institute
V. Reduce production costs			
Reduce costs	Housing	Swine, chicken: evaporative housing	Private
	Feed cost	Swine, cattle, chicken	Kasetsart University, Private
Harvest	Labor cost	Combine harvest (rice)	Private
		Combine harvest (sugar cane)	Private
		Combine harvest (tapioca)/ Knife (sugar cane)	Private
		Elevator (tapioca, sugar cane)	Private
Tillage	Labor cost	Parachute	Farmer
	Seed cost	Plough up and over rice stubble	Farmer

***Source*:** Nipon et al. (2010).

Table 3.6. Yield of Selected Crops (kg per rai)

	Rice	Maize	Cassava	Sugar cane	Rubber	Sorghum	Mungbean	Kenaf	Cotton	Oil Palm	Soybeans	Pineapple
1970	306	291	2,446	6,904	36	183	149	145	139		137	2,449
1971	300	361	2,250	7,640	39	258	156	145	141		151	2,276
1972	270	211	2,366	6,851	40	283	144	145	129		138	1,879
1973	285	326	2,080	8,396	43	252	131	173	157		136	2,606
1974	268	323	2,080	8,254	43	198	145	152	148		134	2,981
1975	275	349	2,180	7,541	40	188	118	151	153		154	3,361
1976	281	333	2,364	8,146	43	166	90	182	174		179	4,510
1977	247	223	2,237	8,366	46	118	76	153	172	659	101	3,886
1978	279	322	2,246	5,349	50	197	98	169	174	618	157	3,275
1979	267	300	2,100	6,445	56	169	95	156	190	506	150	4,593
1980	289	335	2,281	4,698	48	153	93	198	203	474	127	4,521
1981	296	352	2,235	6,781	51	156	93	175	182	540	165	3,762
1982	281	286	2,302	7,830	58	154	93	159	171	897	146	3,324
1983	312	337	2,220	6,696	59	197	95	147	188	910	176	2,495
1984	319	372	2,276	6,618	73	204	107	151	196	1,027	197	3,202
1985	320	399	2,087	7,318	79	209	94	170	239	1,382	203	3,160
1986	306	353	1,969	6,997	88	174	95	162	227	1,328	198	3,542
1987	305	254	2,217	7,256	98	173	92	159	217	1,268	149	3,751
1988	322	408	2,258	7,422	106	191	112	198	270	1,462	206	3,930
1989	320	393	2,394	8,870	120	197	111	191	2,441	1,674	210	3,775
1990	278	341	2,165	7,824	129	195	108	196	210	1,778	199	3,809
1991	342	411	2,114	8,309	136	203	110	204	207	1,563	200	3,773
1992	329	435	2,183	8,282	154	214	109	211	205	1,487	209	3,846
1993	311	398	2,220	6,430	161	190	108	220	203	1,884	197	3,969
1994	348	449	2,165	7,063	172	207	113	227	219	1,831	194	3,697

1995	348	498	2,004	8,594	176	219	107	234	222	2,016	205	3,615
1996	350	523	2,205	9,233	180	241	109	230	223	2,024	212	3,756
1997	367	439	2,287	8,932	182	231	111	227	222	1,900	218	3,888
1998	367	513	2,329	7,370	177	238	119	248	217	1,739	219	3,144
1999	375	555	2,293	8,777	179	259	124	256	214	2,236	220	3,825
2000	418	587	2,574	9,466	249	257	129	261	221	2,325	232	3,683
2001	443	597	2,805	9,042	268	270	129	268	213	2,699	236	3,618
2002	464	594	2,731	9,496	271	286	127	270	200	2,434	238	3,501
2003	464	616	3,087	10,429	286	295	123	259	227	2,725	246	3,733
2004	457	617	3,244	9,269	291	261	121	238	215	2,682	238	3,777
2005	474	611	2,749	7,434	282	298	117	240	189	2,469	250	3,557
2006	467	630	3,375	7,899	282	251	124	259	204	2,827	250	4,280
2007	481	629	3,668	10,194	274	281	128	287	206	2,399	255	3,702
2008	474	652	3,401	11,157	278	268	118	325	233	3,214	256	3,915
2009	460	668	3,628	11,094	266		120			2,560	254	3,344

***Source*:** OAE

Table 3.7. Profitability of Crops Produced under Contract Farming System

Table 3.7-a. Farmers in Chiang Mai, 1994/95

Net revenue (baht/rai/month), contract farmers, 1995/96	**Profit (baht/rai/month) of alternative crops, independent farmers, 1994/95**			
Cotton 875	Cotton 358	Maize 548	Major rice 253	Soybeans 348
Japonica Rice 400	-	-	Major rice 253	Soybeans 348
Green Soybeans 3,500	-	-	Major rice 253	Soybeans 348
Potatoes 4,333	Potatoes 1,084	-	Major rice 253	Soybeans 348
Tomatoes 3,333	Tomatoes 2,880	-	Major rice 253	Soybeans 348

Table 3.7-b. Farmers in Sakaew Province, 2003

Net Income (baht/rai/crop), contract farmers, 2003	**Profit (baht/rai/crop) of crops produced by independent farmers**			
Asparagus 49,916	Tapioca 1,243	Maize 958	Rice 691	-

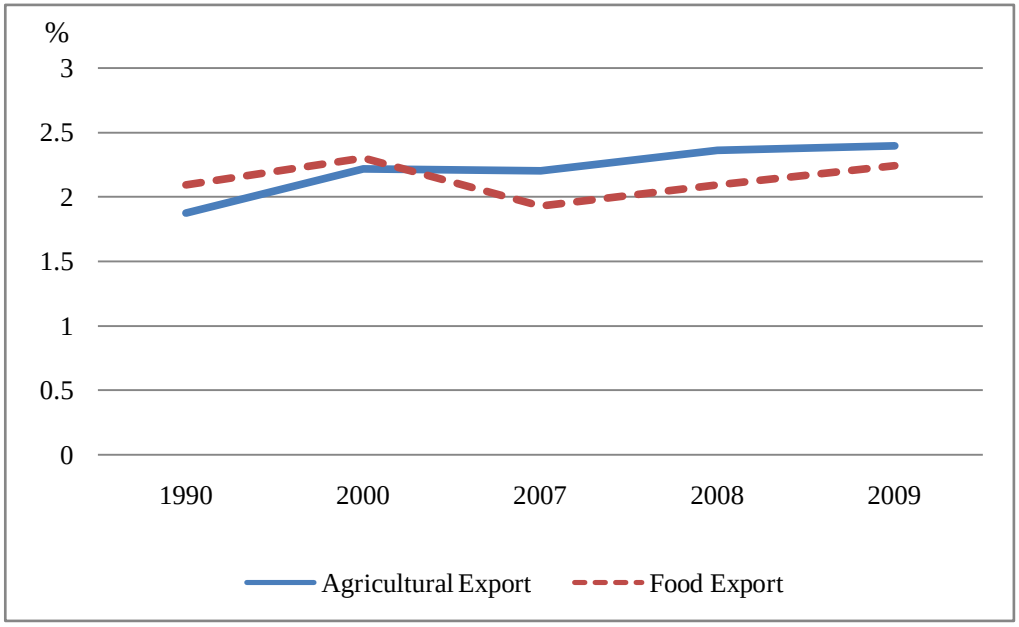
Source: (A) TDRI (1996, 6); (B) Paichayon Uathavikul (2004)

Table 3.8 Technology Upgrading in the Food Industry

Technology	Chicken	Fishery	Swine/dory	Rice	Sugar	Vegetables	Corn
1. Hardware							
- Breeding	hybrid	-	heat-tolerant	hybrid	HYV	seeds	hybrid seeds
- Reproduction		shrimp	AI				
- cultivation							
- Peed	improved	improved	improved				
- Housing	- evaporative - closed system	- closed system	evaporative			- hydroponic farm	
- factory/farm	- sealing up	- sealing up	scaling up		scaling up		
- mechanization	/	-	/	/	/	-	-
2. Software-management							
- GAP, GMP	/	/	/	organic	/	organic	- feed factory
- QCC/HACCP	/	/	/	-	-	/	-
- biosafety / traceability	/	/	/	-	-	/	-
- raw materials	contract & owned farm - skilled workers	- trust & owned farm	- scaling-up collecting station	-	CCS	/ (canned pineapple)	-
- logistics handling		- major implement			- handling station	major improvement	
- procurement/ standards by supermarket	/ (brands)	/ (brands)	/ (brands)	/ -	/ -	/ (brands)	-
- product development	- ready-to-eat	- ready-to-eat	- new production	organic	-	organic	-
- package	/	patsy	/	- small package		/	-
3. Market strategy							
- Brands alliance		- buying brand	-				
- partner	/	/	-	-	/	-	-
abroad	(China)	(china)			(Australia)		

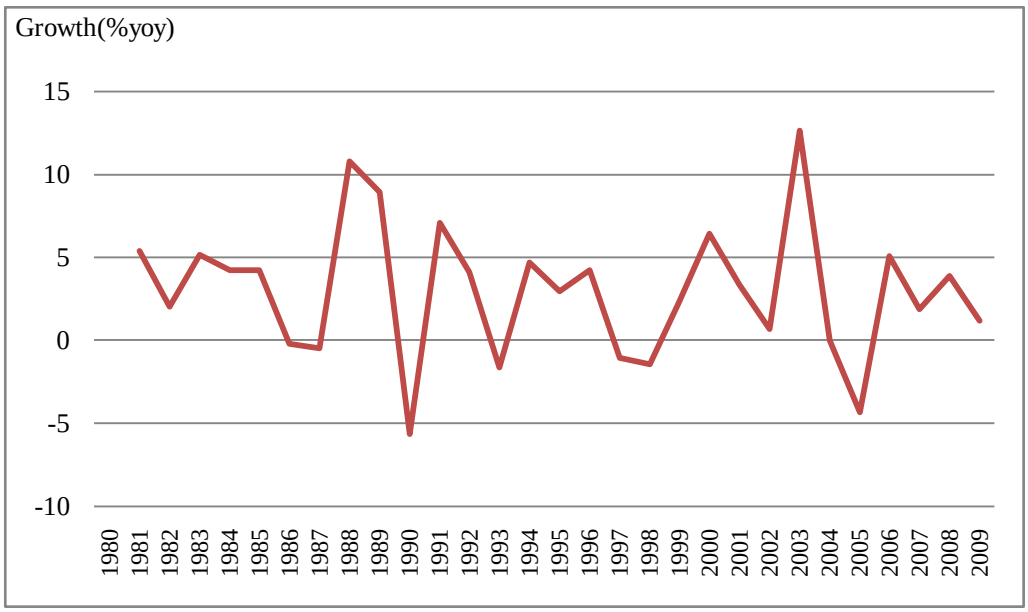
***Sources*:** Achanun (2006); Patarapong (2010); Bhanupong (2007); Poapongsakorn et al. (2010).

Figure 1.1. Market share in the world



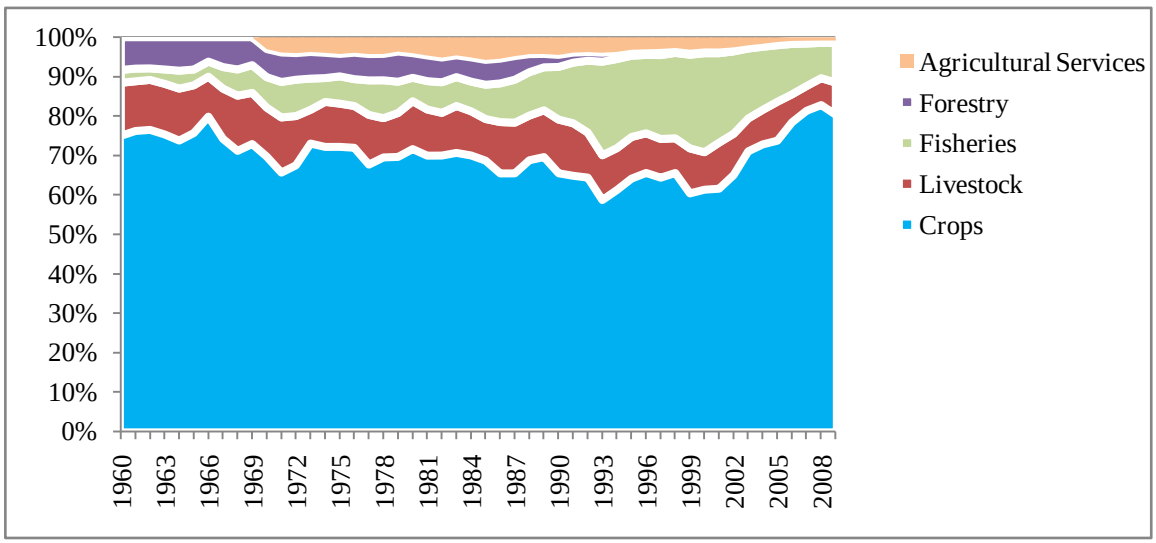
***Source*:** WTO (2010).

Figure 2.1. Annual growth rate in agricultural GDP



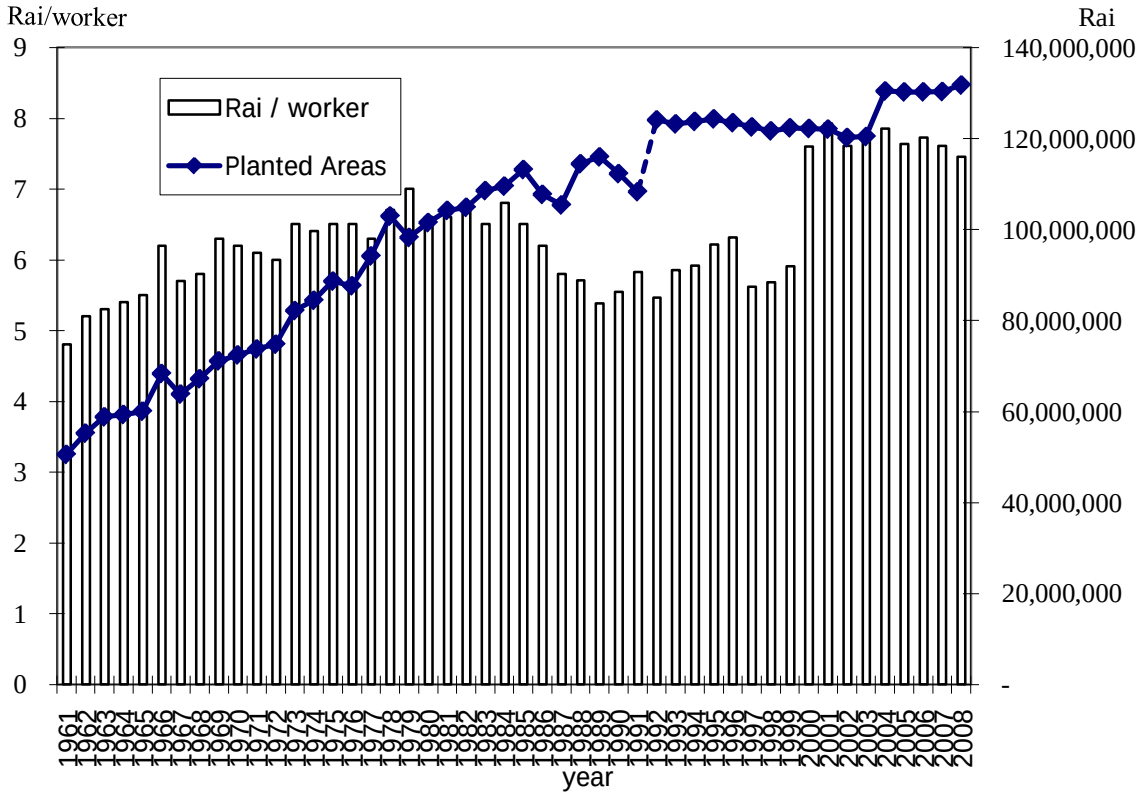
***Source*:** Calculated from NESDB, National Income

Figure 2.2. Share of agricultural subsectors



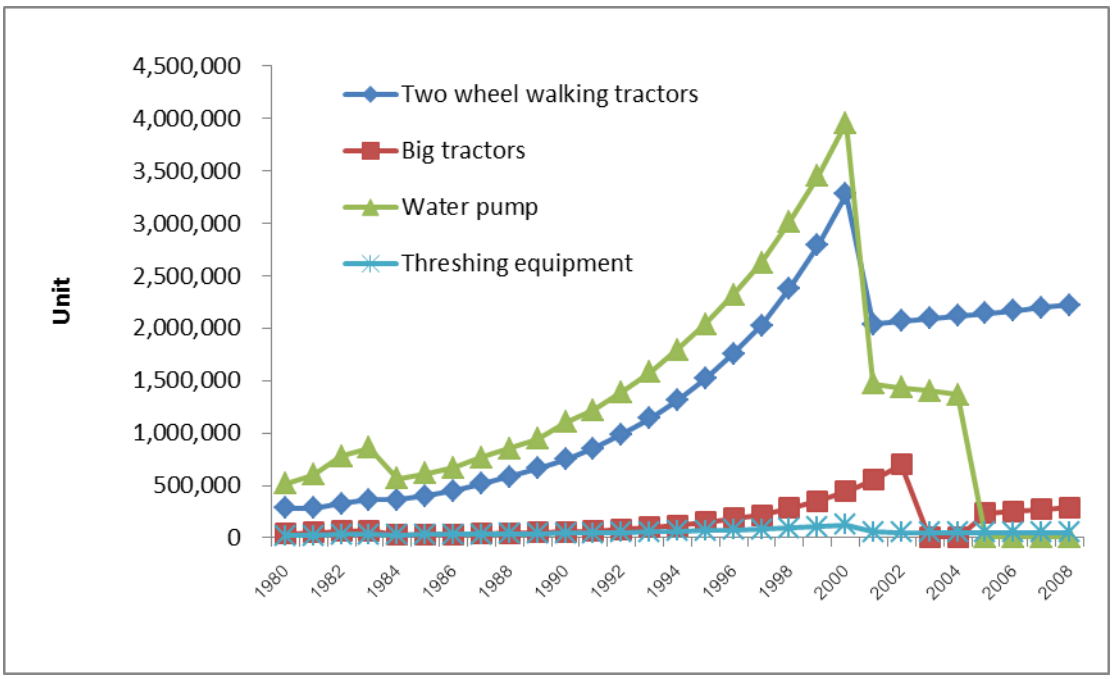
***Source*:** Calculated from NESDB, National Income

Figure 2.3. Planted areas and area per worker



***Sources*:** Office of Agricultural Economics; National Statistical Office Labor Force Survey

Figure 2.4. Investments in agricultural equipment and machinery



Source: Office of Agricultural Economics, Ministry of Agriculture & Cooperatives

: FAO Statistics Division 2011

Note : Two-wheel walking tractors 1980-2002, calculated from OAE

Big tractors 1980—1999, calculated from OAE

Water pump and threshing equipment 1980—2004, calculated from OAE

Two-wheel walking tractors 2003—2008, estimated by FAO

Big tractors 2000—2008, estimated by FAO

Water pump and threshing equipment 2005—2008, estimated by FAO

Table 4.1. Public Research and Extension Budget by Agency and Research Intensity

Year	DOAE	Agricultural research department					Other agricultural research department					Total (Ex. DOAE)		Research Intensity %
		DOA	RD	DLD	DOF	Subtotal	NSTDA	TRF	NRCT	ARDA	Subtotal	Nominal	at 1988 price	
1961	n.a.	26.2	21.6	21.8	8.6	78.3	n.a.	n.a.	n.a.	n.a.	n.a.	78.3		
1962	n.a.	40.3	32.1	34.0	23.0	129.4	n.a.	n.a.	n.a.	n.a.	n.a.	129.4		
1963	n.a.	43.3	36.1	40.6	28.7	148.7	n.a.	n.a.	n.a.	n.a.	n.a.	148.7		
1964	n.a.	49.9	44.0	40.9	37.9	172.7	n.a.	n.a.	n.a.	n.a.	n.a.	172.7		
1965	n.a.	56.3	50.3	45.5	30.6	182.7	n.a.	n.a.	n.a.	n.a.	n.a.	182.7	608.3	
1966	n.a.	77.2	83.6	60.5	42.9	264.2	n.a.	n.a.	n.a.	n.a.	n.a.	264.2	812.4	
1967	n.a.	102.0	81.3	79.2	55.9	318.5	n.a.	n.a.	n.a.	n.a.	n.a.	318.5	996.2	
1968	n.a.	116.1	95.8	82.9	60.5	355.3	n.a.	n.a.	n.a.	n.a.	n.a.	355.3	1,114.1	
1969	n.a.	92.1	52.2	86.8	71.0	302.0	n.a.	n.a.	n.a.	n.a.	n.a.	302.0	916.2	
1970	95.3	104.3	52.3	88.8	60.8	306.1	n.a.	n.a.	n.a.	n.a.	n.a.	306.1	977.7	
1971	124.0	106.4	52.4	87.4	58.3	304.5	n.a.	n.a.	n.a.	n.a.	n.a.	304.5	980.3	0.39
1972	123.0	107.7	53.8	91.0	56.9	309.3	n.a.	n.a.	n.a.	n.a.	n.a.	309.3	936.5	0.31
1973	143.6	173.8	n.a.	118.4	68.5	360.8	n.a.	n.a.	n.a.	n.a.	n.a.	360.8	921.9	0.24
1974	157.1	189.4	n.a.	123.6	82.9	395.9	n.a.	n.a.	n.a.	n.a.	n.a.	395.9	840.9	0.20
1975	231.8	271.2	n.a.	177.0	137.7	586.0	n.a.	n.a.	n.a.	n.a.	n.a.	586.0	1,202.7	0.27
1976	278.8	318.1	n.a.	210.5	177.5	706.1	n.a.	n.a.	n.a.	n.a.	n.a.	706.1	1,386.7	0.29
1977	402.3	342.9	n.a.	264.7	179.3	786.9	n.a.	n.a.	n.a.	n.a.	n.a.	786.9	1,457.8	0.29
1978	480.6	352.2	n.a.	286.2	190.2	828.5	n.a.	n.a.	n.a.	n.a.	n.a.	828.5	1,399.3	0.26
1979	535.7	378.2	n.a.	294.2	212.6	885.0	n.a.	n.a.	n.a.	n.a.	n.a.	885.0	1,375.7	0.25
1980	743.9	432.5	n.a.	360.2	243.2	1,035.9	n.a.	n.a.	n.a.	n.a.	n.a.	1,035.9	1,428.8	0.24
1981	917.5	515.4	n.a.	438.6	300.5	1,254.4	n.a.	n.a.	n.a.	n.a.	n.a.	1,254.4	1,596.5	0.27
1982	1,020.5	583.4	n.a.	501.1	371.1	1,455.6	n.a.	n.a.	n.a.	n.a.	n.a.	1,455.6	1,763.3	0.35
1983	1,215.9	719.8	n.a.	615.7	532.9	1,868.4	n.a.	n.a.	n.a.	n.a.	n.a.	1,868.4	2,183.8	0.41
1984	1,340.8	776.5	n.a.	685.7	585.8	2,048.0	n.a.	n.a.	n.a.	n.a.	n.a.	2,048.0	2,359.4	0.49
1985	1,627.1	797.3	n.a.	784.1	658.2	2,239.7	n.a.	n.a.	n.a.	n.a.	n.a.	2,239.7	2,525.3	0.59
1986	1,530.4	845.8	n.a.	814.2	719.8	2,379.8	n.a.	n.a.	n.a.	n.a.	n.a.	2,379.8	2,639.9	0.59
1987	1,355.9	849.7	n.a.	837.4	671.9	2,359.1	n.a.	n.a.	n.a.	n.a.	n.a.	2,359.1	2,498.8	0.54

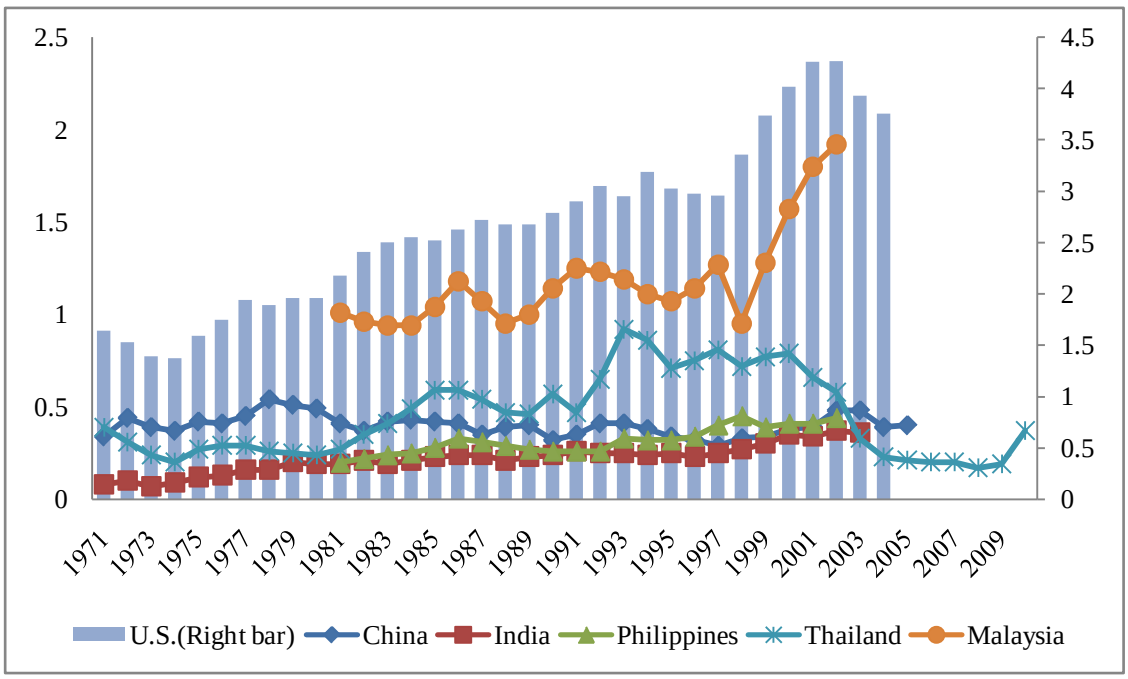
Year	DOAE	Agricultural research department					Other agricultural research department					Total (Ex. DOAE)		Research Intensity %
		DOA	RD	DLD	DOF	Subtotal	NSTDA	TRF	NRCT	ARDA	Subtotal	Nominal	at 1988 price	
1988	1,391.8	979.7	n.a.	1,065.3	735.4	2,780.3	n.a.	n.a.	n.a.	n.a.	n.a.	2,780.3	2,780.3	0.47
1989	1,494.8	1,049.7	n.a.	1,070.6	828.5	2,948.7	n.a.	n.a.	n.a.	n.a.	n.a.	2,948.7	2,778.6	0.46
1990	1,848.4	1,246.4	n.a.	1,415.9	1,486.3	4,148.5	n.a.	n.a.	n.a.	n.a.	n.a.	4,148.5	3,696.1	0.57
1991	2,526.2	1,564.2	n.a.	1,959.9	1,946.0	5,470.1	n.a.	n.a.	n.a.	n.a.	n.a.	5,470.1	4,608.7	0.47
1992	3,042.3	1,768.4	n.a.	1,985.2	2,478.2	6,231.8	n.a.	n.a.	n.a.	n.a.	n.a.	6,231.8	5,024.8	0.65
1993	4,048.3	2,197.0	n.a.	2,735.3	2,717.1	7,649.4	n.a.	n.a.	n.a.	n.a.	n.a.	7,649.4	5,971.4	0.92
1994	4,683.3	2,468.7	n.a.	2,963.0	2,719.4	8,151.0	n.a.	n.a.	n.a.	n.a.	n.a.	8,151.0	6,048.0	0.86
1995	5,460.8	2,534.3	n.a.	3,357.5	3,091.3	8,983.1	n.a.	n.a.	n.a.	n.a.	n.a.	8,983.1	6,312.6	0.71
1996	6,407.5	3,105.4	n.a.	3,799.6	3,412.5	10,317.5	n.a.	n.a.	n.a.	n.a.	n.a.	10,317.5	6,970.8	0.75
1997	6,756.4	3,301.6	n.a.	3,698.6	3,872.6	10,872.8	n.a.	n.a.	n.a.	n.a.	n.a.	10,872.8	7,059.1	0.81
1998	5,306.7	3,051.5	n.a.	3,164.7	3,315.6	9,531.8	n.a.	n.a.	n.a.	n.a.	n.a.	9,531.8	5,665.1	0.58
1999	5,380.1	3,165.1	n.a.	2,861.1	3,368.4	9,394.6	n.a.	n.a.	n.a.	n.a.	n.a.	9,394.6	5,818.5	0.65
2000	5,682.2	3,237.7	n.a.	2,848.9	3,120.3	9,206.9	n.a.	n.a.	n.a.	n.a.	n.a.	9,206.9	5,626.6	0.65
2001	5,591.1	3,190.7	n.a.	2,832.3	3,088.5	9,111.5	n.a.	n.a.	n.a.	n.a.	n.a.	9,111.5	5,455.4	0.60
2002	5,452.5	3,092.9	n.a.	2,583.4	3,302.4	8,978.6	n.a.	n.a.	n.a.	n.a.	n.a.	8,978.6	5,332.2	0.52
2003	4,962.9	2,867.0	n.a.	2,826.6	2,443.4	8,137.0	n.a.	n.a.	n.a.	n.a.	n.a.	8,137.0	4,769.1	0.39
2004	4,602.7	2,971.4	n.a.	3,052.7	2,496.6	8,520.6	n.a.	n.a.	n.a.	n.a.	n.a.	8,520.6	4,842.6	0.35
2005	4,339.6	2,838.7	n.a.	3,011.3	2,664.4	8,514.4	n.a.	n.a.	n.a.	n.a.	n.a.	8,514.4	4,631.2	0.31
2006	4,144.7	3,215.6	n.a.	4,012.6	2,699.2	9,927.3	n.a.	102.9	n.a.	n.a.	102.9	10,030.2	5,183.0	0.39
2007	4,186.1	2,946.3	815.4	6,445.5	2,872.9	13,080.0	n.a.	270.0	n.a.	n.a.	270.0	13,350.0	6,661.9	0.45
2008	4,338.7	2,969.7	1,050.4	4,264.0	2,804.3	11,088.4	n.a.	115.7	n.a.	n.a.	115.7	11,204.1	5,384.3	0.33
2009	4,756.6	3,308.5	1,413.6	4,705.2	3,081.8	12,509.1	635.0	364.0	125.4	102.8	1,227.2	13,736.3	6,601.2	0.37

Table 4.2. Agricultural Research Expenditure by Crops, 2007/10

Product	Output value		No. of Project	Budget		Budget/Project (Million baht)	Intensity (%)
	Million baht	%		Million baht	%		
Pulp and paper	715,823	41.9	52	12.3	0.6	0.24	0.002
Rice	364,031	21.3	588	740.4	34.3	1.26	0.20
Natural rubber	165,661	9.7	273	241.7	11.2	0.89	0.15
Chicken	76,499	4.5	51	28.6	1.3	0.56	0.04
Sugarcane	62,916	3.7	106	111.1	5.2	1.05	0.18
Cassava	62,324	3.7	101	99.3	4.6	0.98	0.16
Shrimp	53,842	3.2	178	125.5	5.8	0.71	0.23
Pig	49,369	2.9	110	120.4	5.6	1.09	0.24
Beef	27,144	1.6	144	204.2	9.5	1.42	0.75
Maize	25,321	1.5	85	37.1	1.7	0.44	0.15
Pineapple	24,544	1.4	36	24.9	1.2	0.69	0.10
Dairy cattle	18,523	1.1	138	70.3	3.3	0.51	0.38
Chili	18,106	1.1	88	73.5	3.4	0.84	0.41
Durian	12,824	0.8	29	22.9	1.1	0.79	0.18
Palm oil	9,783	0.6	106	137.3	6.4	1.30	1.40
Garlic	7,535	0.4	4	1.1	0.1	0.28	0.01
Longan	7,276	0.4	54	30.0	1.4	0.56	0.41
Orchid	5,897	0.3	59	76.2	3.5	1.29	1.29
Total	1,707,418	100.0	2,202	2,157.0	100.0	0.98	0.13

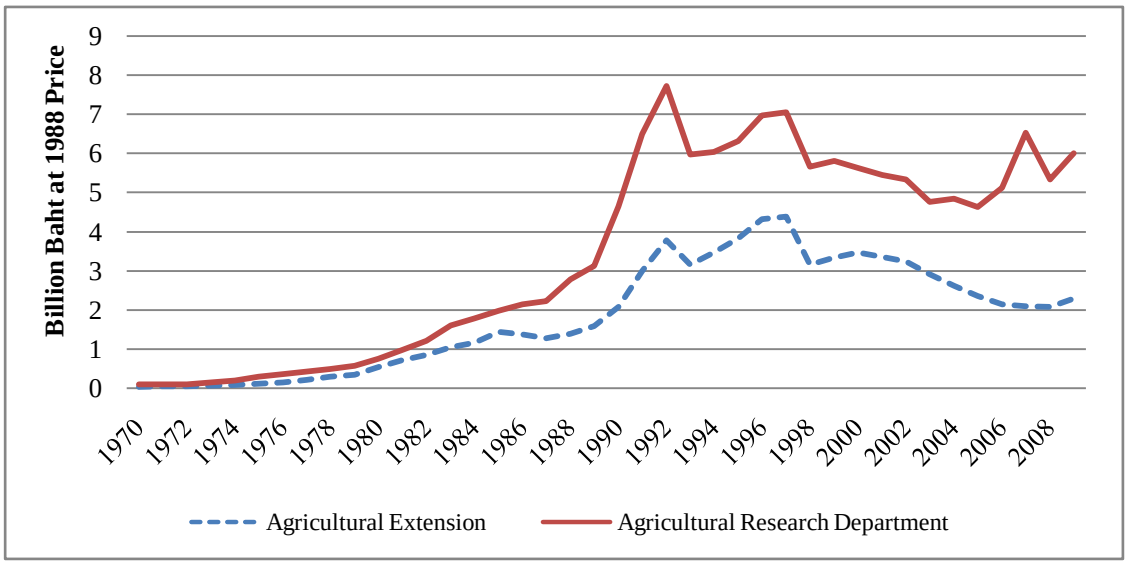
***Source*:** Pongtep et al. (2010).

Figure 4.1. Agricultural research intensity in selected countries



Source: Waleerat (2009) and ASTI database.

Figure 4.2. DOAE's extension and research budgets for four research departments in MOAC (at 1988 price)



***Source*:** Bureau of the Budget

Figure 4.3-a. Number of Thai researchers by fields of research

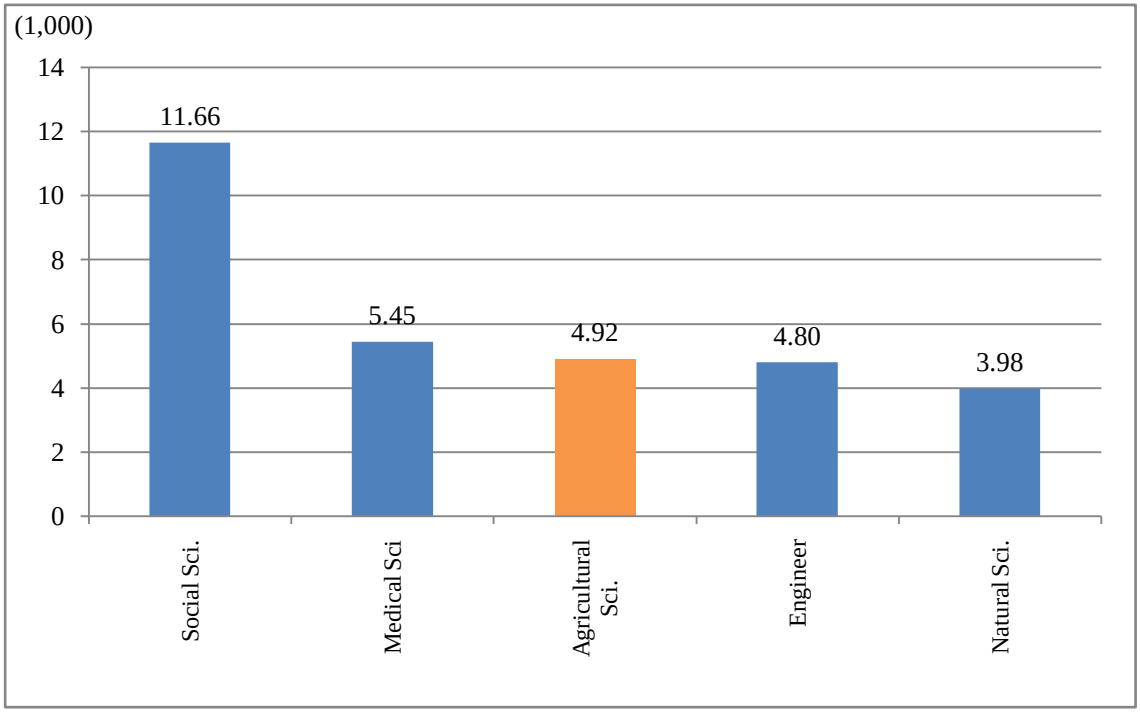
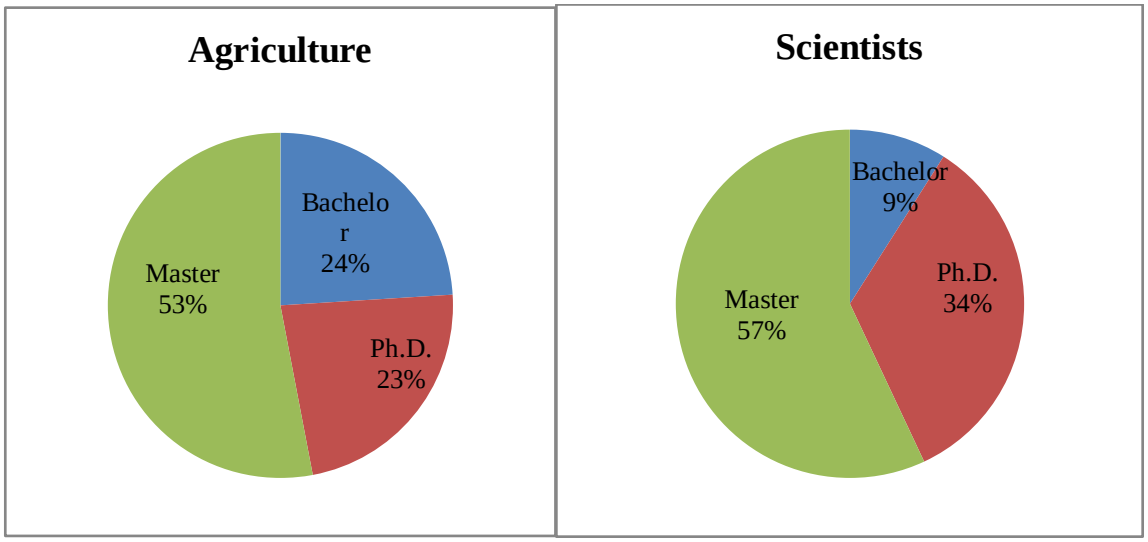
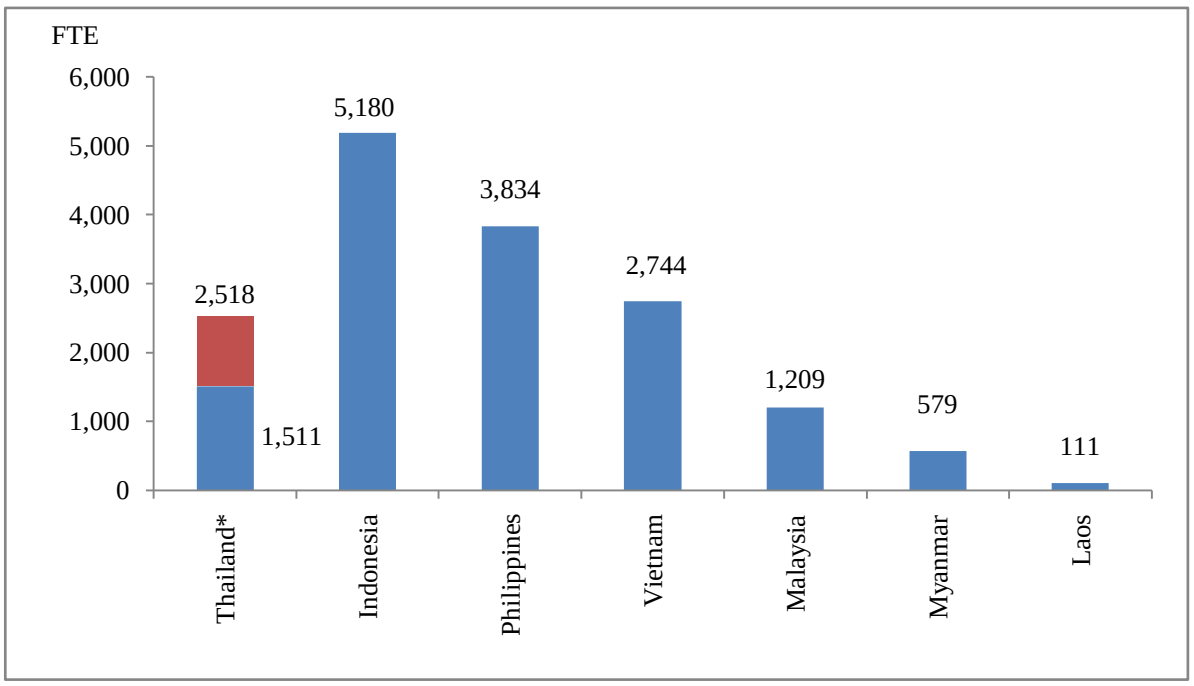


Figure 4.3-b. Educational qualifications of agricultural researchers and natural scientists



Source: Survey of research expenditure and research personnel 2008, National Research Council

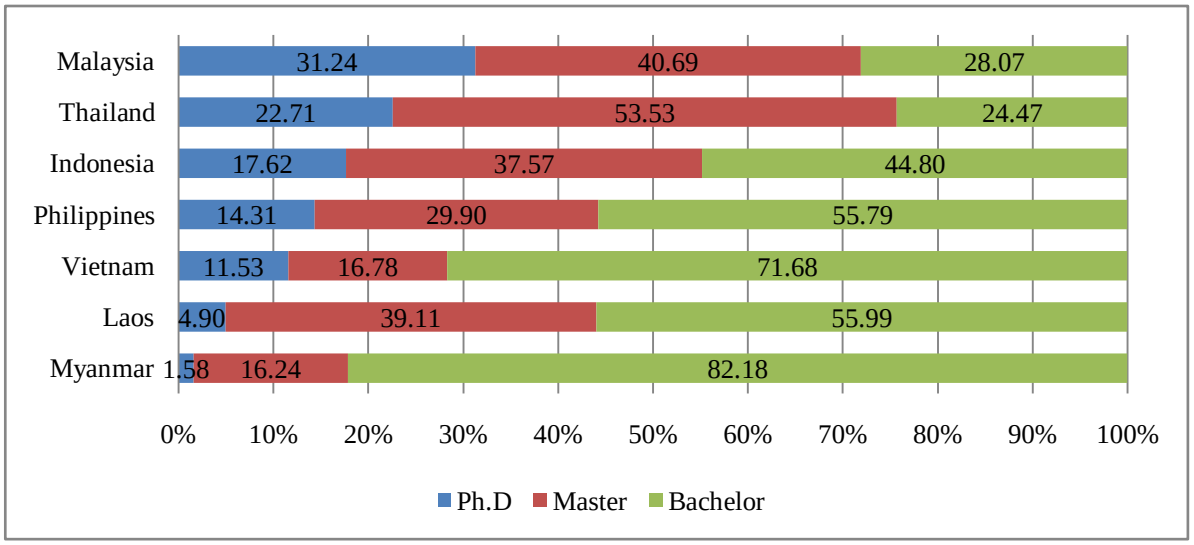
Figure 4.4-a. Number of agricultural researchers in ASEAN countries



Source: Office of the National Research Council of Thailand and Reitzer et al. (2009).

Note: *Thailand FTE calculated from 30 percent and 50 percent of number of researchers.

Figure 4.4-b. Educational qualification of agricultural researchers



***Source*:** Office of the National Research Council of Thailand and Reitzer et al. (2009).