Sweetpotato in China: Economic Aspects and Utilization in Pig Production

Jikun Huang, Jun Song, Fanbin Qiao, and Keith O. Fuglie

International Potato Center
East, Southeast Asia and Pacific Region (CIP-ESEAP)
Kebun Percobaan Muara
Jalan Raya Ciapus
Bogor 16610
Indonesia

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* Jikun Huang, Jun Song, Fanbin Qiao are with the Center for Chinese Agricultural Policy, Chinese Academy of Sciences, Beijing, China. Keith O. Fuglie is with International Potato Center and is based in Bogor, Indonesia.

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Executive Summary

The pattern of grain utilization in China has changed significantly in the past decades, a trend that is likely to continue in the future[1]. As incomes increased, rice and wheat as staple food slowly took the place of sweetpotato, maize and other course grains, which in turn have increasingly been used as animal feed. However, despite the significant shift in the use of both maize and sweetpotato from food to feed, China's domestic feed supply is expected to lag behind the rapidly increasing demand for livestock meat products brought about by the expansion of consumption as a function of increased income. Trade liberalization and China's membership in the World Trade Organization (WTO) are expected to exacerbate the deficit of feed grains, particularly maize. Whether China could or would be willing to import a large amount of maize is an issue of rising concern. Alternative solutions, especially substitution of other domestically produced feed such as sweetpotato are of importance, politically and economically.

Sweetpotato is the fourth major staple crop and the second largest feed grain in China. While production has remained fairly stable at 20-23 million tons/year since the 1970s, the area planted to sweetpotato has declined significantly. Yield growth of sweetpotato has generally been lower than cereals except in the recent years. Further, utilization of sweetpotato as a food staple decreased from about 50 percent of total production in the 1970s to less than 15 percent by the end of the 1990s. Feed and industrial use grew significantly over this period.

This study aims to characterize the changing pattern of China's sweetpotato production and utilization, examine the incentives governing sweetpotato production, and analyze the efficiency of substituting sweetpotato for maize as feed in pig production. In order to achieve these goals, analyses were conducted at national, regional and farm levels. About 200 households from 20 villages in five counties each of the two sweetpotato giants, Sichuan and Shandong provinces, were selected for in-depth analysis. These two provinces together account for more than one third of China's sweetpotato production, nearly double the rest of the world's sweetpotato output.

This study confirms the evidence of significant changes in sweetpotato utilization. The proportion of sweetpotato used as feed and for food processing both surpassed food consumption after the mid 1980s. By the late 1990s, feed use accounted for more than 40 percent and processing demand accounted for one third of total sweetpotato production. Although China is the world's largest sweetpotato producer and is in fact a net exporter, sweetpotato has never been an important commodity in international trade. Sweetpotato was one of the first agricultural commodities liberalized in the early reform period in China, but interregional trade remains small. In many rural areas it is planted primarily as a subsistence crop intended to address household demand for feed and other uses.

Average farm size in the sampled villages was 0.38 hectare, the typical farm size in China. The average household produced 176 kilograms of sweetpotato, about 85 percent of which was used in pig production. Households raised pigs using a variety of feeds, including sweetpotato,

[1] In this report, we use the Chinese definition of "grain" to include rice (measured in paddy form), wheat, maize, soybean, sweetpotato, potato, sorghum, barley and millet. All are measured as dry weight. Dry weight of sweetpotato is computed by dividing fresh weight by 5. Throughout this report, yield and production of sweetpotato are all reported as dry weights.

maize, other grains, meals and forage from home-produced crops. Most of households that raised pigs were typical backyard producers. Nearly two-thirds raised less than three pigs per year. Only five households out of the 200 in our survey raised more than 10 at a time.

Household sweetpotato production was positively associated with pig production up to three heads and then declined with further increases in the number of pigs raised. The results indicate that expanding the scale of pig production with the use of backyard-grown sweetpotato as feed is not ideal because of the limited land area and the need to include other uses in land allocation. Given a declining share of backyard pig production over time and feed use as a primary reason for farmers to plant sweetpotato, the prospects for growing sweetpotato as feed is not promising, unless new sweetpotato feed processing technologies emerge.

Financial analysis based on time series data shows that although sweetpotato once was relatively more profitable than its competing crops such as maize and wheat, its relative profitability appears to have declined since the mid 1980s. This is due to unfavorable terms of trade and the slow progress in generating production technologies, the latter being closely related to public investment in sweetpotato research. Financial profitability analysis based on our primary household survey shows that the farmers in Sichuan province had a negative profit from sweetpotato in 1997.

Although Shandong netted positive profit from sweetpotato production, incentives for substituting other crops for sweetpotato are emerging. In particular, the horticulture sector has been growing rapidly since the early 1990s, providing opportunities for farmers to reallocate land to higher valued crops. Meanwhile, regional market integration favors increased use of traded feed such as maize and compound feed in pig production. The opportunity cost of agricultural labor in many coastal counties in Shandong province is relatively high and is still growing, disfavoring low-value, labor-intensive crops like sweetpotato.

Break-even analysis demonstrates that expanding sweetpotato production will depend highly on future gains in farm productivity. Rising sweetpotato yields due to technology progress since the mid 1990s is an encouraging trend. If China wants to help farmers increase their income from sweetpotato production, increased investments in sweetpotato research and extension are essential. Labor-saving technology will also become critical in rural areas where employment in sweetpotato farms have diminished in value with the increasing opportunities for off-farm employment.

Further analysis based on a Policy Analysis Matrix (PAM) confirmed the above results and showed several other interesting findings. There was a large divergence between the social and private profitability of sweetpotato production. Sweetpotato would be more profitable if all policy interventions were removed. In Shandong, profit per hectare may increase from 790 to 1350 Yuan. Although social profit was still negative in Sichuan, the removal of all distortions would reduce the loss by 320 Yuan per hectare. Comparisons among crops showed that policies penalize sweetpotato while protecting maize production, particularly in Sichuan. Removing the policy distortions would make sweetpotato even more profitable than maize in Shandong and as profitable as maize in Sichuan.

The nominal protection rate of output shows that the policies taxed production of both sweetpotato and maize, but the extent of taxation was higher for sweetpotato than maize. Policies had the effect of lowering sweetpotato domestic prices by about 15 percent, about twice as much as for maize. Careful examination reveals that the distortions mainly come from the overvaluation of the Chinese currency. Policy interventions in input markets also favored maize more than sweetpotato. For the relative comparative advantage of sweetpotato and maize production, the estimated domestic resource cost (DRC) for these two crops were very similar. The similarity of DRCs of sweetpotato and maize implies that under trade liberalization, we do not expect to see much substitution of sweetpotato for maize in animal feed, unless further technological progress is made in sweetpotato production and utilization.

Sensitivity analyses further validate the key role of research and technology investment in increasing the competitiveness of sweetpotato as an animal feed in China. Since it is a labor-intensive crop, labor-saving technology would increase its relatively private and social profitability while lowering the domestic resource cost. Public investment in labor-saving technology, especially in sweetpotato production, reflects a pro-poor bias on the government's part since sweetpotato is primarily a crop grown by marginal farms. Given that poverty alleviation is a policy objective, this provides further justification for additional public support for sweetpotato. Finally, if the exchange rate were devalued to represent the true value of domestic currency, both sweetpotato and maize would become more competitive in the domestic and world markets.

In sum, the results from this study show that both sweetpotato and maize producers are facing great challenges. Policy distortions have penalized sweetpotato and protected maize production. The social profitability of sweetpotato is at least as high as maize in both Sichuan and Shandong, if not higher. The extent to which sweetpotato can substitute for maize in pig feed will highly depend on the direction of future policies and technology developments affecting the two crops. If productivity growth in sweetpotato continues to lag behind that of maize and other feed crops, we can expect to see the use of sweetpotato for feed gradually decline, even in backyard livestock production. Therefore, increased investment in sweetpotato research and extension and removal of the current policy distortions are critical to realize sweetpotato's full potential in China's agricultural economy.

I. Introduction and Overview of the Study

1.1 Introduction

China's gross domestic product has grown by almost 10 percent per year for the last 20 years (SSB, 2000). Surging incomes have led to higher demands for livestock products and animal feed. Although in the future, the economy may not grow as rapidly, many economists believe that China will continue to be one of the fastest growing countries in the world in the early 21st Century. A recent study by Huang et al. (1999) showed that grain requirements in China will grow by more than 40 percent between 1998 and 2020. Most of the increase in grain demand will be due to the rising demand for feed due in turn to the demand for meat and animal products which will nearly double due to income growth, urbanization and rural market development. The share of total grain production used for animal feed will rise from about 25 percent in the mid 1990s to 45 percent by 2020 (Huang et al., 1999).

Within grains, the utilization structure has been changing significantly in the past and this trend is likely to continue. In food consumption, rice and wheat have been substituted for coarse grains (mainly sweetpotato and maize) as income increased, with this trend occurring in both urban and rural areas (Huang and Bouis, 1995; Fan et al., 1995). Maize and sweetpotato, which contributed a large share of food grain consumption in the 1950s and 1960s, have been largely replaced by rice in southern China and wheat in northern China. These grains are now used as staple food only by a small portion of the population who live in the remote and poor areas.

As this substitution in food staples took place, sweetpotato and maize have become increasingly used as animal feed. By 1998, more than 40 percent of sweetpotato and about 80 percent of maize were used for feed in China (CCAP food economy database). However, despite the significant shift in the use of both maize and sweetpotato from food grain to feed, China's domestic feed grain supply growth is expected to lag behind the rapidly increasing demand in the coming decades.[2]

Trade liberalization and China's membership in the World Trade Organization (WTO) are expected to exacerbate the deficit of feed grains. The supply deficit of feed (mainly maize) is projected to reach as high as 30-50 million metric tons by 2020 (Huang and Chen, 1999; Huang et al., 2000; IFPRI, 2000). Whether China could or would be willing to import this large amount of maize from the world market (in order to support the expansion of domestic livestock sector) is an issue of rising concern. Alternative solutions to substitute maize with other domestically produced feeds such as sweetpotato and forage crops have been proposed by some researchers and policy makers but current knowledge provides very little evidence on the economic viability of these alternatives.

In China, sweetpotato is the fourth major staple crop (after rice, wheat, and maize) and the second largest feed grain (only next to maize). China is by far the largest producer of

[2] According to our review of literature, this seems to be a consensus viewed by both government decision makers and scholars. An exception is a study by Simpson et al. (1994), which predict that China would not be a net importer of feedstuffs until at least 2025.

sweetpotato in the world, accounting for about 85 percent of global production. Sweetpotato area in China peaked in the early 1960s at over 10 million hectares, or about 80 percent of total global area in sweetpotato. Sweetpotato area declined by 40 percent between 1961-1985, but has remained at about 6 million hectares since the mid 1980s.

Table 1.1. Importance of China in world sweetpotato production[a], 1961-99

Year	China		China as Percentage of World	
	Area (000 ha)	Production (000 MT)	Area (%)	Production (%)
1961~65	10,030	15,700	79	78
1969~71	8,746	21,826	75	84
1982	7,045	22,058	71	85
1990	6,305	20,980	69	85
1995	6,095	23,475	66	86
1999	5,946	25,229	65	86

[a] Sweetpotato production is reported on a dry weight basis. Dry weight is computed by dividing fresh weight by 5.

Sources: China's sweetpotato production and area data before 1971 are from MOA, Agricultural Yearbook of China, various issues. All others are from FAO Production Yearbook, various issues.

Total production has remained relatively constant at 20-25 million tons/year since the late 1960s. Yield increases offset the decline in total area planted to sweetpotato to keep production at this level. Between the 1970s and 1990s, sweetpotato's share in total grain area declined from about 9.4 percent to about 5.3 percent by the late 1990s. Its share of total grain production fell from about 8.6 percent to 5 percent (Table 1.2). A clearer understanding of China's sweetpotato balances and changing utilization patterns is an important issue because of its role in meeting feed demand for livestock sector expansion and its contribution to farm income and employment, particularly in marginal rural areas.

Interviews with plant breeders and researchers working on sweetpotato indicate a bright future for the crop. They claim that there is a high potential for substituting sweetpotato for maize as feed in small-scale pig raising ventures (i.e., backyard production). Since livestock production, particularly pig production, has been small-scale at the farm household level, and sweetpotato is mainly produced and used on the farm instead of flowing into the market, feed use of sweetpotato may increase in the short- and medium-term (Gitomer, 1996). Other uses of sweetpotato such as starch for both food processing and industrial purposes are also claimed to

have large potential if better processing technology and more efficient markets are developed (Zhang, 1999). However, others believe that the potential of sweetpotato as a substitute for feed maize is limited due to the increasing opportunity cost of labor, commercialization of livestock production, its poor storability in fresh form, low energy density on a fresh basis, and low protein content. These debates are becoming important issues deserving close attention from researchers and the agribusiness sector.

Table 1.2. Importance of sweetpotato in grain production in China, 1961-99

Year	Total Grain[a]		Sweetpotato as Percentage of Total Grain Production	
	Area (000 ha)	Production (000 tons)	Area (%)	Production (%)
1961-65	121107	171910	8.15	9.77
1969-71	119239	233683	9.44	8.57
1982	113396	353425	6.09	6.20
1990	113466	451841	5.51	4.60
1995	110061	466617	5.53	5.03
1999	113161	508387	5.25	4.96

[a] Grain includes rice (measured in paddy form), wheat, maize, soybean, sweetpotato, potato, sorghum, barley and millet. Sweetpotato and potato production are included on a dry weight basis. Dry weight is computed by dividing fresh weight by 5.

Sources: MOA, Agricultural Yearbook of China, various issues; MOA, Statistics for China Rural Economy, 1949-86. Sweetpotato production and area in 1961-65 and 1969-71 are from FAO Production Yearbook, various issues.

Several questions are raised in this report. How has non-maize feed (i.e., sweetpotato) production in China contributed to the increasing domestic demand for feed? To what extent could sweetpotato substitute for maize as feed in livestock production? What are the farmers' behavior, perceptions, and attitudes toward sweetpotato production and using sweetpotato as feed in livestock production? Does sweetpotato have a comparative advantage as a substitute for feed maize? How do exchange rates and other government price and marketing policies influence the use of sweetpotato for feed as well as sweetpotato economy? What are the future prospects for sweetpotato production and utilization in China?

Answers to these questions are by no means clear in China, and previous studies have focused on either cereal grains in general or rice and wheat in particular (Huang and Rozelle, 1999). Although some descriptive studies have been conducted recently[3], no studies have

[3] Jiang, Rozelle and Huang (1994) and Gitomer (1996) present overviews in sweetpotato production and utilization in China. Zhang (1999) provides a more analytical work on marketing of sweetpotato and sweetpotato products in Sichuan.

systematically examined most of the questions raised on the economics of sweetpotato in China's agriculture.

Answers to these questions require knowledge on the relative profitability of sweetpotato production compared with other feed crops at various locations, relative price trends of competing crops, demand for various uses of sweetpotato, farmers' practices of crop and livestock production, and efficiency of livestock production under different production scales and types of feed.

1.2 Objectives of the Study

The overall goals of this study are to characterize the changing pattern of China's sweetpotato production and utilization, examine the farm incentives governing sweetpotato production, and analyze efficiency of substituting sweetpotato for maize as feed in swine production.

In order to achieve these general goals, the following six objectives were pursued:

1) Examine the changing role of sweetpotato in the economy and trends in sweetpotato production and productivity in China;
2) Examine the changing patterns of sweetpotato utilization over time in major sweetpotato producing regions;
3) Identify and examine major macro-economic factors (i.e., exchange rates, off-farm employment and trade liberalization), price and non-price policies which affect the incentive structure of sweetpotato and competing crops (i.e., maize);
4) Examine the efficiency of sweetpotato as a substitute for maize as feed in pig production; and
5) Improve our understanding of sweetpotato production and utilization in the future.

1.3 Structure of the Report

Chapter 2 describes trends in sweetpotato area, yield, production and utilization as well as current consumption patterns. This chapter also provides new, comprehensive information on China's sweetpotato utilization. Chapter 3 focuses on sweetpotato production, its linkage with household pig production, and utilization in our study areas in Sichuan and Shandong provinces. It starts by describing the study sites, including the sampling procedure and the local agricultural production, and is then followed by a detailed examination of relationships between sweetpotato and pig production, farmers' production practices and their perceptions on sweetpotato production and utilization.

Chapter's 4 and 5 present the main analytical results of the report, including some answers to the questions raised above. Here we examine input, output, the productivity of sweetpotato, and the financial profitability of sweetpotato production. Chapter 5 presents the results of a Policy Analysis Matrix (PAM) that examines the social profitability of sweetpotato and maize production as feed for livestock production. Domestic resource costs and other measures of

maize and sweetpotato profitability are compared under alternative policies. These results provide useful information for policy makers in designing more conducive policies to enhance the role of sweetpotato for livestock sector expansion. The final section of this report summarizes the major findings and policy implications.

II. Sweetpotato Production and Utilization in China

2.1 Sweetpotato Production

Overall Production Growth

The growth of agricultural production in China since the 1950s has been one of the main accomplishments of the nation's development policies. Except during the famine years of the late 1950s and early 1960s, the country has enjoyed rates of production growth that have outpaced the rise in population (Table 2.1). Even in the 1970s, prior to the reform period, agricultural gross domestic product in real terms and grain production, respectively, grew at 2.7 percent and 2.8 percent per annum (Table 2.1). Except for grain and oil crops, horticulture, livestock and fishery sectors have been growing at accelerated rates since the reform started in 1979, with average annual growth rate of between 7 and 14 percent (Table 2.1). For grain production, after accelerating to 4.7 percent per year in the early reform period, 1978-84, its growth slowed to about 1.8 percent in 1985-99, but even this rate is higher than population growth.

Table 2.1 The annual growth rates (%) of China's agricultural economy, 1970-99.

	Pre-reform	Reform period		
	1970-78	1979-84	1985-95	1996-99
Gross domestic products (GDP)	4.9	8.5	9.7	8.0
Agriculture GDP	2.7	7.1	4.0	3.6
Grain production	2.8	4.7	1.7	1.9
Oil crops	2.1	14.9	4.4	3.4
Fruits	6.6	7.2	12.7	9.4
Red meats	4.4	9.1	8.8	9.2
Pork	4.2	9.2	7.9	9.0
Fishery	5.0	7.9	13.7	10.4
Population	1.80	1.40	1.37	0.97
Per capita GDP	3.1	7.1	8.3	7.0

Note: Figure for GDP in 1970-78 is the growth rate of national income in real terms. Growth rates are computed using regression method. Growth rates of individual and groups of commodities are based on production data; sectoral growth rates refer to value added in real terms. Growth rate of sweetpotato production in 1970-78 includes both sweetpotato and potato.

Source: SSB, Statistical Yearbook of China, various issues; MOA, Agricultural Yearbook of China, various issues.

Before the 1980s, sweetpotato had been one of the most important food crops in China's agricultural economy, with area planted reaching a historical high of over 11 million hectares in 1970 and accounted for 9.4 percent of total grain area (Table 1.2). But its importance in grain

production has since declined. By 1999, its share of area sown to grain was only 5.3 percent and its share of total grain production was just under 5 percent. .

The diminished importance of sweetpotato in China's grain economy is due to both the decline in its production area and a relatively slow rate of yield improvement. Contrary to the acceleration of overall grain production growth in the early reform period (1978-84), sweetpotato production growth declined from 2.4 percent per year in the pre-reform period (1970-78) to 0.5 percent per year in 1978-84 (Table 2.2). In the early reform period, the sweetpotato area fell by 3.3 percent per year, compared with a rate of decline of 1.1 percent for all grains (Table 2.2). Although annual growth of sweetpotato yield increased from 1.3 percent in 1970-78 to 3.8 percent in 1978-84, this performance was considerably less than that achieved by the major grains, which averaged about 6 percent per year. Since the mid 1980s, total grain area has remained about constant although sweetpotato area has continued to decline. Sweetpotato yield growth continued to underperform compared to rice, wheat, and maize until the mid 1990s. It was only in recent years that sweetpotato yield performance was better than cereal grains. Annual yield growth rate reached 2.2 percent in 1995-99, offsetting the fall in the crop areas (-6 percent per year), such that sweetpotato production grew annually by 1.6 percent in these years (Table 2.2).

China's sweetpotato economy and its growth pattern remains a mystery but is unattractive to researchers. In the past, China tightly regulated its rice, wheat, and maize sectors, but let sweetpotato be since the beginning of the reform period (Zhang, 1999). However, liberalization of sweetpotato production did not stimulate the sector's growth, neither in area planted or yield. Explanations for the performance and trends in sweetpotato production have to come from other forces of change in the economy and the sweetpotato sector itself. Some of these forces include changes in the structure of food demand and commodity utilization. Factors affecting technological progress in sweetpotato also play an important role.

Today, rising incomes, urbanization, market development, and other transitional forces push consumers to demand more rice and wheat and less course grains such as maize and sweetpotato (Huang and Bouis, 1995 and 2001). These same forces lead consumers to demand more livestock, fish and horticultural products. The demand for animal and fish products in turn increases farm-level demand for animal feed. This is reflected in the rapid expansion of maize production as evidenced by its growth that has outpaced all other grains since the 1970s despite the substantial decline in demand for maize as food (Table 2.2).

Sweetpotato, the second most important feed grain in many areas of rural China, seemingly was not much influenced by this opportunity. Sweetpotato area has steadily declined during the entire reform period, and there was very little yield improvement prior to the mid 1990s (Table 2.2). The absence of substantial yield growth in 1978-95 raises the question whether sufficient resources were devoted to research and extension for sweetpotato. Research-driven technological change has been the engine of growth in China's agricultural economy in general and for cereal grains in particular (Huang and Rozelle, 1996; Rozelle and Huang, 1999). Our interviews with the officials from the Ministry of Agriculture and the Ministry of Sciences and Technology indicated that sweetpotato has indeed been a relatively neglected crop by the research community. The impressive yield growth recorded for sweetpotato in the late 1990s

Table 2.2. Growth rates of grain production, sown area and yields in China, 1970-1999

Commodity	Pre-reform	Reform period		
	1970-78	1978-84	1984-95	1995-1999
Grain				
Production	2.8	4.7	1.7	1.9
Sown area	0.0	-1.1	-0.1	0.7
Yield	2.8	5.8	1.8	1.2
Rice				
Production	2.5	4.5	0.6	1.6
Sown area	0.7	-0.6	-0.6	0.3
Yield	1.8	5.1	1.2	1.3
Wheat				
Production	7.0	8.3	1.9	2.1
Sown area	1.7	0.0	0.1	0.1
Yield	5.2	8.3	1.8	2.1
Maize				
Production	7.4	3.7	4.7	3.2
Sown area	3.1	-1.6	1.7	2.9
Yield	4.2	5.4	2.9	0.3
Sweetpotato				
Production	2.4	0.5	0.4	1.6
Sown area	1.1	-3.3	-0.3	-0.6
Yield	1.3	3.8	0.7	2.2
Cash crop sown area	2.4	5.1	2.1	3.5

Note: Growth rates are computed using regression method.
Sources: SSB, ZGTJNJ (1980-2000) and ZGNYNJ (1980-2000).

may be explained by the rapid diffusion of some relatively simple production technologies, such as virus-free planting materials, which boosted yield by about 20 percent in Shandong Province (Fuglie et al., 1999).

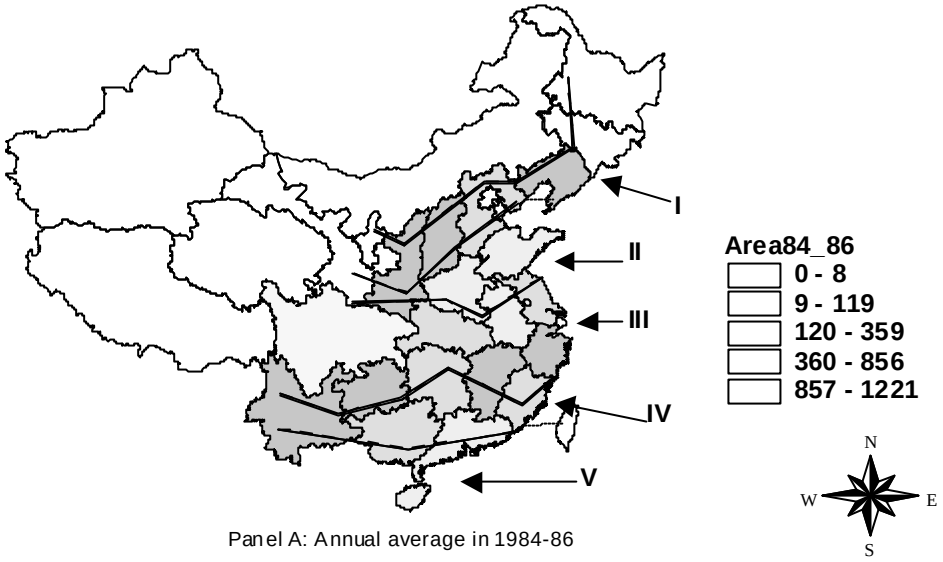
Regional Distribution of Sweetpotato Production

After sweetpotato was introduced in the 16th century, the crop became one of major staple food grains in many parts of China. Farmers in almost all provinces planted sweetpotato (Map 2.1), but cropping patterns, crop intensity and importance of sweetpotato varied from region to region (JSAAS and SDAAS, 1984).

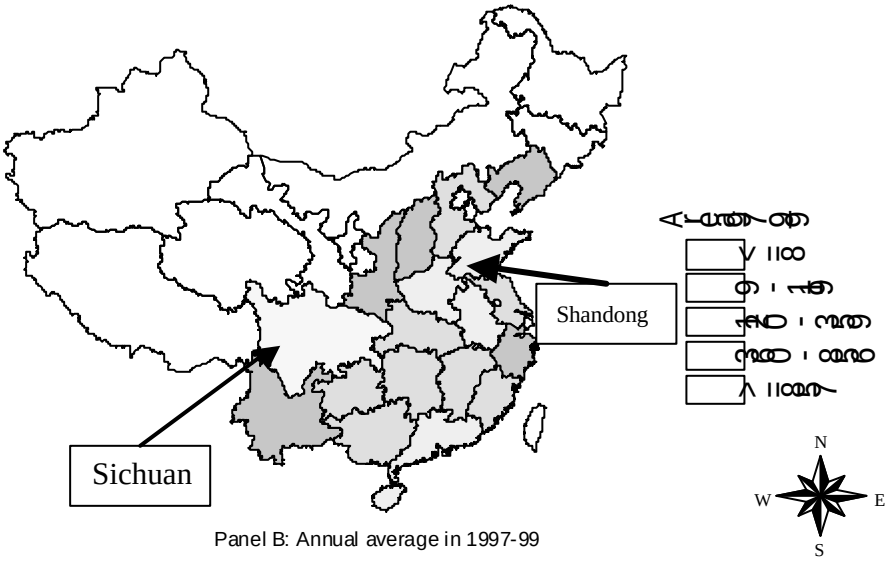
Geographical distribution extends from Hainan Island (18^{o} north latitude) to Heilongjiang province (45^{o} north latitude), and covers altitudes from sea level to more than 2,000 meters (Lu et al, 1989). Based on the ecological conditions and planting seasons, sweetpotato production in China is divided into five agro-climatic zones (JSAAS and SDAAS, 1984). They are the

Northern Spring Sweetpotato Region (I), the Huang-Huai Basin Spring and Summer Sweetpotato Region (II), the Yangzi River Basin Summer Sweetpotato Region (III), the Southern Summer and Fall Sweetpotato Region (IV), and the Southern Fall and Winter Sweetpotato Region (V).

The Northern Spring Sweetpotato Region or Region I is a humid or semi-humid monsoon temperate and cold temperate zone. In this region, sweetpotato is planted in both plain and hilly or mountainous areas. Because the temperate is low and the growing season is short in the regions, sweetpotato is a very minor crop (Map 2.1).



Panel A: Annual average in 1984-86



Panel B: Annual average in 1997-99

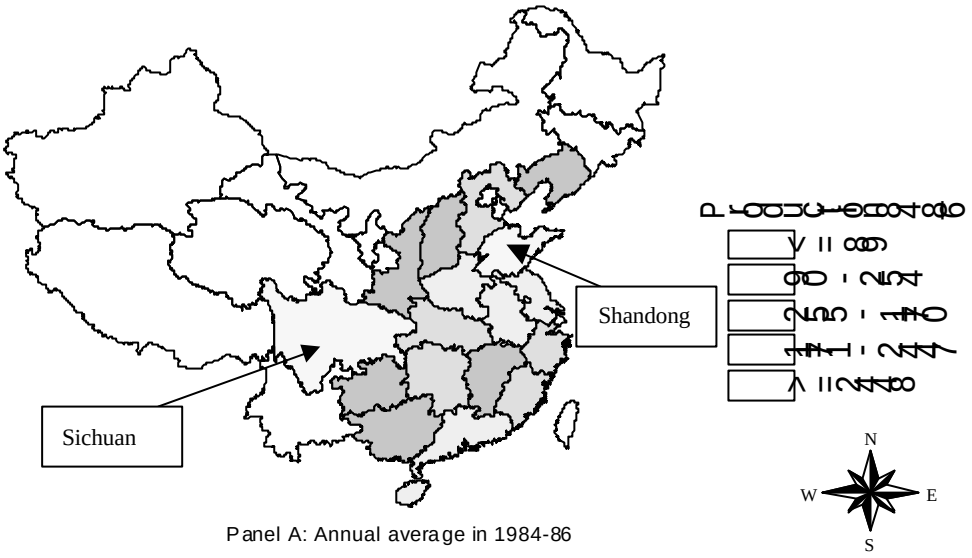
Map 2.1 Annual sweetpotato sown area (000ha) by province in China in 1984-86 and 1997-99

The Huang-Huai Basin Spring and Summer Sweetpotato Region (Region II) shows the most significant decline in sweetpotato area and production since the mid 1980s (Maps 2.1 and 2.3). The region accounted for more than 20 percent of sweetpotato area and nearly 30 percent of production in the early 1980s, but both area and production shares declined significantly over time. By the late 1990s, the region's share in China's sweetpotato area and production fell to less than 15 percent and 20 percent, respectively. While all provinces in the region showed a decline in the crop area, most of the decline in sweetpotato area occurred in Shandong province, from about 1 million hectares in the early 1980s to less than 500,000 hectares in the late 1990s (Map 2.1 and Appendix Table 1).

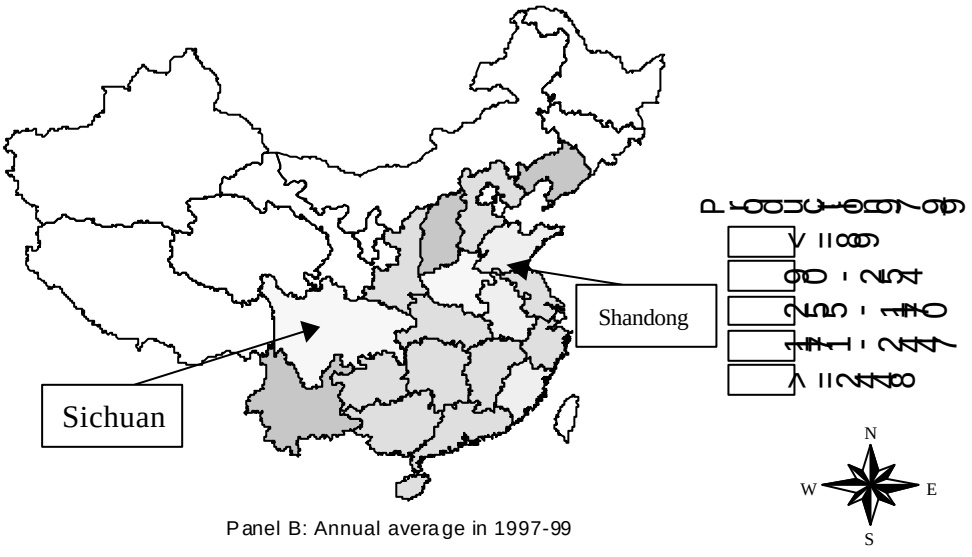
It is interesting to note that this significant decline of sweetpotato area occurred in one of the highest sweetpotato yielding regions in China and in a region with significant increase in yield (Map 2.3). From the ecological point of view, the region located in Huang-Huai basin has favorable climatic conditions for sweetpotato production. It is a temperate semi-humid monsoon area with large differences between day and night temperatures, and often has dry sunny days with sunlight sufficient for high photosynthetic efficiency. Our field interviews with farmers and local agricultural officials provided several hypotheses on the reasons underlying the decline of sweetpotato production. These include the changing pattern of sweetpotato utilization, relative decline in sweetpotato profitability compared with other crops, and a loosening of the linkage between sweetpotato and pig production (see Sections 3-5).

The Yangzi River Basin Summer Sweetpotato Region (Region III) is the most widespread sweetpotato production region (Maps 2.1 and 2.2). The region includes almost all the Yangzi River Basin such as Jiangsu, Anhui, and Henan provinces, south of the Huai River, the most southern part of Shaanxi province, most of the Guizhou province, the northern parts of Hunan, Jiangxi, and Yunnan provinces, and the entire Sichuan Basin. The climate in the region is characterized by the northern monsoon subtropical humid. Solar radiation and sunlight are the lowest among all the regions. Because of the large number of rivers in the upper and middle reaches of the Yangzi River, high evaporation, heavy clouds, and fog all tend to affect sweetpotato cultivation adversely. Sweetpotato is primarily planted in hilly areas on loess and red soils. The growing season in this region is 140-170 days, beginning in late April to June with harvesting in late October and November. The main production area is Sichuan Basin. Sweetpotato production in this region has been rising (Map 2.2) such that in the late 1990s, the region accounted for about 60 percent of national sweetpotato production (Appendix Table 2).

The other two regions, the Southern Summer and Fall Sweetpotato Region (Region IV) and the Southern Fall and Winter Sweetpotato Region (Region V) are located in southern China. Region IV includes a long and narrow strip just north of the tropic of Cancer in the south and central parts of the monsoon semitropical humid climate region. This includes the southern parts of Fujian, Jiangxi, and Hunan, the northern parts of Guangdong and Guangxi, central Yunnan and a small part of southern Guizhou (Map 2.1). Summer sweetpotato is sown in May and harvested between August and October. An autumn crop of sweetpotato is planted between early July and early August and harvested between late November and early December. Sweetpotato in this region is mainly distributed in hilly areas on red, yellow and crimson soils. Region V includes the south of Guangdong, Guangxi, Hainan, Yunnan, Taiwan, and the South China Sea

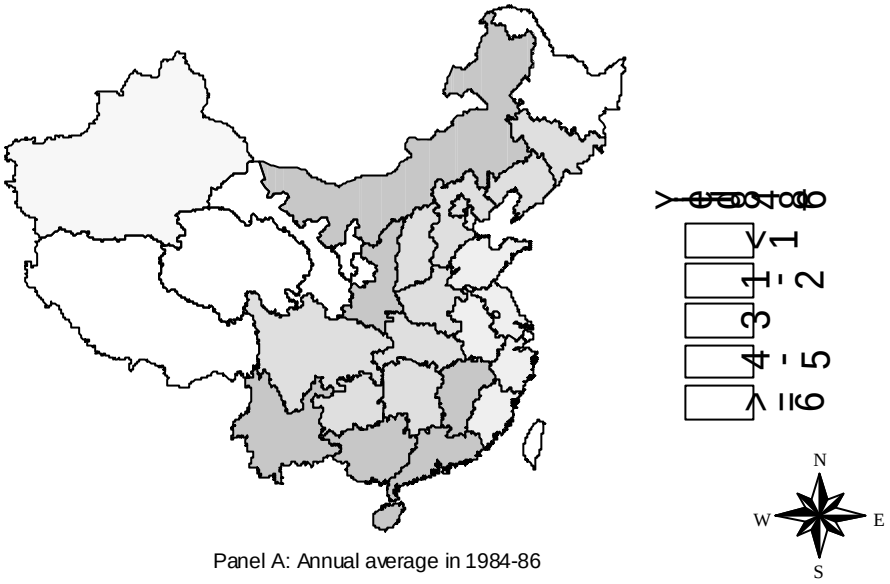


Panel A: Annual average in 1984-86

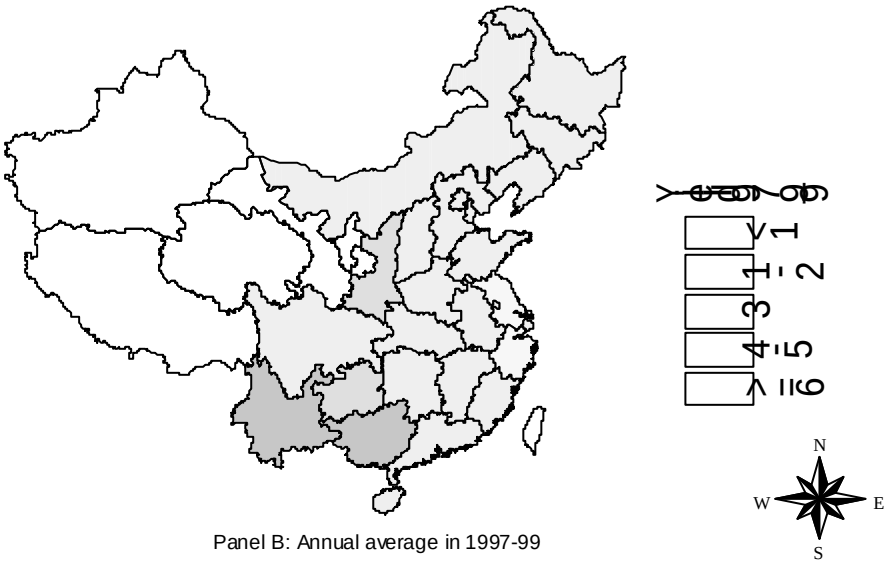


Panel B: Annual average in 1997-99

Map 2.2 Annual sweetpotato production (000ton) by province in China in 1986-86 and 1997-99



Panel A: Annual average in 1984-86



Panel B: Annual average in 1997-99

Map 2.3 Annual sweetpotato yield (ton/ha) by province in China in 1984-86 and 1997-99

islands. It belongs to humid tropical monsoon climate area with a hot season of 8-10 months long and the lowest day and night temperature differential in China. Although sweetpotato can be grown year-round, farmers plant it mostly in autumn and winter months. Fall sweetpotato in lowlands is planted from mid-July to mid-August, whereas upland areas are planted from early July to early August. Both are harvested from early November to late December. The growing period ranges from 120-150 days. Most winter sweetpotato is planted in November and harvested in April or May of the following year, with a growing period of 170-200 days.

Regions IV and V together accounted for 15-20 percent of the national sweetpotato area and an even smaller share of the national production average (Map 2.3) although its share of sweetpotato production against the national total has increased over time (Maps 2.1 and 2.2).

Table 2.3 presents another dimension in sweetpotato production showing the distribution by province. While sweetpotato production is widely distributed over China's 30 provinces, the top 10 provinces accounted for 82 percent of the national area and 87 percent of total production in 1997-99 (Table 2.3). Indeed most of the production is concentrated in 5 provinces, namely Sichuan, Shandong, Henan, Guangdong (including Hainan) and Anhui. These five provinces accounted for 62 percent and 67 percent of sweetpotato area and production, respectively, in 1997-99. Sichuan alone accounts for more than 20 percent of China's sweetpotato production and more than the total production in the rest of the world (FAO database).

Apparently, the economic reforms introduced in the late 1970s did not affect the geographic distribution of sweetpotato substantially. The share of production of the top five and top ten provinces declined between 1984-86 and 1997-99 (Table 2.3). Within the top five sweetpotato producers, the most significant changes took place in Sichuan and Shandong provinces. Both area and production increased in Sichuan and fell in Shandong such that Sichuan overtook Shandong as the largest sweetpotato producer in the 1990s. This further points out the importance of sweetpotato utilization and the demand forces in shaping the crop's production pattern.

2.2 Sweetpotato Utilization

Existing Literature on Sweetpotato Utilization Estimates

Lack of available information on how sweetpotato is utilized has been one of the most serious difficulties in understanding the sweetpotato economy of China. While several studies have attempted to estimate sweetpotato demand by various users, these are based either on small samples in specific locations or at a particular point in time. Not surprisingly, inconsistencies emerge when one attempts to put these estimates together. Projections based on alternative assumptions of sweetpotato utilization could lead to a wide range of perceptions on the future of sweetpotato in China and implications in the policies toward crop production, processing and investment.

Table 2.3 Sweetpotato production in top 10 producing provinces in China

Province	Sown area (000 ha)	Yield (ton/ha)	Production (000 tons)	Per capita production (kg/person)	Share in nation total	
					Area (%)	Production (%)
Annual average for 1984-86						
National total	6232	3.40	21172	25.0	100	100
Shandong	856	5.42	4634	68.6	14	22
Sichuan	1221	3.19	3891	43.6	20	18
Anhui	654	3.74	2447	54.5	10	12
Henan	799	2.69	2153	31.3	13	10
Guangdong	580	2.41	1401	27.0	9	7
Jiangsu	284	4.76	1354	26.1	5	6
Hebei	359	3.26	1170	24.4	6	6
Hunan	267	2.97	794	16.2	4	4
Fujian	218	3.52	767	33.2	3	4
Zhejiang	119	5.36	639	18.7	2	3
Top 5	4110	3.56	14525	45.1	66	69
Top 10	5358	3.59	19249	36.4	86	92
Annual average for 1997-99						
National total	5946	4.11	24414	26.6	100	100
Sichuan	1463	3.48	5098	54.3	25	21
Shandong	451	6.90	3113	44.3	8	13
Henan	609	4.46	2716	36.2	10	11
Guangdong	589	4.29	2525	42.4	10	10
Anhui	477	4.50	2150	42.9	8	9
Fujian	289	4.79	1384	51.9	5	6
Hunan	302	3.76	1136	21.3	5	5
Jiangsu	163	6.15	1002	19.1	3	4
Hebei	249	3.91	972	18.3	4	4
Hubei	212	4.20	889	22.3	4	4
Top 5	3589	4.35	15602	44.7	61	64
Top 10	4804	4.37	20985	36.5	82	87

Note: Sweetpotato production is reported on a dry weight basis. Dry weight is computed by dividing fresh weight by 5. Guangdong includes Hainan and Sichuan includes Chongqing.

Table 2.4 summarizes our review of some previous studies on sweetpotato utilization in China. While most of these studies show that direct food consumption of sweetpotato has declined over time, the magnitude of estimates vary widely. For example, Qiu et al. (1995) claimed that the share of sweetpotato used for direct food consumption declined from 50 percent in the 1950s to 12 percent in the 1980s, while other studies estimated that direct food consumption still accounted for as much as 34 percent (Gitomer, 1996) or even 77 percent (FAO database) in the 1980s (see the first row of Table 2.4). Significantly, different estimates are also found for utilization of sweetpotato for feed, industry, and food processing. Estimates of the proportion of feed utilization for the 1990s ranged from 34 to 85 percent, and processing demand ranged from less than 15 to 40 percent (the 4th row of Table 2.4).

Despite these discrepancies, the literature does provide some consensus on structural changes in sweetpotato utilization over time. Sweetpotato was once an important food crop in China in 1950s-1960s. However, with the rapid economic development and rising farmer's income since the beginning of the reform period in 1978, sweetpotato, often considered as an inferior good, has gradually progressed from being a staple food to animal feed and other uses. Rice and wheat have been the preference among the course grains (including sweetpotato) in food consumption as income rose (Huang and Bouis, 1995). Demand for sweetpotato in food processing expanded over time as rural markets developed and food consumption diversified (Zhang, 1999). Further, there are apparently large differences in utilization patterns among regions. This suggests that estimates of utilization trends based on a small case study may not be appropriate for analysis of regional or national trends, and such results need to be interpreted with caution.

New Estimates for Sweetpotato Utilization in China

To estimate a consistent and plausible database for sweetpotato utilization in China, we conducted a nationwide survey of agricultural leaders and administrators from agricultural bureaus (in charge of sweetpotato production) and grain bureaus (in charge of grain marketing) in each province. Knowledgeable officials in each province were asked to make their best estimates of sweetpotato utilization in their province over time. After receiving the survey forms from all provinces, a consultative meeting that included experts on sweetpotato production and marketing was held in Beijing to evaluate and revise the estimates. Table 2.5 summarizes the results from two leading sweetpotato production provinces, Sichuan and Shandong from the 1950s to the 1990s. Table 2.6 presents yearly estimates of sweetpotato utilization for all China from 1980 to 1997.

The estimates from this survey confirm large differences in sweetpotato utilization across regions and over time. For example, while the proportion of sweetpotato used as feed in Sichuan (14 percent) and Shandong (20 percent) was small and similar in 1950s, it has increased substantially over time. In the 1980s, feed utilization reached 60 percent in Sichuan but only increased to 30 percent in Shandong. Use of sweetpotato for food processing industries accounted for nearly half of sweetpotato production in Shandong in the 1990s. Although food processing demand for sweetpotato was considerably smaller in Sichuan, both provinces registered steady growth in this use over time.

Table 2.4 A review of sweetpotato utilization studies in China.

	1950s[1]	1950s[2]	1960s[3]	1970s	1980s[1]	1980s[4]	1980s[6]	1980s[7]	1990s[3]	1990s[5]	1990s[8]	1990s[9]
Direct Food	50%	60%	>50%	N.A.	12%	77%	15%	39%	<15%	14%	10	4~18%
Feed	30%	N.A.	N.A.	N.A.	30%	15%	30%	34%	N.A.	34%	70	71~85%
Seed	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	2%	N.A.	N.A.	N.A.	6~9%
Processing /Industry	10%	N.A.	N.A.	N.A.	45%	3%	44%[6]	20%	N.A.	40%	<15%	0%
Waste	N.A.	N.A.	N.A.	N.A.	N.A.	5%	N.A.	5%	N.A.	N.A.	N.A.	2~7%

Source:
[1]: Unpublished material by Qiu, Lin, Ping and Dai, Juangsu Academy of Agricultural Sciences; and Hu Jian Xun and Liu Xiao Ping, Anhui Academy of Agricultural Sciences, 1995.
[2]: Lu et al, 1989.
[3]: Li Weige, 1992; Wang et al. 1995.
[4]: The FAO balance sheet for 1984, Horton, 1988.
[5]: Adapted from Tang et al, 1990. National data is the percentage breakdown, which refers to Shandong, Sichuan, Anhui, Henan, Jiangsu, Hebei, and Hunan only, based on provincial percentages weighted by production.
[6]: Wiersema, Hesen and Song, 1989. Of the 44% of production utilized for processing, 14% is devoted to food products and 30% to industrial products including starch, alcohol and others.
[7]: Adapted from Gitomer C. S. 1996. National data is the percentage breakdown, which refers to Shandong, Jiangsu, Sichuan, Guangdong and Guangxi provinces only, based on provincial percentages weighed by production.
[8]: Data for Sichuan only from Sichuan government office.
[9]: Author's field survey, 1998. Data only refers to Sichuan, Chongqing and Shandong in livestock production areas rather than sweetpotato processing areas.

Table 2.5 Sweetpotato utilization (%) in Sichuan and Shandong provinces.

	1950s	1960s	1970s	1980s	1990s
Sichuan					
Direct food	65	60	50	20	11
Feed	14	19	29	60	60
Seed	6	6	6	5	5
Processing	3	4	5	10	19
Waste	12	11	10	5	5
Shandong					
Direct food	50	45	40	20	10
Feed	20	25	30	30	30
Seed	5	5	5	4	4
Processing	15	15	15	38	48
Waste	10	10	10	8	8

Note: Sichuan includes Chongqing.
Sources: Figures are provided by Sichuan and Shandong Academies of Agricultural Sicences.

Table 2.6 Changing utilization pattern (%) of sweetpotato in China, 1980-97.

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Food	36	36	35	34	32	30	27	25	23	21	19	18	17	16	15	14	14	14
Feed	31	30	31	31	31	32	34	35	36	37	38	39	39	39	40	40	40	41
Seed	6	6	6	6	6	6	5	5	5	5	5	5	5	5	5	5	5	5
Processing	15	16	17	18	20	22	24	25	26	27	28	29	30	31	32	33	33	33
Waste	12	12	11	11	11	10	10	10	10	10	10	9	9	9	8	8	8	7

Sources: Based on authors' surveys.

Our field interviews in Sichuan and Shandong reveal that less dramatic shift in the use of sweetpotato from food to feed in Shandong is associated with rapid development of local food processing industry and availability of alternative feeds such as maize. Shandong, one of most developed agricultural food processing provinces in China, has taken advantage of its proximity to urban and export markets to process sweetpotato for various food and industrial products such as noodles, starch and alcohol. In Sichuan, on the other hand, growth in maize production has not kept up with the rapid growth in livestock production. Sichuan is not only the largest sweetpotato producing province but also one of the largest and fastest growing livestock producer. While the maize deficit in Sichuan has been partially filled by shipments of maize from northern China (especially Jilin and Liaoning provinces), high transportation costs and lack of capital to purchase feed in Sichuan provide greater incentive for marginal farmers to use home-grown sweetpotato as feed (see next sections for more discussion).

At the national level, our estimates show that feed and processing demands have dominated sweetpotato utilization since the mid 1980s (Table 2.6). Feed use exceeded food use by 1985 and processing demand surpassed food use by 1988. By 1997, the proportion of sweetpotato used for feed had reached 41 percent and processing use was at 33 percent. It is interesting to note that although both feed and processing utilization rose significantly in the past two decades, the growth in processing use has been higher than the growth in feed use (a result consistent with a study in Sichuan by Zhang,1999).

2.3 Sweetpotato Food Balance Sheet

An estimate of the direct food consumption of sweetpotato by rural and urban consumers was made based on household income and expenditure surveys conducted by the State Statistical Bureau and interviews and surveys done for this study. A sweetpotato supply and utilization food balance sheet was also created for China from 1980 to 1997 using sweetpotato utilization information presented in Table 2.6 and production and trade data from government publications (SSB). End year stocks were estimated as the residual of production, trade and consumption balance.

Although sweetpotato is a net export trade commodity of China, it has never been considered an important crop. In many rural areas, it is not planted primarily as a cash income source, but as a crop intended to address household food and feed needs, and a cash income source through processing into starch and food products. Total utilization of sweetpotato remained at 20-24 million metric tons (mmt) per year during the entire period between 1980 and 1997. This demand was met entirely through domestic production. Among various uses, direct food consumption declined from 8.5 mmt in 1980 to less than 3 mmt in 1997, feed demand increased from 7.3 mmt to 8.4 mmt and industry use (processing) from 3.5 mmt to 6.8 mmt over the same period (Table 2.7). The small quantity of exports reported in table 2.7 refer only to trade in fresh sweetpotato. There was also a small but growing export of sweetpotato-processed products such as starch and starch-based noodles, but the overall quantity of these exports are not known.

The decline in sweetpotato consumption as direct food resulted from two major factors. One is income growth, which is negatively correlated with per capita consumption, and the second is

rural to urban migration. Urban residents consume only about one-third the amount of sweetpotato consumed by rural villagers. The share of urban consumption increased from less than 20 percent in 1980 to 30 percent in 1997. It is expected that growing urbanization will continue to be a major factor lowering per capita sweetpotato food consumption in the future.

Table 2.7 Sweetpotato supply, utilization food balance sheet in China, 1980-97.

	Units	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Area harvested	1000 ha	7914	7274	6908	6840	6427	6094	6175	6277	6307	6274	6256	6199	6062	6133	6062	6085	6062	5963
Yield	t/ha	2.992	2.957	3.173	3.537	3.547	3.394	3.244	3.646	3.315	3.337	3.32	3.369	3.493	3.685	3.545	3.86	4.085	3.434
Production	1000 t	23675	21505	21920	24190	22795	20686	20033	22886	20904	20936	20771	20886	21175	22603	21491	23485	24761	20474
Ending stock	1000 t	4735	4729	4722	4715	4708	4696	4686	4674	4659	4643	4627	4612	4596	4579	4551	4549	4549	4548
Net import	1000 t	-100	-100	-110	-121	-114	-207	-200	-229	-314	-314	-312	-313	-318	-339	-555	-41	-4	-10
Import	1000 t	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Export	1000 t	100	100	110	121	114	207	200	229	314	314	312	313	318	339	555	41	4	10
Consumption	1000 t	23581	21411	21817	24076	22688	20491	19843	22668	20606	20638	20475	20589	20873	22281	20964	23446	24757	20465
Food use	1000 t	8487	7706	7634	8183	7258	6144	5355	5664	4736	4331	3887	3703	3546	3562	3140	3282	3466	2865
Urban	1000 t	636	593	610	641	492	497	425	423	365	358	345	349	362	376	375	442	413	397
Rural	1000 t	7851	7112	7024	7543	6766	5646	4930	5241	4370	3973	3543	3355	3184	3187	2765	2840	3053	2468
Feed use	1000 t	7308	6422	6761	7461	7031	6553	6743	7930	7412	7630	7774	8023	8134	8683	8374	9378	9903	8390
Seed use	1000 t	1421	1290	1315	1451	1368	1241	1002	1144	1045	1047	1039	1044	1059	1130	1075	1174	1238	1024
Industry use	1000 t	3536	3425	3708	4332	4536	4505	4760	5664	5353	5568	5729	5966	6257	6902	6700	7737	8170	6753
Waste	1000 t	2829	2569	2399	2648	2495	2048	1983	2266	2059	2062	2046	1852	1877	2004	1675	1876	1981	1432
Per cap food	kg/cap	8.65	7.75	7.59	8.06	7.08	5.88	5.02	5.23	4.30	3.87	3.42	3.22	3.04	3.02	2.63	2.72	2.85	2.33
Urban	kg/cap	3.38	3.01	2.91	2.89	2.10	2.02	1.65	1.57	1.30	1.23	1.15	1.15	1.15	1.14	1.11	1.27	1.16	1.09
Rural	kg/cap	9.90	8.93	8.82	9.50	8.55	7.07	6.09	6.44	5.33	4.8	4.24	3.96	3.74	3.75	3.24	3.31	3.54	2.85
Population	Million	981.2	993.9	1005.9	1015.9	1025.6	1044.5	1066.8	1084.0	1101.6	1118.7	1135.2	1150.8	1165.0	1178.4	1191.8	1204.9	1217.6	1230.1
Urban	Million	188.2	197.4	209.6	222.0	234.3	245.7	257.3	270.2	281.7	291.0	298.7	303.7	314.6	328.7	338.3	347.4	355.6	364.7
Rural	Million	793.1	796.5	796.3	794.0	791.3	798.8	809.5	813.8	820.0	827.6	836.5	847.1	850.4	849.8	853.5	857.5	861.9	865.4

Note: Sweetpotato is reported on a dry weight basis. Dry weight is computed by dividing fresh weight by 5.
Source: From CAPSiM database and authors' estimates.

III. Sweetpotato Production and Utilization in Major Pig Production Areas

3.1 Data and Samples

General Background

The data used in this study come from both primary and secondary sources. Primary data were gathered on sweetpotato production, utilization, price, cropping technologies, farming systems, marketing institutions and policies at the national and provincial level as well as in the study areas. The secondary data came from various official statistical publications in China.

Primary farm household surveys were conducted to gain a better understanding of sweetpotato production practices, utilization of products, incentives in crop production and the efficiency of substituting sweetpotato for maize as feed in swine production. Some 200 farm households from 10 counties in Shandong and Sichuan provinces were selected based on the following criteria for the interview: 1) the areas should include sweetpotato and/or maize as part of the local farm production system; 2) raising pigs is an important or popular activity in the locality; 3) within selected villages, households were randomly stratified by income so that different income groups are represented; and 4) the samples are designed to include those villages and households with varying numbers of pig raised at farm level.

Based on these criteria, Sichuan and Shandong, the two largest sweetpotato provinces in China, were selected as case study areas. Further, localities were selected in areas where sweetpotato was primarily used as feed. Although in Shandong, the volume of sweetpotato used for food processing exceeds that used for feed, we purposely selected counties where feed is a primary use of sweetpotato. The results on sweetpotato utilization and production in Shandong are therefore not representative of the province as a whole.

Counties selected as the primary survey areas for farm level data collection included Jiangjin, Jiange and Leshan in Sichuan and Feixian and Zhucheng in Shandong. Two villages were selected in each county and 20 households were sampled in each village according to the criteria described above. Interviews were conducted in 1997 to get data on cost of production by crops, livestock production at household level and feed use, and again in1998 to gather information on farm household characteristics, production and consumption of major crops such as sweetpotato, maize, wheat and others.

In addition, county-level time series data on the production costs of sweetpotato, maize, wheat and rice for 1985-97 were collected from two counties each in Sichuan and Shandong provinces.[4] These data provided means for analyzing the changes in the profitability of crop production over time.

[4] These counties had records on sweetpotato production cost and return data.

Sichuan and Shandong Provinces

Sichuan[5]

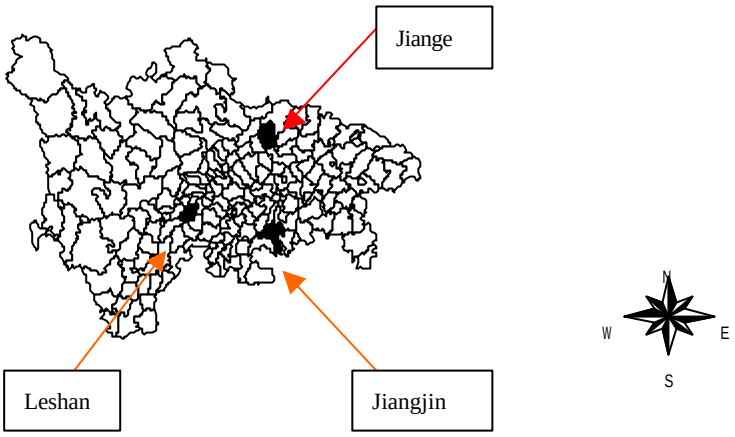
Sichuan is located in Southwest China on the upper stretch of the Yangtze River. Except for the northwest part of Sichuan Plateau, the province belongs to the Yangzi River Basin Summer Sweetpotato Region (Region III, Map 2.1). Sichuan has 173 counties and 49 city-level urban districts. The research area Jiangjin is located in the southeast part of the province, Leshan in the south and Jiange in the north (Map 3.1, Panel A). Sweetpotato production and pig production are important agricultural activities in these counties (Table 3.2).

Table 3.1 Background information on provinces and counties in 1997 farm survey

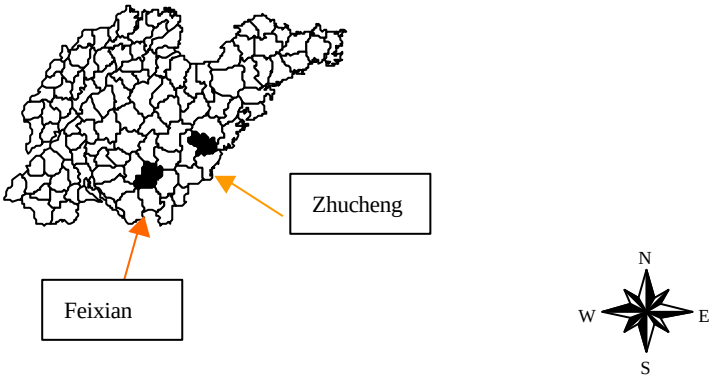
	Total population (million)	Farmer per capita net income (Yuan)	Share of agricultural income of farmer (%)	Per capita cultivate land (ha)	Grain area Share (%)
National	1236	2090	56	0.078	73
Sichuan	114.72	1662	72	0.054	78
Jiangjin	1.446	2117	60	0.051	62
Jiange	0.666	1282	80	0.081	65
Leshan	0.525	1762	75	0.040	75
Shandong	87.85	2292	67	0.076	74
Feixian	0.904	1958	75	0.066	53
Zhucheng	1.040	3138	65	0.101	36

Source: China Statistical Yearbook, 1998; Statistical Yearbook of Sichuan, Chongqing and Shandong, 1998; County Statistical Bureaus in Surveyed Counties.

[5] Sichuan province was divided into two parts with the separate administration of Chongqing city since 1996. However, in order to obtain a series of consistent data for Sichuan, it is defined as the old administrative classification by the government in this report, which includes Chongqing city.



Panel A: The sample counties in Sichuan province



Panel B: The sample counties in Shandong province

Map 3.1 Sample counties in Sichuan and Shandong province in 1997.

The province has marked physical and ecological diversity. More than 85 percent of land is classified as either hilly or mountainous and these areas are where sweetpotato is widely grown. With a population of 114.7 million in 1997 (Table 3.1), Sichuan remains one of the largest and most populous provinces in China[6], with about 80 percent of its people residing in rural areas. Per capita cultivated land is 0.054 hectare or about two-thirds of the national average (0.078 hectare, Table 3.1). Per capita rural net income in 1997 was 1662 Yuan (1 US$ = 8.3 RMB Yuan), 72 percent of which came from agriculture. This is about 80 percent of national average per capita net income of 2090 Yuan (Table 3.1) and ranked more so, it ranked 22nd among 30 provinces (SSB, 1998).

Sichuan is the largest producer of both swine and sweetpotato in China. Based on the official figures,[7] per capita pork production reached 41 kilogram in 1997, 46 percent higher than the national average (Table 3.2). Per capita sweetpotato production was 40.4 kilogram in 1997, more than twice that of the national average (16.6 kg, the last column of Table 3.2). Within the crop sector, rice, wheat, maize and sweetpotato are the most important crops, accounting for 23 percent, 18 percent, 14 percent and 11 percent of total crop area, respectively, in 1997 (SSB, 1998). On average, farmers in the province planted 2.1 crops annually (or multiple cropping index) on the same land.

Table 3.2 Per capita livestock and sweetpotato production in 1997.

	Meat Production (kg)	Pork Production (kg)	Slaughtered fattened pigs (head)	Sweetpotato area (ha)	Sweetpotato production[a] (kg)
National	41.7	28.0	0.36	0.005	16.6
Sichuan	51.2	40.9	0.59	0.013	40.4
Jiangjin	76.3	67.1	0.84	0.016	76.9
Jiange	97.2	86.0	1.24	0.007	27.0
Leshan	93.5	68.9	1.06	0.007	28.0
Shandong	44.7	22.7	0.28	0.005	37.8
Feixian	93.3	62.6	0.66	0.002	18.8
Zhucheng	112.4	60.6	0.68	0.007	44.5

[a] Sweetpotato is reported on a dry weight basis. Dry weight is computed by dividing fresh weight by 5.

Source: China Statistical Yearbook, 1998; Statistical Yearbook of Sichuan, Chongqinq and Shandong, 1998; County Statistical Bureaus in Surveyed Counties.

[6] After Chongqing separated from Sichuan in 1996, Sichuan had a population of about 84 million, the third largest province in terms of population (just next to Henan, 92 million, and Shandong, 87 million in the same year).
[7] The official figures on livestock production is believed to be inflated by more than 100% in 1997 (Ma, Huang and Rozelle, 2001).

Shandong

Shandong is a coastal province located in the North China Plain and belongs to the Huang-Huai Basin Spring and Summer Sweetpotato Region (Map 2.1). It is the third most populous province among 30 provinces (only next to Sichuan and Henan) in China with 87.85 million in 1997 (Table 3.1), accounting for 7.1 percent of the national population. Seventy-four percent of the population reside in rural areas. Shandong has 94 counties and 62 city-level urban districts. The study area, Feixian, is located in the southern part of the province, and Zhucheng is in the southeast of the province (see Map 3.1, Panel B).

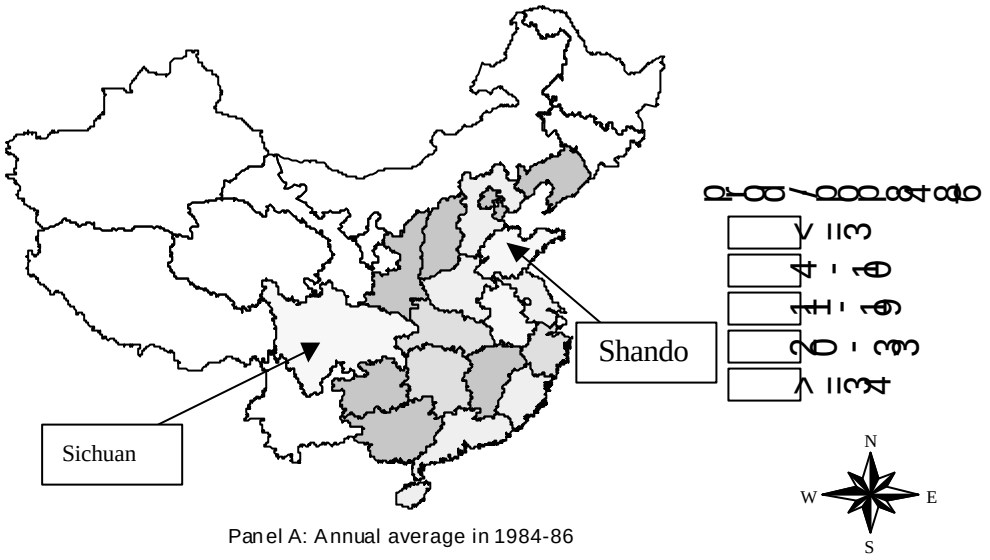
Shandong has much less ecological diversity than Sichuan. Only about 30 percent of its land is classified as hilly or mountainous areas. Per capita cultivated land (0.076 hectare in 1997) is slightly lower than the national average (Table 3.1), but per capita rural income (2292 Yuan) is about 25 percent higher than Sichuan, ranking ninth among 30 provinces. About two-thirds of farm household income is derived from agriculture. The top five crops planted in the province are wheat, maize, peanut, soybean and sweetpotato, accounting for 37, 24 , 7, 5 and 4 percent, respectively, of total crop area in 1997 (SSB, 1998). Per capita sweetpotato production was 2.3 times higher than the national average in 1997 (Table 3.2) and was the highest in China in the mid 1980s (Map 3.2).

Shandong is the largest livestock producer in terms of output value in China. Total value of livestock production was 75 billion Yuan in 1997 (68 billion Yuan for Sichuan, the second largest producer), accounting for 35 percent of agricultural output (SSB, 1998). Pork accounted for half of livestock production, a figure much lower than Sichuan (94 percent). Based on official data, the province produced about two million tons of pork in 1997, making Shandong the sixth largest producer in terms of quantity (or weight) in China.

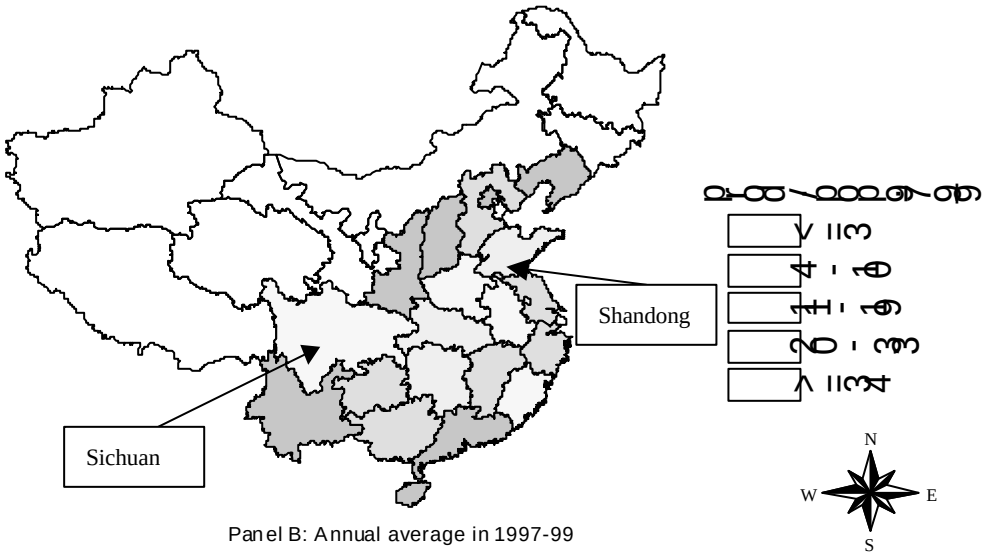
Trends in Sweetpotato Production

At the national level, sweetpotato production in China was stabilized at 20-24 mmt per year during the 1980s and 1990s despite the decline in the crop area (Table 3.3) although the growth pattern varies among provinces (Appendix Tables 1-3). Sichuan is a typical case where, after 10 years of falling sweetpotato production (Table 3.3), it started to grow at nearly 4 percent per year in 1990s (Table 3.4). This growth came from both area expansion and yield increases. By the late 1990s, Sichuan accounted for about 25 percent of national sweetpotato area, a 5 percent increase from the early 1980s. Its share of production in China also increased from about 19 percent in the early 1980s to 22 percent in the late 1990s (Table 3.3).

Shandong experienced another story. Sweetpotato area sharply declined in the early reform period (1981-85) with an annual growth of -8 percent (Table 3.4). Although the decline in area slowed to -2.14 percent per year in 1986-90, it resumed an accelerated decline of more than – 6 percent per year in 1990s. By 1999, sweetpotato area had fallen to 481,000 hectares, about 1/3 of the area in 1980. Despite an impressive gain in yield of about 2.7 percent per year in the 1990s, production fell from 5.55 mmt in 1980 to 2.76 mmt in 1999 (Table 3.3).



Panel A: Annual average in 1984-86



Panel B: Annual average in 1997-99

Map 3.2 Annual per capita sweetpotato production (kg) by province in China in 1984-86 and 1997-99

No study in the literature has examined the determinants and sources of sweetpotato production growth in China and in the major regions. However, the changing utilization patterns of sweetpotato at the national level and differences between Sichuan and Shandong may suggest that sweetpotato production is strongly driven by demand. The demand for sweetpotato as feed and for food processing could be foremost as engines of future sweetpotato production development. Because the demand for sweetpotato as feed depends to a large extent on comparative advantage of sweetpotato versus other feed grains such as maize, we need to look at the production profitability of sweetpotato and competing crops as well as the behavior of farmers toward using sweetpotato for feed.

Table 3.3 Sweetpotato sown area and production in Sichuan and Shandong provinces and China, 1980-1999.

Year	National	Sichuan	Shandong	Share in China	
				Sichuan	Shandong
	Sown area (000 hectares)			Area share (%)	
1980	7296	1483	1275	20.3	17.5
1985	6094	1207	821	19.8	13.5
1990	6256	1340	743	21.4	11.9
1995	6085	1415	549	23.3	9.0
1999	5937	1464	416	24.7	7.0
	Production (000 tons)[a]			Production share (%)	
1980	22872	4480	5555	19.6	24.3
1985	20686	3942	4373	19.1	21.1
1990	20771	3319	4120	16.0	19.8
1995	23479	4558	3316	19.4	14.1
1999	25191	5464	2764	21.7	11.0

[a] Sweetpotato is reported on a dry weight basis. Dry weight is computed by dividing fresh weight by 5.
Sources: Agricultural Yearbook of China, various issues.

Table 3.4 Annual growth rate (%) in sweetpotato production in China, Sichuan and Shandong provinces, 1982-99.

	Area	Yield	Production
National			
1981-85	-4.71	3.91	-0.88
1986-90	0.52	-0.34	0.18
1991-95	-0.55	2.82	2.25
1996-99	-0.69	2.20	1.51
Sichuan			
1981-85	-4.28	2.41	-2.01
1986-90	2.07	-4.10	-2.11
1991-95	1.22	2.91	4.17
1996-99	0.98	2.70	3.70
Shandong			
1981-85	-8.00	6.76	-1.78
1986-90	-2.14	-1.53	-3.64
1991-95	-5.88	2.68	-3.36
1996-99	-6.67	2.74	-4.07

Note: Growth rates are computed using regression method.
Source: SSB, Statistics Yearbook of China, various issues; Agricultural Yearbook of China, various issues.

3.2 Sweetpotato Production and Utilization

Characteristics of Sample Households

Four villages in each county were selected with 10 random households from each village. A total of 200 households from 20 villages in the five counties were interviewed. Among 200 households interviewed, eight were excluded in our analysis due to insufficient information provided by these households, bringing the effective samples down to 192.

The characteristics of the sampled households from Jiangjin, Jiange and Leshan counties in Sichuan and Feixian and Zhucheng counties in Shandong are summarized in Tables 3.5-3.7. Farm sizes in the sampled villages are close to the average for their respective counties, with a mean of 0.38 hectare (Table 3.5). This size is typical for an individual farm in China. For the sample in Sichuan, irrigated paddy land accounted for 61 percent of total arable land, but this varied considerably among counties, from 34 percent in Jiange to 79 percent in Leshan. In Shandong, upland (nonpaddy land) is dominant among the sample households, accounting for 94 percent of total arable land (Table 3.5). Croplands in Shandong are all irrigated using groundwater.

The average family size was 3.8 persons with 2.71 laborers who were mainly engaged in agricultural production. Each family had to allocate its limited land to various uses in order to meet the needs of the household, and market only the surplus for cash income. Among various grains planted, rice is the most important crop in Sichuan while wheat and maize are dominant in Shandong (Table 3.6). Sweetpotato is the second major grain in Jiangjin county in Sichuan, and the third major crop in the other two Sichuan counties. In Shandong, the shares of sweetpotato in total grain area ranged from 4 percent in Zhucheng to 16 percent in Jiangjin and Feixian (Table 3.6).

Table 3.5 Household characteristics of farms included in 1997 survey

County	Family size (person)	Farm size (ha)	Per family labor	Per capita arable land (ha)	Land structure (%)		
					Paddy land	Dry land	Hill land
Sichuan	3.72	0.36	2.59	0.10	60.7	23.4	16.1
	(1.04)	(0.28)	(0.89)	(0.09)	(26.2)	(15.2)	(21.5)
Jiangjin	3.73	0.29	2.77	0.08	72.4	26.3	1.7
	(1.28)	(0.17)	(0.97)	(0.04)	(14.7)	(12.9)	(5.2)
Jiange	3.98	0.56	2.35	0.15	34.4	26.5	39.1
	(0.95)	(0.36)	(0.70)	(0.12)	(16.9)	(13.3)	(17.8)
Leshan	3.44	0.21	2.69	0.06	79.1	17.8	3.3
	(0.85)	(0.07)	(0.98)	(0.02)	(17.8)	(17.4)	(8.5)
Shandong	3.91	0.41	2.88	0.11	3.2	94.0	2.8
	(1.09)	(0.18)	(1.06)	(0.05)	(15.5)	(18.1)	(9.9)
Feixian	3.93	0.38	2.57	0.10	7.0	86.8	6.2
	(0.83)	(0.18)	(0.77)	(0.04)	(22.6)	(25.2)	(14.0)
Zhucheng	3.89	0.43	3.14	0.12	0	100	0
	(1.28)	(0.17)	(1.20)	(0.05)	(0)	(0)	(0)
Average	3.80	0.38	2.71	0.10	39	50.0	11.0
	(1.06)	(0.25)	(0.95)	(0.25)	(36.1)	(38.0)	(19.0)

Note: Standard errors in the parentheses.
Source: Authors' primary survey.

Table 3.6 Sweetpotato and cereal grain production of farms in 1997 survey

	Grain area (ha)	Sweetpotato area (ha)	Rice area (%)	Wheat area (%)	Maize area (%)	Sweetpotato area (%)
Sichuan						
Jiangjin	0.33	0.05	56	13	14	16
Jiange	0.44	0.02	36	35	23	5
Leshan	0.24	0.02	70	17	3	9
Shandong						
Feixian	0.39	0.07	0	46	37	16
Zhucheng	0.60	0.02	0	52	44	4

Sources: Authors' primary survey.

Livestock production, particularly pig raising, is the second most important farming activity after grain production in the sampled areas. The households interviewed raised an average of 4.72 pigs in Sichuan and 1.9 pigs in Shandong (Table 3.7). Poultry is the second most important livestock and is produced by almost all households in the sample. Cattle and sheep were found in a small number of households.

The farmers' income heavily depended on agricultural production, mainly grain and livestock. Non-agricultural income contributed 20 percent to the farmer's net income in both Sichuan and Shandong, a level much less than the national average of about one-third. But the average net income of the sampled households in Shandong was much higher than that in Sichuan. Heads of households in Shandong were also better educated, with an average of 7.3 years of formal schooling, than household heads in Sichuan, with only 5.7 years of schooling (Table 3.7).

Sweetpotato Utilization

Households in the sample produced an average of 176 kilograms of sweetpotato in 1997 (Table 3.8). Feed use dominated sweetpotato utilization. Farmers used about 85 percent of the sweetpotato that they produced for feed. The rest (15 %) went to family food consumption, saved for seed use, and include post harvest losses as well. Marketing of sweetpotato was minimal, with only 13 kilograms sold and 6 kilograms purchased, implying a very high level of self-sufficiency at both household and community levels. More than half of marketed sweetpotato was for direct food consumption by local consumers and the rest was used to make starch by local food processors. The variations of utilization patterns were small among five counties studied. Note that because we selected counties where the primary use of sweetpotato

was for animal feed, these figures understate the average amount of sweetpotato used for food and industrial processing in these provinces.

Table 3.7 Other household characteristics of farms included in 1997 survey

	Per capita income (Yuan)	Share of non-agri income (%)	Number of livestock (average of beginning and end-year inventory) (head)				Head schooling years (year)
			Pig	Cattle	Sheep	Poultry	
Sichuan	1958	22.3	4.72	0.35	0.33	7.36	5.68
	(1241)	(30.2)	(21.1)	(0.6)	(1.1)	(16.9)	(2.6)
Jiangjin	1645	11.6	8.40	0.007	0.017	9.55	5.23
	(800)	(18.2)	(19.8)	(0.0)	(0.1)	(13.7)	(2.1)
Jiange	1866	22.4	3.16	0.80	0.89	4.00	6.15
	(1193)	(31.7)	(2.4)	(0.7)	(1.7)	(4.6)	(2.5)
Leshan	2294	30.5	3.49	0.15	0	9.13	5.54
	(1492)	(33.9)	(5.7)	(0.4)	(0)	(25.1)	(2.8)
Shandong	2904	19.4	1.90	0.14	0.24	4.76	7.33
	(2214)	(21.3)	(5.2)	(0.4)	(1.6)	(13.2)	(2.4)
Feixian	2153	17.7	3.52	0	0.53	5.65	6.60
	(1119)	(20.6)	(7.3)	(0)	(2.4)	(4.7)	(2.3)
Zhucheng	3531	20.7	0.56	0.25	0	4.01	7.94
	(2680)	(22.0)	(1.2)	(0.5)	(0)	(17.5)	(2.3)

Note: Standard errors in the parentheses.
Sources: Authors' primary survey.

Table 3.8 Sweetpotato production, utilization and marketing (kg)[a] on surveyed farms

	Sample number	Production	Utilization					Purchased	Sold	Stock change
			Total	Food	Feed	Seed	Waste			
Whole samples	192	176	174	9	148	10	7	6	13	-5
Sichuan	124	158	158	11	127	10	9	6	4	2
Jiangjin	42	278	283	17	230	19	18	10	2	2
Jiange	40	76	74	12	55	4	3	0	1	1
Leshan	42	118	113	3	95	7	7	8	9	4
Shandong	68	209	204	5	187	11	2	6	30	-20
Feixian	30	382	371	10	346	13	2	13	60	-37
Zhucheng	38	72	72	1	61	9	2	0	7	-6

[a] Sweetpotato is reported on a dry weight basis. Dry weight is computed by dividing fresh weight by 5.
Sources: authors' survey.

3.3 Linkage of Pig and Sweetpotato Production

Among 192 households interviewed, 146 households or 76 percent, raised pigs. Local farmers used various feed sources including sweetpotato, maize, other grains (for example, low quality indica rice in Sichuan), various meals and succulents from home-produced sweetpotato tops, vegetables, and others crops to raise pigs (Table 3.9). Compound feed was introduced recently to the local farmers, but the rate of use is still very low.

Most of households that were into backyard pig raising are typical of their kind in China. The number of households with less than three pigs accounted for nearly two-thirds of the households engaged in pig production (Table 3.10). Only five households with more than 10 pigs were in our entire sample. Local villagers call these producers as households that specialize in pig production. One of the most interesting findings from the sample is that household sweetpotato production is positively associated with the number of pigs raised up to three pigs. For those households that did no go into swine production, average production of sweetpotato was only 51 kilograms. As the number of pigs produced increased to 0.5-1.5, sweetpotato production increased to 188 kilograms. Households producing 2-3 pigs produced 253 kilograms of sweetpotato (Table 3.10). But further increases in the number of pigs were not associated with a further rise in sweetpotato production. In fact, sweetpotato production declined slightly after the number of pigs reached three.

Several factors may explain the linkage between swine and sweetpotato production. Home-produced sweetpotato is a traditional and cheap source of feed for household backyard pigs, particularly when the rural feed market is not very developed and therefore alternative commercial feed is not available locally or too expensive for credit-constrained households. Increase in the number of pigs raised is therefore positively associated with the household sweetpotato production when the number of pigs is small. However, because farm size is small, the number of pigs raised using household-produced feed is usually limited to two or three.

Table 3.9 Share of various feeds (%) used in pig production on surveyed farms

	Sichuan	Shandong
Grain and other feed		
Sweetpotato	20	34
Maize	25	37
Other grain	38	8
Various meals	1	9
Compound	8	11
Others	8	1
Total grain and other feed	100	100
Fodder		
Sweetpotato vine	38	68
Non-sweetpotato stalk	1	5
Other fodders	61	27
Total fodder	100	100

Sources: Authors' primary survey.

Table 3.10 Swine and sweetpotato production of farms included in 1997 survey

Number of pigs on farm	Sample number	Total pig number	Pig per household	Sweetpotato production (kg)	Sweetpotato used as feed per pig (kg/pig)
0 pig	46	0	0.00	51	na
0.5-1.5 pigs	47	48	1.01	188	158
2.0-3.0 pigs	46	112	2.42	253	90
3.5-27 pigs	53	274	5.16	206	34

Note: Number of pigs on the farm is the average number at the beginning and ending of the year. Sweetpotato is reported on a dry weight basis. Dry weight is computed by dividing fresh weight by 5.
Source: authors' survey.

With only about 0.4 ha, the household has to allocate land not only to feed production but also to vegetables and other food crops for both home food consumption and government procurement requirements. Further expansion of sweetpotato production may also be limited by

the availability of family labor, since growing sweetpotato is more labor intensive than other grain crops. Therefore, increasing the number of pigs raised above this limit would require the use of alternative feed grains or commercial feed, unless suitable technologies can be found to raise sweetpotato yield and reduce labor requirements.

The above discussion implies that future prospects for sweetpotato used as feed for pig production will largely depend on the following factors: 1) grain (and feed) marketing development as well as government grain procurement system reform; 2) growth or decline of backyard pig production; and 3) the comparative advantage of sweetpotato as feed for raising pig. It is evident from the preceding discussion that the first two factors are unlikely to result in the full development of sweetpotato as livestock feed source. China is liberalizing its grain sector and WTO accession is expected to further liberalize this sector. Further, agricultural grain markets, especially for maize, have become increasingly integrated nationally since the late 1980s (Yu and Huang, 1998; Rozelle et al., 2000). The last factor is a central issue of this study that will be investigated in Chapters 4 and 5.

The share of backyard pig production has been declining since the middle 1980s by about one percent per year. According to a nationwide survey conducted by the Ministry of Agriculture, the backyard producers accounted for 94.6 percent of pig production in China in 1985. This share had fallen 80.7 percent by 1996 (Table 3.11). A recent study by Chen (2001) shows that many factors that determine pig production favor its intensification at the expense of backyard pig raising, particularly labor market development and migration, farm income growth, and various risks associated with farm production. However, the trends in backyard pig production vary widely across provinces. The share of households that raise pigs has been falling sharply in coastal provinces but remains high or has even increased in some interior provinces like Sichuan and Hunan (Zhang, 1998).

Table 3.11 Share (%) of pig production by different sizes of farms

	Backyard	Specialized household	Intensive
1985	94.6	2.9	2.5
1993	88.3	8.2	3.5
1996	80.7	14.6	4.7

Note: Annual average number of slaughtered pigs was 3.2 for backyard producer and 436 for specialized household in 1993 and 1996, and 1.7 for backyard producer and 30 for specialized household in 1985.

Source: RERC, 1997.

Table 3.12 presents how sweetpotato is utilized and marketed by households that ventured into pig raising. The results show that the majority of sweetpotato produced by farmers were consumed on farm as feed, food, seed, or were lost after harvest. Marketing of sweetpotato was minimal and the number of pigs raised was not correlated with the quantity of sweetpotato

marketed. For comparison, Table 3.13 shows similar information in the utilization and marketing of maize by the backyard swine raisers. The results also show that most of maize produced by farmers are utilized on farm as feed, food, and others. Tables 3.12 and 3.13 also indicate that an increase in pig feed demand is met mainly by home-grown sweetpotato and maize in our sample areas. This points out the importance of the relative competitive advantage (or profitability) of sweetpotato versus maize production in determining feed utilization in backyard pig production.

Table 3.12 Sweetpotato production, utilization and marketing (kg) by number of pigs per household in 1997.

Pig number	Production	Home use	Purchased	Sold	Stock change
Whole samples					
0 pig	51	41	0	7	2
0.5-1.5 pigs	188	184	9	23	-10
2.0-3.0 pigs	253	253	13	13	-1
3.5-27 pigs	206	211	2	10	-13
Sichuan					
0 pig	26	27	0	0	0
0.5-1.5 pigs	129	131	1	3	-3
2.0-3.0 pigs	187	190	15	11	2
3.5-27 pigs	181	178	3	0	6
Shandong					
0 pig	58	46	0	9	3
0.5-1.5 pigs	275	262	21	53	-20
2.0-3.0 pigs	621	609	0	27	-15
3.5-27 pigs	369	432	0	75	-137

Note: Sweetpotato is reported on a dry weight basis. Dry weight is computed by dividing fresh weight by 5.
Sources: Authors' survey in Sichuan and Shandong.

Table 3.13 Maize production, utilization and marketing (kg) by number of pigs per household in 1997.

Pig number	Production	Home use	Purchased	Sold	Stock change
Whole samples					
0 pig	815	330	88	497	76
0.5-1.5 pigs	398	354	30	106	-32
2.0-3.0 pigs	377	318	12	83	-12
3.5-27 pigs	480	477	55	34	24
Sichuan					
0 pig	101	60	5	45	1
0.5-1.5 pigs	157	193	48	5	7
2.0-3.0 pigs	332	304	14	23	19
3.5-27 pigs	376	383	36	24	5
Shandong					
0 pig	1040	415	114	643	96
0.5-1.5 pigs	753	592	2	205	-42
2.0-3.0 pigs	625	401	0	280	-56
3.5-27 pigs	1160	1095	179	203	41

Sources: Authors' survey in Sichuan and Shandong.

Econometric analysis of the determinants of sweetpotato area and production confirm the relationship between backyard pig activity and sweetpotato production (Table 3.14). While crop area and production had strong positive links with the number of pigs raised, the marginal increase in sweetpotato declined with the number of pigs raised, and did not increase after three pigs.

Among households using sweetpotato in the farm sample, feed accounted for 85 percent of use and the rest (15 %) was nearly equally divided among food, seed and post-harvest losses (Table 3.15). Differences in sweetpotato use among the sample counties were small. There was also no significant difference in the pattern of sweetpotato utilization among different sizes of pig production (Table 3.15). Because there is limitation to sweetpotato expansion at the household level, increasing the number of pigs raised was accompanied by a reduction in the amount of sweetpotato available per pig (Table 3.10).

Table 3.14 Determinants of household sweetpotato yield, area and production.

	Ln (Yield)	Ln (Area)	Ln (Production)
Constant	3.638 (2.71)***	-3.643 (-6.45)**	5.177 (4.25)***
Ln(Area)			0.660 (4.31)***
Ln(Fertilizer/ha)	0.024 (0.43)		0.055 (1.10)
Ln(Labor/ha)	0.262 (1.88)*		0.199 (1.67)*
Male head	3.561 (3.69)***	0.269 (0.54)	3.530 (4.03)***
Family population		0.100 (1.71)*	
Pig number		0.083 (2.13)**	0.161 (2.32)**
(Pig number)^2		-0.004 (-2.37)**	-0.009 (-2.62)***
County dummy			
Jiange	-0.593 (-1.84)*	-1.174 (-6.87)***	-1.100 (-3.18)***
Jiangjin	-0.063 (-0.18)	-0.264 (-1.47)	-0.176 (-0.55)
Leshan	-0.958 (-2.57)**	-0.823 (-4.51)**	-1.087 (-3.10)***
Zhucheng	0.077 (0.15)	-0.199 (-0.76)	0.019 (0.04)
Adjusted R^2	0.16	0.30	0.45

Note: Total sample is 139 (for those households with sweetpotato production).

Table 3.15 Patterns of sweetpotato utilization in households included in 1997 survey

	Sample number	Shares in total home use (%)				
		Total	Food	Feed	Seed	Waste
Whole sample	192	100	5	85	6	4
Sichuan	124	100	7	81	6	6
Jiangjin	42	100	6	81	7	6
Jiange	40	100	16	74	5	4
Leshan	42	100	3	84	6	7
Shandong	68	100	2	91	5	1
Feixian	30	100	3	93	3	1
Zhucheng	38	100	0	84	12	3
By number of pigs raised (all farms)						
0 pig	46	100	4	84	10	2
0.5-1.5 pigs	47	100	5	87	6	3
2.0-3.0 pigs	46	100	6	86	5	3
3.5-27 pigs	53	100	5	84	6	6
By number of pigs raised (farms with sweetpotato production only)	146	100	12	77	7	5
0 pig	12	100	19	63	16	2
0.5-1.5 pigs	39	100	13	77	6	4
2.0-3.0 pigs	45	100	12	78	5	4
3.5-27 pigs	50	100	9	79	6	6

Sources: Authors' survey in Sichuan and Shandong.

3.4 Farmers' Perception on Sweetpotato Production and Utilization

In order to gain a better understanding of sweetpotato farmers' perceptions on sweetpotato production and utilization, the farmers were asked to answer several pre-designed questions. One question asked about the reasons farmers decided to plant sweetpotato to which more than 90 percent in Sichuan and 73 percent in Shandong replied that the primary reason was for home feed use (Table 3.16). Home food consumption and crop profitability were not among the major factors influencing farmers' decision to plant sweetpotato. The same question was asked regarding maize. The answers from Sichuan's farmers were not much different for the two crops, sweetpotato and maize. This may be due to the fact that maize in our Sichuan sample was also mostly used as home feed and not for commercial sale. But about 20 percent of farmers from Shandong considered high profit of maize production as the top reason for planting maize.

Table 3.16 Farmer's main reasons (%) for growing sweetpotato and maize for households included in 1997 survey

Reason	Sichuan				Shandong		
	Average	Jiangjin	Jiange	Leshan	Average	Feixian	Zhucheng
What is your main reason for planting sweetpotato?							
Home food use	0	0	0	0	0	0	0
Home feed use	91	88	95	89	73	84	56
Profitable	1	0	3	0	0	0	0
Others	7	9	3	8	20	13	33
Not applicable	2	3	0	3	6	3	11
What is your main reason for planting maize?							
Home food use	2	0	0	7	0	0	0
Home feed use	85	97	95	59	55	70	42
Profitable	1	0	3	0	20	13	25
Others and NA	11	3	3	33	26	17	33

Note: NA is for those farmers who did not plant sweetpotato at all.
Sources: Authors' primary survey.

IV. Financial Profitability of Sweetpotato, Maize and Other Competing Crops

4.1 Background on the Data

Financial profitability of sweetpotato production is examined based on the cost of crop production calculated from two data sources. Time series data on sweetpotato production costs and revenue were provided by the provincial and county governments that have coordinated an agricultural production cost survey for all major local crops since the early 1980s. This survey is conducted jointly by several bureaus in each county, including price bureau, grain bureau, commercial bureau, and others that are responsible for the commodities concerned. The data are very unique for examination of the trends of profitability of various crops over time. However, the validity of this data set should be kept in mind because of the limited number of households surveyed. Normally, each county official selects only a few "representative" households that may be biased in favor of "model farmers". Moreover, the sampled households often change over time. The higher average crop yield from the official cost of production surveys presented in Tables 4.1 and 4.2 seems to confirm the hypothesis of sample bias. But if we assume this sample bias is consistent across crops, then it should still provide a good assessment of the relative profitability among crops.

The time series production cost data for Sichuan are from Jiangjin and Hechuan counties and the data for Shandong are from Lunan and Xixia counties. These counties have records on sweetpotato production costs since the mid 1980s. The second data set is from our 192 households surveys that may be able to overcome the sampling bias as our samples are larger and randomly selected.

Relative financial profitability of sweetpotato is examined through comparisons of sweetpotato with other major competing crops in the regions. For time series data, the competing crops considered in this study were maize, wheat and rice. For our primary production cost survey data, we compared sweetpotato with maize, since maize is the major alternative to sweetpotato for feeding pigs in China.

Production cost data from both the secondary time series and our primary household survey include labor cost, non-labor (seed, fertilizer, manure, pesticide, plastic, and other materials) costs, and taxes and fees charged to farmers' crop production. Because nearly all farm activities are conducted by family labor and most sweetpotato production is for on-farm use (not sold), pricing family labor and sweetpotato produced right on the farm is critical in examining the financial profitability of sweetpotato production in China. For the secondary time series data on crop production costs and revenue, labor wage is uniform for all households in the province and is assigned by the provincial price bureau based on their perception of the agricultural wage in the province. Crop output and input prices are based on the total value divided by the total output for the households surveyed. The sweetpotato price computed from our household survey is slightly lower than market price reported from the secondary time series data. This may be due to quality differences as marketed sweetpotato often has better quality than sweetpotato used on-farm for feed. In our primary household survey, the family labor wage is estimated on the opportunity cost for those working in non-agricultural activity. Our estimates of family labor

Table 4.1 The costs and returns (Yuan/ha) of major crops in Sichuan province, 1985-97.

	Main output		Total revenue			Total cost	Non-labor variable costs							Labor cost	Fixed cost	Net return	Return to labor
	Product kg/ha	Price y/kg	Total	Main product	By-product		Sub-total	Seed	Fertilizer	Manure	Pesticide	Plastic	Others				
Sweetpotato																	
1985	4448	0.30	1821	1349	472	983	275	87	52	136	0	0	0	591	118	838	1429
1990	3805	0.57	2521	2161	360	1804	546	198	109	239	0	0	0	1096	163	716	1812
1996	4515	0.87	4542	3910	632	3949	1503	319	762	132	0	0	291	2323	123	593	2916
Maize																	
1985	5393	0.32	1892	1736	156	1593	608	79	261	254	12	0	3	835	151	299	1134
1990	5933	0.48	3179	2838	341	2567	982	107	490	345	22	16	2	1417	168	612	2029
1996	4163	1.55	6856	6447	408	5193	1898	201	1164	301	13	26	192	2959	337	1662	4621
Wheat																	
1985	2820	0.40	1212	1133	80	1136	384	66	129	160	9	0	20	593	160	76	669
1990	2835	0.50	1632	1407	225	1846	675	112	300	205	27	16	31	1011	159	-213	798
1996	2871	1.71	5190	4911	279	4096	1504	341	675	214	25	26	249	2289	303	1094	3383
Rice																	
1985	7118	0.33	2510	2349	161	1334	572	74	161	51	17	0	269	597	165	1176	1773
1990	7826	0.49	4351	3814	537	1907	819	147	329	48	37	47	211	871	217	2444	3315
1996	7627	1.53	12345	11648	697	4986	2010	232	830	133	102	83	629	2517	459	7359	9876

Note: Sweetpotato is reported on a dry weight basis. Dry weight is computed by dividing fresh weight by 5. Data are from Jiangjin and Hechuan counties.

Table 4.2 The costs and returns (Yuan/ha) of major crops in Shandong province, 1985-97.

	Main output		Total revenue			Total cost	Non-labor variable costs							Labor cost	Fixed cost	Net return	Return to labor
	Product kg/ha	Price y/kg	Total	Main product	By-product		Sub-total	Seed	Fertilizer	Manure	Pesticide	Plastic	Others				
Sweetpotato																	
1985	6160	0.25	1673	1523	150	938	439	131	78			0	80	426	73	735	1161
1990	6680	0.37	2838	2475	363	2236	1049	482	267	150	0	37	114	1106	82	602	1708
1996	9340	1.04	10193	9689	505	3581	1341	545	479	145	4	20	175	1912	327	6613	8525
Maize										121	0						
1985	4553	0.32	1564	1459	105	771	366	51	155			0	40	332	73	793	1125
1990	4991	0.43	2415	2158	258	1409	681	121	428	120	0	0	78	535	193	1007	1542
1996	5850	1.38	8546	8070	476	3468	1467	331	935	51	4	0	155	1802	200	5077	6879
Wheat										0	46						
1986	4043	0.51	2197	2074	123	1103	703	99	318			0	139	310	91	1094	1404
1990	4095	0.53	2419	2163	256	1888	1294	234	503	136	11	0	294	488	107	531	1019
1996	4445	1.77	8146	7871	275	4922	3099	422	1252	241	21	175	909	1395	429	3223	4618

Note: Sweetpotato is reported on a dry weight basis. Dry weight is computed by dividing fresh weight by 5. Data are from Lunan and Xixia counties.

wage are slightly higher than (about 20 percent) those found in the secondary time series cost of crop production data.

To overcome the potential problems associated with uniformly assigned family labor wage and the price of sweetpotato produced right on the farm, as well as likely sample bias in the secondary time series data, we conducted a breakeven analysis for family labor wage, sweetpotato price and yield. The estimated breakeven values provide useful benchmark information for farmers to decide whether they should produce sweetpotato for profit consideration. The breakeven values also offer policy decision makers with information in formulating policy, including input and out pricing and productivity-enhancing investment policies.

4.2 Financial Profitability Based on Secondary Time Series Data

Net Return of Crop's Production

Sichuan

From the secondary time series data from Sichuan, sweetpotato once was profitable although its profitability relative to alternative crops has declined over time. Among four competing commodities in Jiangjin and Hechuan counties of Sichuan province, the profitability of sweetpotato ranked second after rice in 1985 (Table 4.1). Net return per hectare was at 838 Yuan, much higher than maize and wheat. Percentage of net return to total cost (85 percent) in sweetpotato production was also significantly higher than those in wheat (19 percent) and maize (7 percent) and only marginally lower than that in rice (88 percent, Table 4.1).

However, between 1985-96, the financial profitability of sweetpotato production declined while the profitability of competing crops such as rice and maize rose. Given an inflation rate (consumer price index) of 314 percent in the rural area over the period of 1985-96 (SSB, 2000), real profit from sweetpotato production per hectare in 1996 was only about 22 percent of that in 1985. For maize, wheat and rice, the increases in the net return (or profit) were 5.6, 14.3 and 6.3 times, respectively, over the same period. This growth is much higher than the price inflation in the rural areas.

The most important factor explaining the decline in sweetpotato profitability in these data is a decline in sweetpotato price relative to cereal grains. The price of sweetpotato in1996 was 0.87 Yuan/kg, an increase of 290 percent in nominal terms from 1985 (and indeed a decline in real price given an inflation index of 314 percent over this period), while the prices of the other competing crops rose 4-5 times in the same period (Table 4.1). Relative yields and input costs, on the other hand, did not change much in these counties of Sichuan.

The apparent decline in profitability of sweetpotato in our study area in Sichuan belies the rising trend in production in this province. One explanation may lie in cropping system constraints. Sweetpotato in Sichuan is typically grown in hilly areas (not rice land) in rotation with wheat or maize. The benefit of rotations and reduced soil erosion on hilly land from sweetpotato are not captured in the crop budgets. Another factor is the expansion of backyard pig

raising in Sichuan, which is closely associated with sweetpotato production (see the discussion in section 3.3 and regression results in table 3.14). In a 1997 survey of animal production in China, 89 percent of all farm households in Sichuan were raising pigs, the highest proportion for any province in China (Zhang 1998). Third, for credit-constrained farmers, sweetpotato may continue to be a profitable crop because it requires less inputs than maize or rice, and about the same as wheat (Table 4.1). Finally, it is possible that conditions in the study area differ from those in the rest of the province, although the data presented in Chapter 3 suggest that the study area was fairly typical for sweetpotato farmers in Sichuan.

Shandong

The time series data on cost of production for Lunan and Xixia counties of Shandong show that sweetpotato profitability has been rising, and is significantly more profitable than that in Sichuan. Net return per hectare rose from 735 Yuan in 1985 to 6613 Yuan in 1996 in nominal terms (Table 4.2). Major competing crops in these counties are maize, wheat, groundnuts and vegetables (but comparative time series data on cost of production are only available for maize and wheat). While net returns as percentage of total cost in sweetpotato production were lower than those of maize and wheat in 1985 and 1990, the former exceeded the latter two crops in 1996 (Table 4.2). In 1996, the net return per hectare in maize production (5077 Yuan) was lower than that in sweetpotato production (6613 Yuan) while what was the least profitable.

A careful examination of various costs and revenues presented in Table 4.2 clearly indicated that the higher profitability of sweetpotato production in 1996 was due to the outstandingly high yield (9340 kg/ha) and relatively high price of sweetpotato in the study area in Shandong (Table 4.2). Average sweetpotato yield in the study area in Shandong was much higher than the provincial average in 1996 (6600 kg/ha, Appendix Table 2) and more than twice the yield in Sichuan. The trend in the terms of trade was also more favorable for sweetpotato production in Shandong than in Sichuan. In Shandong, the nominal price of sweetpotato rose 4.2 times (from 0.25 Yuan/kg to 1.04 Yuan/kg) in 1985-96, an increase similar to maize (4.3 times) but much larger than wheat (3.5 times) (Table 4.3). On the other hand, in Sichuan, sweetpotato market price grew by only 2.9 times (a rate less than the general price inflation rate) in 1985-96, a growth significantly lower than those for maize (4.8 times), wheat (4.3 times), and rice (4.6 times) in the same period.

One explanation for slower growth in sweetpotato prices in Sichuan than in Shandong rests with local market supply and demand of the product. Sweetpotato production grew by 32 percent from 3.94 mmt tons in 1985 to 5.19 mmt in 1996 in Sichuan, while crop production declined by 22 percent from 4.37 mmt to 3.42 mmt in Shandong in the same period. Our interviews with sweetpotato traders revealed that inter-province trade of sweetpotato is minimal. This implies that sweetpotato prices are largely determined by local provincial market demand and supply forces. An increase in sweetpotato production in Sichuan may well meet the rising demand, for the price not to increase as much as other crops. While in Shandong, the decline in production is a driven force for the price to increase at a much higher rate than that in Sichuan.

Table 4.3 Break-even wage, price and crop yield in Sichuan and Shandong

	Observed			Break-even values		
	Wage Yuan/day	Price Yuan/kg	Yield kg/ha	Wage Yuan/day	Price Yuan/kg	Yield kg/ha
Sichuan:						
Sweetpotato	7.48	0.87	4515	9.39	0.73	3830
Maize	7.48	1.55	4163	11.68	1.15	3089
Wheat	7.48	1.71	2871	11.06	1.33	2231
Rice	7.48	1.53	7627	29.35	0.56	2808
Shandong						
Sweetpotato	7.75	1.04	9340	34.55	0.33	2965
Maize	7.75	1.38	5850	29.6	0.51	2170
Wheat	7.75	1.77	4445	25.66	1.05	2624

Note: Sweetpotato is reported on a dry weight basis. Dry weight is computed by dividing fresh weight by 5. Data for Sichuan are from Jiangjina nd Hechuan counties and for Shandong are from Lunan and Xixia counties.

Break-even Analysis

The results of the previous sub-section may be misleading if the secondary data from the production cost survey has a large sample bias in measuring the following key variables in the analysis of financial profitability: wages, commodity prices, and crop yields. In order to see the extent to which the profitability assessment shown in Tables 41 and 4.2 may be sensitive to these measures, we conducted a break-even analysis for these key variables by finding the minimum values necessary for the net return from crop production to be at or above zero. Table 4.3 presents the break-even wage, price and yield of sweetpotato and competing crops in Sichuan and Shandong.

The break-even wage for sweetpotato production in 1996 was 9.39 Yuan per day in Sichuan, only about 25 percent higher than the observed wage (7.48, Table 4.3). This small margin of the difference between the break-even wage and the wage used in the crop production cost survey could have several implications. A conventional or standard explanation is that if the wage rate used in the official production cost accounting is accurate or underestimated, the profitability of sweetpotato production will soon be reduced to zero with the declining wages and production growth. This break-even value also implies that the farmers in many rich areas where local wages are higher than 9.39 Yuan will shift from sweetpotato to other crops or other economic activities. Rice has a much higher break-even value for wage (29.35) while the values for maize and wheat are higher than sweetpotato by nearly two Yuan per day. These further indicate that the possibility of substitution of rice, wheat and maize for sweetpotato production may happen (although recall that in Sichuan, sweetpotato is grown primarily on hilly land whereas rice is grown on flat irrigated land).

In our sample area in Shandong province, the break-even value for wage in sweetpotato production was very high (34.55 Yuan) and even higher than other crops. The crop is still very attractive for rural households engaged in agricultural production although the expansion of sweetpotato is limited by the need to allocate larger portions of the farm land to produce various foods for home consumption.

The ratio of break-even values to observed prices of crops in Sichuan are lowest for rice (0.37, computed from 0.56/1.53, Table 4.3), and then followed by maize (0.74), wheat (0.78) and sweetpotato (0.84). The larger these ratios are, the greater the possibility for sweetpotato to be replaced by other crops. Prices and yield of sweetpotato are clearly important to sweetpotato production growth in Sichuan province. But as discussed above, for subsistent farmers, other determinants such as household's own consumption demand and derived feed demand from the backyard pig production, are even more important than the simple financial budget analysis for a less marketable product such as sweetpotato.

The analyses from Shandong shows the possibility of profit from sweetpotato production falling from the current level to zero through a decline in crop yield or if market price decreases. (Table 4.3). Break-even yield and prices for sweetpotato in Shandong are very low even though sweetpotato production in our sampled households has been stagnant and sweetpotato crop area for the whole province has significantly been declining. This may suggest that the marketability of sweetpotato and the determinants of household backyard pig production are the driving forces for sweetpotato production in the province.

4.3 Financial Profitability Based on Primary Household Survey Data

Input and Output of Sweetpotato and Maize Production

Table 4.4 summarizes the inputs and outputs of sweetpotato and maize production in our sampled households. While all inputs except manure and irrigation are higher in Shandong than in Sichuan, sweetpotato yield in Shandong (5289 kg/ha) is much higher than in Sichuan (4665 kg/ha) due to better land and growing conditions. In Sichuan , sweetpotato is mainly planted on hillsides and mountain slopes while in Shandong, the sweetpotato cropland is usually flat and with better quality soil. Moreover, sweetpotato has a longer growing period in Shandong than in Sichuan.

In our sample, farmers applied an average of 285 kg of fertilizer in Sichuan, compared to 204 kg in Shandong (Table 4.4). Because of poor soil conditions and cheaper labor in Sichuan compared with Shandong, manure use is much higher in Sichuan. The flat land and higher opportunity cost of labor in Shandong causes farmers to use less labor in sweetpotato production. Farmers spent 305 man-days/ha for sweetpotato production in Jiange of Sichuan province and more than 500 man-days/ha in Leshan. In Feixian and Zhucheng of Shandong province, farmers used only 257 man-days/ha. The differences in input levels between Sichuan and Shandong are even larger for maize production. Farmers applied much more fertilizers, manure, and labor in maize production in Sichuan than in Shandong (Table 4.4).

Table 4.4 Per hectare input and output of sweetpotato and maize production for households in 1997 farm survey

		Sichuan				Shandong		
		Average	Jiangjin	Jiange	Leshan	Average	Feixian	Zhucheng
				Sweetpotato				
Output	kg/ha	4665	5136	3344	5154	5289	5662	4151
Input:								
Fertilizer	kg/ha	285	322	289	229	204	220	152
Manure	kg/ha	2455	1935	1067	5041	375	422	225
Pesticide	kg/ha	0	1	0	0	3	2	4
Plastic	kg/ha	6	7	3	7	9	10	8
Labor	day/ha	420	458	305	526	257	274	201
				Maize				
Output	kg/ha	5133	5843	5064	3163	4327	4897	4069
Input:								
Fertilizer	kg/ha	614	612	716	272	284	289	280
Manure	kg/ha	1970	2320	868	4571	51	70	35
Pesticide	kg/ha	6	6	3	19	3	3	4
Plastic	kg/ha	13	8	20	0	0	0	0
Labor	day/ha	406	483	351	333	155	180	135

Note: Sweetpotato is reported on a dry weight basis. Dry weight is computed by dividing fresh weight by 5. Data are from authors' survey.

Profitability in Sweetpotato and Maize Production

Financial profitability in sweetpotato production shows that all three counties surveyed in Sichuan province had a negative profit in 1997 when the cost of family labor is based on the returns from alternative activities in the local area. Net profits from sweetpotato ranged from –964 Yuan/ha in Jiange to –2645 Yuan/ha in Leshan (Table 4.5). These results differ from the financial profitability analysis using secondary data that showed a positive profit in planting sweetpotato (Tables 4.1 and 4.2). Crop yield variation, higher wages, lower price of sweetpotato, and higher cost of inputs (more fertilizer use) all contributed to this difference.

In order to see how sensitive the results are to input and output prices as well as yield, we again conducted a break-even analysis following a similar process as with the time series data. Break-even analysis shows that the observed wage (9.4 Yuan/day) is 51 percent higher than the break-even value for the wage (6.21 Yuan/day) in sweetpotato production. It appears that labor-saving technology in sweetpotato production is critical if it is to remain profitable for the average farmer in Sichuan province. This will become even more critical over time with increasing opportunity cost of farm labor. The break-even value for sweetpotato price (1.21 Yuan/kg) is 32 percent higher than the actual price (0.92 Yuan/kg) farmers received in 1997. Break-even yield

is also high (6124 kg/ha), a very high level for Sichuan to reach given the current technology (4665 kg/ha in the sampled households in 1997).

Table 4.5 Farm costs and returns of sweetpotato production for households in 1997 farm survey

	Sichuan				Shandong		
	Average	Jiangjin	Jiange	Leshan	Average	Feixian	Zhucheng
I. Total revenue (Yuan/ha)	4967	5400	3752	5417	6176	6563	4992
Main product	4292	4725	3077	4742	5501	5888	4317
By-product	675	675	675	675	675	675	675
II. Non-labor (Yuan/ha)	2358	2386	1881	2963	2619	2810	2172
Seed cost	251	204	173	420	710	728	654
Fertilizer	1335	1435	1266	1288	1481	1745	776
Manure	300	236	130	616	46	52	27
Pesticide	4	12	0	0	66	53	113
Plastic	54	68	29	68	85	93	77
Other costs	8	0	0	29	3	4	0
Various taxes	407	431	282	542	228	137	525
III. Labor cost (Yuan/ha)	3951	4214	2835	5099	2767	2824	2258
IV. Total cost (Yuan/ha)	6309	6600	4716	8062	5386	5634	4430
V Net return (Yuan/ha)	-1342	-1200	-964	-2645	789	929	562
VI. Return to labor (Yuan/ha)	2609	3014	1871	2454	3556	3753	2820
Break-even values:							
Wage (Yuan/day)	6.21	6.58	6.14	4.67	13.85	13.69	14.05
Output price (Yuan/kg)	1.21	1.15	1.21	1.43	0.89	0.88	0.90
Yield (kg/ha)	6124	6440	4392	8029	4530	4768	3611
Observed values:							
Wage (Yuan/day)	9.40	9.20	9.30	9.70	10.78	10.30	11.25
Output price (Yuan/kg)	0.92	0.92	0.92	0.92	1.04	1.04	1.04
Yield (kg/ha)	4665	5136	3344	5154	5289	5662	4151

Source: Authors' survey.

All these indicators show that the farmers in our sample in Sichuan province are facing great challenges in sweetpotato production. This also confirms our previous discussion on the reason why farmers plant sweetpotato -- not really for profit but mainly for its use in household livestock production.

Profitability in sweetpotato production in Shandong is much better than in Sichuan mainly due to three factors: higher yield, higher price, and lower labor input (Table 4.5). However, it

should be noted that the opportunity cost of agricultural labor is close to the break-even value (13.85 Yuan/day) in many coastal counties in Shandong province. This may partially explain the significant decline of sweetpotato area over time in Shandong as many coastal counties have been moving out of sweetpotato production to horticulture and other economic activities.

Despite much higher yield of maize in our sampled households in Sichuan than in Shandong, the high inputs in chemical fertilizer and manure, pesticide, labor inputs made maize production less profitable in Sichuan than in Shandong. Evaluated at the locally observed agricultural wage rate, net return (profit) was –559 Yuan/ha in Sichuan province while the farmers in Feixian and Zhucheng, both of Shandong province, enjoyed a profit of about 1064 Yuan/ha.

V. Efficient Use of Sweetpotato and Maize as Feed in Pig Production

5.1 Notes on Methodology

There are at least two basic ways to analyze the efficiency of sweetpotato as a substitute for maize feed. The first is to examine the efficiency of pig-raising activity with the two alternative feed sources, sweetpotato and maize. However, in our sampled households, farmers actually used a mix of feeds in raising pigs (Table 3.9) and no farmer applied only sweetpotato or maize for feed. Farmers who produce sweetpotato primarily for feed also apply substantial amounts of maize, other grains and forage (Table 3.9). In other words, sweetpotato is used as feed simultaneously with maize. Investigating the efficiency of sweetpotato as a substitute for maize in feeding pig is difficult through a direct comparison of these two alternatives in swine production.

Because sweetpotato in our sampled households is grown primarily for feed use in pig production, the second way to examine the efficiency of sweetpotato as substitute for maize is to compare the profitability of producing alternative feed crops at the household level. That is, we compare the cost of producing sweetpotato for feed versus growing or buying maize for feed.[8] In this study, we used an indirect measure and applied "Policy Analysis Matrix" (PAM) developed by Monke and Pearson (1989).

PAM uses the concepts of private and social profit (the difference between costs and revenues evaluated at private and social prices) as its point of analysis (Monke and Pearson, 1989). It can also be used to study the efficiency of alternative technologies in producing the same commodity as well as the impacts of various policies on alternative production systems. The general framework of PAM is summarized in Table 5.1. The method distinguishes between private and social profitability. Private profitability is determined using the first row measure of all inputs and outputs at actual prices prevailing in the domestic market. It presents (reflects or indicates instead of presents?) the actual competitiveness of alternative production systems (i.e., sweetpotato versus maize) under current policies and technologies.

Social profitability, which provides a measure of comparative advantage, is estimated after removing the price-distorting effects of policies. With no policy distortions, social profitability measures the actual costs and benefits of the production system for the country or region. Social profitability is shown in the second row of Table 5.1. At the margin, a positive social profit indicates that the system uses scarce resources efficiently and the commodity has a static comparative advantage. When social profits are negative, a sector cannot sustain itself without assistance or continued policy interventions from the government. A negative social profit implies that at the margin, the real cost of producing the commodity exceeds the cost of

[8] One limitation of this approach is that comparing only the cost of crop production ignores differences in pig raising costs that may result from the use of maize versus sweetpotato. Producers who rely more on cereal-based feeds obtain higher feed conversion efficiency than producers who use mainly tuber crops, roughage, and food processing wastes (Zhang 1998). Further, using sweetpotato for feed often requires additional inputs for feed preparation (e.g. chopping and cooking). However, alternative on-farm feed preparation technologies, such as fermentation of sweetpotato vines and roots can overcome these differences by improving nutrient uptake (and thereby increasing feed conversion and reducing feed preparation inputs by eliminating the need for cooking the roots (Liu et al. 2001).

importing it. Comparing social profitability of alternative uses of land for feed crop production such as sweetpotato and maize provides useful information to policy makers in determining whether they should phase out any existing policies that hamper efficiency in crop production and feed use.

Table 5.1 General framework of a Policy Analysis Matrix (PAM)

	Revenues	Costs		Profits
		Tradable inputs	Domestic Factors	
Private values	A	B	C	D
Social values	E	F	G	H
Divergences	I	J	K	L

Private profits D=A-(B+C).
Social profits H=E-(F+G).
Output transfers I=A-E.
Tradable input transfers J=B-F.
Domestic factor transfers K=C-G.
Net transfers L=D-H=I-(J+K).

Source: Monke and Pearson, 1989.

Because social values are the values given under the assumption of no policy interventions and competitive markets for both inputs and outputs, exported goods (for both input and output) are measured at f.o.b. (free on board) price and imported goods are at c.i.f. (costs, insurance, freight) price. The different internal (domestic) transportation cost between national borders and regions is included in the analysis. For non-tradable goods, their prices are measured as the return from the best alternative use.

The last row of the matrix in Table 5.1 calculates the divergences between private and social valuations of revenues, costs, and profits. These divergences are considered as the effects of distorting policies that lead to inefficiency. From the policy analysis matrix, one can derive several important policy indicators such as the nominal protection rate on tradable output (NPRO), the nominal protection rate on tradable input (NPRI), the effective protection rate (EPR), domestic resource cost (DRC), and social cost-benefit ratio (SBC). These measures are explained below.

The protection rates are common indicators used to measure the impact of government policy on agricultural prices. The domestic price is compared with the price under free trade. The nominal protection rate (i.e., NPRO and NPRI) reflects the impact of commodity-specific price interventions such as the domestic procurement and distribution system, import tariffs, export taxes, and quantitative restriction on domestic trade. The nominal protection rate is the percentage difference between the domestic and border prices converted at the official exchange

rate. From the PAM or policy analysis matrix of Table 5.1, for the tradable output, NPRO (A/E) indicates the degree of output transfer. For the tradable inputs, NPRI (B/F), shows the degree of tradable input transfer. To measure the total effect of government interventions, including the effect of exchange rate distortions, the EPR is estimated as a ratio of value added in private prices (A-B) to value added in the world prices (E-F). EPR measures the percentage difference between domestic and border prices converted at the market equilibrium exchange rate. This coefficient indicates the degree of policy transfer from output and tradable input distortions.

The DRC and SCB are used to compare the relative efficiency or comparative advantage between agricultural commodities. The DRC is defined as G/(E-F) and is a proxy measure for social profits in cross-commodity comparisons. The DRC indicator is widely used in developing countries to measure comparative advantage and guide policy reforms. However, the DRC may be biased against activities that rely heavily on domestic non-traded factors, i.e., land and labor. A good alternative for the DRC is the SCB, which accounts for all costs and avoids classification errors in calculation of DRC (Masters and Winter-Nelson, 1995).

5.2 Data and Policy Description

In our study, we examined the efficiency of sweetpotato as a substitute for maize to produce the same commodity (pork) in our survey areas in Sichuan and Shandong. Previous sections showed that sweetpotato was not planted primarily as a cash crop but as a semi-subsistence crop intended to address both household food needs, feed requirements, and to earn part of the household's cash income. This may violate what is embodied in the profitability analysis, which assumes that sweetpotato would be planted as cash crop and its production is responsive to market prices. However, sweetpotato has been a substitute for maize and other grains for feed use in backyard livestock production ventures in sweetpotato producing regions, and interviews with farmers and local livestock extension technicians found that there is no significant difference in productivity if maize is used as alternative feed. If this assumption holds, then efficient use of sweetpotato as feed can be examined directly by comparing the profitability of sweetpotato and maize production in the households that raise pigs.

Output and Input Prices

To determine the profitability of sweetpotato versus alternative crop, (i.e., maize) as pig feed, expected expenses in planting were estimated using two sets of prices. Financial price, the actual market price paid by farmers for inputs and received for outputs, determines financial or private profitability. Economic price, which is a shadow price representing the scarcity value of inputs and outputs in the Chinese economy are then substituted for the financial price to determine economic or social profitability.

Data on financial prices, representing prices actually paid and received by farmers during the 1997-98 crop season, were gathered as part of the farm survey. For maize, the financial prices are 1.39 Yuan/kg in Sichuan and 1.21 Yuan/kg in Shandong (Table 5.2). Sweetpotato was priced much cheaper by 0.92 Yuan/kg in Sichuan and 1.04 Yuan in Shandong.

The divergences of these prices from the economic or social prices are associated with the domestic price and marketing policies as well as other policies that have impact on the sector performance. Price and market reforms are key components of China's development policy shift

from a socialist to a market-oriented economy. The price and market reforms initiated in the late 1970s were aimed at raising farm level prices and gradually liberalizing the market. These reforms included increases in government procurement quota prices, reduction in the quota levels, introduction of above quota bonuses, negotiated procurement of surplus production of grains, oils, and most other commodities, and flexibility in marketing of surplus production of all categories of agricultural products privately. Sweetpotato is one of the first crops that was liberalized in the early 1980s when the government procurement quota was phased out. Its price has since been determined by local demand and supply conditions.

Table 5.2 Assumptions about private and social prices and tradability of inputs and outputs used in Policy Analysis Matrix (PAM)

	Sichuan			Shandong		
	Private price (Yuan/kg)	Social price (Yuan/kg)	Tradable share (%)	Private price (Yuan/kg)	Social price (Yuan/kg)	Tradable share (%)
			Sweetpotato			
Sweetpotato	0.92	1.12	100	1.04	1.23	100
By-product	1.00[a]	1.00[a]	0	1.00[a]	1.00[a]	0
Capital inputs:			73			91
Seed	1.00[a]	1.08	100	1.00[a]	1.05	100
Fertilizer	4.68	5.26	100	7.26	7.90	100
Manure	0.12	0.12	0	0.12	0.12	0
Pesticide	18.18	20.43	100	24.00	26.53	100
Plastic	8.93	10.48	100	9.44	10.79	100
Tax & depreciation	1.00[a]	1.17	20	1.00[a]	1.17	20
Other cash costs	1.00[a]	1.02	50	1.00[a]	1.02	50
Labor	9.41	10.35	0	10.77	11.84	0
			Maize			
Maize	1.39	1.46	100	1.21	1.35	100
By-product	1.00[a]	1.00[a]	0	1.00[a]	1.00[a]	0
Capital inputs:			87			87
Seed	1.00[a]	1.08	100	1.00[a]	1.05	100
Fertilizer	4.82	5.42	100	5.25	5.71	100
Manure	0.12	0.12	0	0.12	0.12	0
Pesticide	41.17	46.26	100	27.00	29.85	100
Plastic	8.92	10.46	100	9.40	10.74	100
Tax & depreciation	1.00[a]	1.17	20	1.00[a]	1.17	20
Other cash costs	1.00[a]	1.02	50	1.00[a]	1.02	50
Labor	9.39	10.33	0	10.77	11.85	0

a: Prices of by-products are normalized at 1. Tradable shares for all capital inputs are weighted average based on amount of input uses and private price. They are marginally lower (1-2 percent) than those at social prices. Shadow exchange rate is 11.28 Yuan/US$, which is 34.86% higher than the official exchange rate (8.29 Yuan/US$).

Price and marketing reform in rice, wheat and maize has lagged far behind that of other agricultural commodities. Despite substantial efforts to liberalize the price and market structure of the agricultural sector, grains continue to be heavily affected by commodity specific policies. Through procurement policies, farmers have received prices below the competitive market price (except for the years after1998, Huang, 2000). These distortions in price incentives depress agricultural production and redistribute income from farmers to urban consumers and the agro-processing sector.

In this study, because sweetpotato is not under government procurement, the financial price for sweetpotato is the price that the farmer should pay for sweetpotato for feed use in the local market. The financial price for maize is the weighted average price received by farmers from government procurement and the local market.

To calculate economic (social) prices, tradable and non-tradable resources are treated differently. Because sweetpotato is not widely traded (except for its processing products), the social price converted at effective or shadow exchange rate is about 10 percent higher than private or financial price due to an overvalued exchange rate. The critical issue we are looking at is the social profitability of substituting this less or non-tradable sweetpotato feed for tradable maize feed in pig production. China has been both importer and exporter of maize. Domestic market prices have been consistently higher than border prices (protected by a tariff on imported maize), Nevertheless, China has become a net exporter of maize since middle 1980s except for 1995 and 1996 when export of maize was banned due to the rapid grain price inflation and fear of food supply deficit in 1994-95 (Huang, 1999). To offset the higher domestic price, the government has provided a substantial subsidy for maize exports. In 2000, export subsidy rate reached as high as 400 Yuan (or 48 USD) per ton. In this study, we considered maize as an importable commodity and measured its social price at c.i.f. (costs, insurance, freight) price. The internal (domestic) transportation cost between ports and the study sites (Shandong and Sichuan) are considered and added to the social price. With all these considerations, social prices for maize were 1.46 Yuan per kg in Sichuan and 1.35 Yuan in Shandong using the shadow exchange rate.[9] These are about 5 percent higher than the private prices in Sichuan and 12 percent higher than the private price in Shandong.

Input shadow prices are also required for the PAM. China imported seeds, chemical fertilizer, plastic materials, and pesticides from international markets. The shadow prices for seeds, chemical fertilizer, plastic materials, and pesticides are the respective import parity prices at the farm gate (Table 5.2). For non-tradable inputs like land and labor, prices are measured at the highest return offered by alternative uses. Using the official exchange rate, most border prices of inputs are lower than the domestic prices. But when measured at the shadow exchange rate, all input social prices are lower than the domestic prices.

Labor is not tradable. The level set for family labor wage is a critical factor in PAM analysis as the labor costs exceed all other input (materials) costs for both sweetpotato and maize

[9] At the official exchange rate, social prices for maize are 1.08 Yuan/kg in Sichuan and 1.00 Yuan/kg in Shandong

production in most of the households interviewed in Sichuan and Shandong. The social value of alternative use of labor is assumed to be the local wage rate for off-farming employment. But note that for some households the opportunity cost of time may be less than local off-farm wages, especially if farm labor is supplied by other family members or during hours when off-farm jobs are not available. We also investigated the sensitivity of our results to assumptions on wages.

Land price is not computed in the analysis due to lack of data on land rental rates in our farm survey. Land price should also consider agricultural tax that farmers have to pay to the government. In China, this is mainly paid in kind such as grain, based on the area of "contract land".[10]

Exchange Rate

China's open door policy contributed to the rapid growth of external economy and to greater reliance on both domestic and international trade to meet consumer demand. Historically, the overvaluation of domestic currency for trade protection purposes had reduced agricultural incentives. Real exchange rates remained constant and even appreciated during the 30 years prior to reforms. However, the foreign exchange rate has been reformed substantially since the early 1980s. The purpose of China's foreign exchange reform was to reduce administrative intervention and increase the role of market forces.

From 1979, a foreign exchange retention system was applied in China, although foreign exchange swap market was gradually developing. In early 1994, official Remninbi (RMB or Yuan) exchange rates were unified with the market rate. The banking exchange system was adopted and a nationwide unified inter-bank foreign exchange market was established, with conditional convertibility of RMB on current accounts. Since 1996, foreign invested enterprises ("FIEs") were also permitted into the banking exchange system, and the remaining exchange restrictions on current accounts were eliminated. China had formally accepted the obligation as an IMF member to remove exchange restrictions on current account transactions.

From 1978 to 1994, the real exchange rate depreciated more than 400 percent. Falling exchange rates increased export competitiveness and contributed substantially to China's phenomenal export growth record and the spectacular national economic performance of the 1980s. In recent years, however, the situation has changed. The nominal exchange rate has been kept about constant since 1994. There is a consensus among analysts that China's currency has been and is still overvalued (see Yin and Stoever, 1994). In this study, we assumed that the 1994 unified exchange rate was at the time a shadow nominal exchange rate, with relative purchase power parity holding between China and the United States. For 1997, we calculated the shadow nominal exchange rates as the exchange rates consistent with relative purchase power parity holding for the period of 1996-97. The estimated shadow nominal exchange rate was 11.18 RMB/US$ in 1997, while the official exchange rate was 8.29 RMB/US$ in the same year.

[10] For details on China's agricultural land contracting system, see Brandt et al. (2001).

Tradable and Non-tradable Measures

We decomposed both total private and total social costs into their domestic and tradable-factor components. Tradable goods are those that can be imported or exported. Examples of tradable goods include production inputs such as seed, fertilizer, tractors, irrigation pumps etc. and maize output. Social prices for tradable goods are determined by their value in the international market such as discussed above, since these reflect the value of the tradable goods to the national economy.

Assumptions on the share of tradable and non-tradable amounts of each input and output are summarized in Table 5.2. This involves calculating the appropriate import or export parity price. In a few cases where parity prices are difficult to compute because no clear trading pattern is evident, the domestic market-clearing price is used, with appropriate adjustments for significant distortions attributable to government policies or market failures, e.g. price controls, taxes, subsidies, and exchange rate distortions. It is worth noting that sweetpotato is rarely traded in the world market.[11] Because the sweetpotato in our study sites are produced primarily for feed uses and not for marketing, two alternative assumptions were made in this study for the degree at which sweetpotato is tradable: zero and 10 percent.

Alternative Assumptions for Sensitivity Analysis

In the sensitivity analysis, various alternatives were made in the input and output prices, tradability of sweetpotato, productivity enhanced investment (i.e., changes in yield) and exchange rate adjustments to explore the likely effects on the efficiency and comparative advantage in producing the two major feed crops, sweetpotato and maize.

5.3 Results of PAM Analyses

Table 5.3 summarizes the whole matrix of PAM for sweetpotato and maize. More detailed computation can be found in Appendix Tables 5-8. Based on the parameters presented in Table 5.3, several important policy indicators on protection rates and domestic resource costs of the two alternative feeds, sweetpotato and maize, are derived and presented in Table 5.4.

Negative divergences of private profit from social profit of sweetpotato production in both Sichuan and Shandong indicate that sweetpotato would be more profitable if all policy interventions were removed. In Shandong, profit would be raised from 790 Yuan/ha to 1350 Yuan/ha, or by 70 percent. Although both private and social profit of sweetpotato are negative in Sichuan, the removal of all distortions would reduce the loss by 320 Yuan/ha, or by about 30 percent.

Maize presents a different story for Sichuan and Shandong. The effect of policies is to increase the private profit of maize production in Sichuan but decrease profitability in Shandong. Maize farmers in Shandong are effectively taxed by about 20 percent through the distortionary policies. While both private and social profitability of maize production are negative in

[11] The processed products of sweetpotato such as sweetpotato starch and noodle are tradable, but the traded quantity is thought to be small.

Sichuan, the effect of policies is to make maize production less negative. This difference is explained by the variation of input structure between these two provinces and larger gains in output revenue in Sichuan than in Shandong. But it is worth noting that social profits are negative for both sweetpotato and maize in Sichuan but are positive in Shandong. Negative profitability would generally imply that the economic incentive to grow the crop is small. But it may also mean that farmers who produce the crop face conditions other than the average conditions assumed in the model. For example, the opportunity cost of family labor used for crop production may be less than off-farm wage if off-farm employment opportunities are limited. Further, if crop is mostly consumed on-farm for food or feed rather than on a commercial sale, then these households need to factor (what are they going to factor into the decision?) into the farmer's decision to grow the crop.

Table 5.3 Results of Policy Analysis Matrix for sweetpotato and maize production (Yuan/ha).

		Costs		
	Revenues	Tradable inputs	Domestic factors	Profits
Sweetpotato				
Sichuan				
Private values	4967	1729	4580	-1342
Social values	5884	1932	4975	-1023
Divergences	-917	-203	-395	-320
Shandong				
Private values	6176	2389	2997	790
Social values	7203	2579	3274	1350
Divergences	-1027	-190	-277	-561
Maize				
Sichuan				
Private values	7565	3756	4368	-559
Social values	7934	4208	4749	-1023
Divergences	-369	-452	-381	464
Shandong				
Private values	5668	2615	2053	1000
Social values	6291	2872	2220	1199
Divergences	-623	-257	-167	-199

Table 5.4 Policy intervention indicators derived from PAMs for sweetpotato and maize production

	NPRO	NPRI	EPR	PRPS	DRC	SCB
Sweetpotato						
Sichuan	0.84	0.90	0.82	1.31	1.26	1.17
Shandong	0.86	0.93	0.82	0.58	0.71	0.81
Maize						
Sichuan	0.95	0.89	1.02	0.55	1.27	1.13
Shandong	0.90	0.91	0.89	0.83	0.65	0.81

NPCO is nominal protection rate on tradable output.
NPCI is nominal protection rate on tradable input.
EPR is effective protection rate.
PRPS is ratio of profits measured in private and social values.
DRC is domestic resource cost.
SCB is social cost-benefit ratio.

Finally, cropping system requirements (i.e., the need for crop rotation) and limited ability to substitute crops across land types, may mean that the opportunity cost of farm land is less than what the model may assume (although in our analysis we do not impose a land rental cost, only land taxes). What may be more useful in this analysis is to examine the relative profitability (comparative advantage) between sweetpotato and other commodities, which should be less affected by these potential biases.

Crop-wide comparison shows that the effect of policies is to penalize sweetpotato while protecting maize production, particularly in Sichuan (Table 5.3). Removing the distortions would make social profits identical between sweetpotato and maize production in Sichuan (although they are still negative).

The nominal protection rate of output (NPRO) shows that the policies taxed production of both sweetpotato and maize, although the extent of taxation is higher in sweetpotato. The distortion lowered sweetpotato domestic price over the world price by 16 percent in Sichuan and 14 percent in Shandong (Table 5.4). Policies also decreased the producer's price of maize over the world price by 5 percent in Sichuan and 10 percent in Shandong. Careful examination reveals that the policy distortions mainly come from the overvaluation of domestic currency. Indeed, at the official exchange rate, NPRO is 1.01 for sweetpotato in both Sichuan and Shandong and 1.26 for maize in Sichuan and 1.19 in Shandong. These figures imply that the total impact of all domestic policies (excluding foreign exchange rate policy) are nearly neutral for sweetpotato, but protect the maize sector by raising its domestic price 19-26 percent over the world price (converted at official exchange rate).

All estimated values for NPRI are about 0.90 (Table 5.4), indicating that the policies reduced input costs for both sweetpotato and maize. The average market price for tradable

inputs is about 90 percent of social prices. Again, the major distortion is due to the foreign exchange policy.

The values of the EPC show that there is a large transfer from sweetpotato and tradable input policies. Sweetpotato is taxed by 18 percent (1-0.82) on its value added in both provinces (Table 5.4). Maize in Sichuan faces almost no distortion in value added, while it is taxed by 11 percent in Shandong. From the analysis of EPC, it is likely that sweetpotato would gain more in value added than maize if all distortion policies were phased out.

For the relative comparative advantage of sweetpotato and maize production, the estimated values of DRC and SCB in Table 5.4 show that they are very similar.[12] The values of DRC for sweetpotato and maize are 1.26 and 1.27, respectively, in Sichuan, pointing out the challenge in both sweetpotato and maize production under trade liberalization. On the other hand, the DRCs for sweetpotato and maize in Shandong province are much lower than 1. They are 0.71 for sweetpotato and 0.65 for maize. The similarity of DRCs of these 2 crops point out that their production substitution under trade liberalization is limited. This may suggest that substituting sweetpotato for maize as feed in swine production in our sample areas will lead to gain in resource allocation efficiency under trade liberalization if the future technology progress in sweetpotato is more than that in maize. The estimates of social and cost benefit ratio (SCB) lead to the same conclusion.

In order to test the sensitivity of the above results and conclusions to the assumptions that are made in PAM analysis, alternative assumptions are defined and all policy indicators are re-estimated. These alternative assumptions deal with the major driving factors that have impacts on social profit and DRC, namely, crop yield, tradability of sweetpotato products, and opportunity cost of family labor. The results of this sensitive analysis are summarized in Table 5.5. For comparison convenience, we call the results estimated from the assumptions listed in Table 5.2 as "baseline" and report private and social profits as well as DRC and SCB in Table 5.5.

Given the relative lower level of sweetpotato yield in Sichuan than Shandong, the first sensitivity analysis is made by assuming that sweetpotato yield would increase by 20 percent in Sichuan and 10 percent in Shandong through adoption of higher yielding variety while holding input levels constant. This assumption alters social profit of sweetpotato production from negative (-1023 Yuan/ha) to positive (19 Yuan/ha) in Sichuan and increases social profit by nearly 50 percent in Shandong (from 1350 Yuan/ha to 2003 Yuan/ha, Table 5.5). The DRC of sweetpotato also declines from 1.26 to 0.99 in Sichuan. Although this DRC is still higher than the DRC of maize in the province, it eventually diminishes to a value less than one – a turning point for comparative advantage of any crop production venture. The same result can be derived from the SCB values. This points out the importance of research and technology investment in sweetpotato to increase the crop competitiveness over other crops in order to minimize the substitution of sweetpotato by other crops as feed in livestock production.

[12] The estimates of DRCs for maize in our sample households in Sichuan and Shandong are lower than estimated by Fang and Belghin (1999), and Huang, Ma and Xu (2001). /the estimates from the latter source are about 0.8 to 1.0 for the whole China. Our estimates are close to those estimated by Zhang and Xu (2001) for Sichuan and Shandong provinces.

Table 5.5 Sensitive analyses of crop yield, wage, tradability of sweetpotato and shadow exchange rate used in PAM.

	Private profit	Social profit	DRC	SCB
		Baseline		
Sweetpotato				
Sichuan	-1342	-1023	1.26	1.17
Shandong	790	1350	0.71	0.81
Maize				
Sichuan	-559	-1023	1.27	1.13
Shandong	1000	1199	0.65	0.81
		Sweetpotato yield: 20% increase in Sichuan and 10% in Shandong		
Sweetpotato				
Sichuan	-484	19	1.00	1.00
Shandong	1340	2003	0.62	0.74
		Sweetpotato tradability: 10% only		
Sweetpotato				
Sichuan	-1342	-1848	1.59	1.37
Shandong	790	426	0.88	0.93
		Family labor wage: private = social		
Sweetpotato				
Sichuan	-1342	-628	1.16	1.11
Shandong	790	1627	0.65	0.77
Maize				
Sichuan	-559	-641	1.17	1.08
Shandong	1000	1366	0.60	0.78
		Foreign exchange: if shadow rate = official rate = 8.29		
Sweetpotato				
Sichuan	-1342	-1807	1.60	1.41
Shandong	790	330	0.91	0.94
Maize				
Sichuan	-559	-1870	1.65	1.31
Shandong	1000	431	0.84	0.91

The unit for profit is Yuan/ha.
NPCO is nominal protection rate on tradable output.
NPCI is nominal protection rate on tradable input.
EPR is effective protection rate.
PRPS is ratio of profits measured in private and social values.
DRC is domestic resource cost.
SCB is social cost-benefit ratio.

Changing sweetpotato from a fully tradable commodity to a less tradable commodity will make the crop less competitive. While the private profit is the same as that under baseline, social profit declines, and the values for DRC and SCB rise (Table 5.5). Equalizing private and social

values of family labor (under baseline, social value is 10 percent higher than private value, that is the highest alternative use of family labor is 10 percent higher than the actual observed wage in crop production) increases the crop's social profit and lowers domestic resource cost. The impacts are similar for both crops. The last alternative examined is related to our assumption on the overvaluation of domestic currency. That is, what could be the implications on the results of PAM analysis if the current official exchange rate would represent the true value of domestic currency? The last four rows in Table 5.5 show that the impacts are significant. The results from the baseline show that sweetpotato can become less competitive.

In sum, the results from this study show that both sweetpotato and maize production are facing great challenge in Shandong and Sichuan. Distortionary prices and trade policies have penalized sweetpotato while protecting maize production. While the financial (private) profitability of maize appears to be greater than sweetpotato, the social profitability of the two crops are about equal. Sweetpotato used as feed has been a common practice in swine production in China's major production regions of Sichuan and Shandong. The extent to which sweetpotato can substitute for maize as feed in pig production will highly depend on the direction of future policy intervention and technology development in the sweetpotato and maize sectors. If sweetpotato productivity growth is less than that of other competing feed crops, then these other feed crops will likely gradually substitute for sweetpotato in backyard livestock production. A similar trend may result if policies continue to discriminate against sweetpotato producers. Therefore, increased investment in sweetpotato research and extension and removal of current policy distortions will be critically important to the future of sweetpotato as livestock feed in China.

VI. Conclusions and Implications

A rapidly increasing demand for feed grains in China is expected in the coming decades due to an expansion of the livestock sector, a sector that will grow to meet the equally increasing demand for animal products. This trend has not escaped the attention of leading feed exporters, particularly the U.S., Canada and Australia. Studies in food projections from organizations such as IFPRI, the World Bank, and CCAP have lead to a consensus that the increasing demand for feed in China will be supplied by both domestic and foreign producers. Since China is a less competitive maize producer than the world's major maize exporters, a large portion of the demand for feed in China is likely to be met by importing maize. The use of sweetpotato as feed (the second largest feed grain in China) has increased significantly in the past two decades, although production has been stagnant and sown area has declined significantly since the 1970s. In this report we addressed the possibility of promoting sweetpotato production so that it can be economically used as a substitute for maize in feeding pigs, the dominant component of China's livestock sector.

The results from this study show that not only has the substitution of rice and wheat for sweetpotato as food consumption been occurring, but that without policy actions the possibility of substituting maize with sweetpotato in pig production in the future is not promising. The projected reduction in domestic maize prices following China's WTO accession may even partially substitute imported maize for both domestic maize and sweetpotato for feed use. Expecting sweetpotato to serve as a substitute for maize as feed in pig production should be taken cautiously in the absence of policy changes.

Financial analysis from time series data shows that the relative profitability of sweetpotato declined since the mid 1980s and incentives for substituting sweetpotato with alternative crops are emerging. The horticulture sector has been growing rapidly since the early 1990s. Rising regional market integration favors introducing commercial feeds such as maize and compound feed in backyard pig production. The opportunity cost of agricultural labor in many coastal counties in Shandong Province is high and growing. Break-even analysis demonstrates that the extent of expanding sweetpotato production will highly depend on future trends in farm productivity. Providing new, labor-saving technology in sweetpotato production may become critical in some rural areas where off-farm employment opportunities are increasing.

While incentives to produce sweetpotato may decline without new technologies, PAM analyses reveal that policies have been biased against sweetpotato producers. A large divergence between the private and social profitability of sweetpotato production indicates that incentives to grow sweetpotato would be higher if these policy interventions were removed. The policy distortions penalize sweetpotato while protecting maize. The major distortion comes from an overvaluation of the Chinese currency, which alters the terms of trade against domestic producers. For maize producers, protective tariffs offset terms-of-trade effects of currency overvaluation, but sweetpotato farmers enjoy no such advantage. Estimates of effective protection rate suggest that sweetpotato would gain more in value-added than maize if all distortion policies were removed. In terms of comparative advantage in crop production, the estimated values of domestic resource cost illustrate that both crops are very similar within the

provinces of Sichuan and Shandong but differ substantially between provinces. We find that without new technological improvements or policy changes, there is not much support for the argument that sweetpotato will substitute for maize as feed in pig production. .

The declining profitability of sweetpotato given the current status of technology, increasing opportunity cost of labor, commercialization of livestock production, and trade liberalization, call for new policy initiatives to be considered. Millions of sweetpotato producers and backyard pig growers, who are often poor and lack access to credit, may find themselves increasingly disadvantaged. Relative slow growth in sweetpotato productivity over the past few decades reflects the result of underinvestment in agricultural research and extension for this crop. Technological change has been the engine of China's agricultural economy, in general, and for grains, like rice and wheat, in particular. The future development of sweetpotato will highly depend on the productivity growth of the crop and diversification of sweetpotato utilization, which requires increasing investment in sweetpotato research and extension for production and post-harvest utilization.

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Appendix Table 1. Sweetpotato sown area (1000 hectares) by province, 1982-99.

Province	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Beijing	6	6	7	10	8	7	7	7	7	7	7	7	6	6	5	5	5	5
Tianjin	9	8	10	8	7	6	5	5	5	5	4	4	4	3	3	3	3	2
Hebei	336	348	357	369	352	346	346	334	322	312	298	320	287	266	265	256	244	246
Shanxi	37	39	45	46	45	48	49	48	49	46	48	53	53	52	55	49	52	55
Inner Mongolia	0.3	0.2	0.4	0.1	0.6	0.5	1.1	0.7	0.4	0.4	0.8	1.1	6.5	5	5.2	9.5	3	5
Liaoning	30	37	48	47	42	39	44	43	42	41	45	47	41	44	43	43	42	48
Jilin	4	4	7	6	4	5	5	5	6	5	5	7	6	7	6	6	6	6
Heilong	0	0	0	0	0	0	0	0	0	0	0	0	2.2	6.7	4.7	1.4	3	4
Shanghai	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3	0.1	0.9
Jiangsu	326	316	295	282	275	266	251	248	222	215	193	164	180	167	181	170	163	157
Zhejiang	136	131	125	117	115	118	113	119	121	120	113	140	100	112	114	114	118	123
Anhui	683	746	690	613	658	669	703	644	643	593	570	512	526	523	501	462	476	494
Fujian	238	231	221	216	217	224	225	233	244	256	259	322	274	281	288	290	289	289
Jiangxi	109	104	105	106	105	107	113	120	128	140	142	107	151	144	159	167	161	157
Shandong	1081	1007	927	821	818	817	771	766	743	692	670	659	569	549	522	481	456	416
Henan	1081	970	851	763	783	767	805	759	746	708	725	531	649	699	660	623	591	612
Hubei	195	199	191	185	186	187	195	201	197	208	196	324	198	197	212	195	215	225
Hunan	297	288	271	266	265	272	277	285	297	313	306	328	303	301	303	302	302	303
Guangdong	615	610	592	569	579	584	574	582	589	587	558	623	639	622	617	610	606	552
Guangxi	230	216	211	216	237	258	250	252	248	262	253	271	308	313	323	331	346	344
Sichuan	1390	1305	1226	1207	1230	1287	1276	1316	1340	1357	1342	1376	1416	1415	1416	1466	1459	1464
Guizhou	92	95	97	97	110	113	117	130	126	137	125	150	159	177	183	191	211	217
Yunnan	56	78	55	42	41	57	75	80	84	85	87	87	80	79	84	90	90	105
Tibet	0	0	0.1	0	2	0	0	0	0	0	0	0	1.7	0	0	0	0	0
Shaanxi	98	102	102	106	98	102	100	100	97	96	103	102	104	108	109	96	99	109
Gansu	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Qinghai	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0
Ningxia	42	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.1	1	0	0
Xinjiang	0	0	0	0	0	0	0	0	0	0	0	0	0.1	9.2	0	0	0	0
National total	6908	6840	6427	6094	6175	6278	6307	6274	6256	6199	6062	6133	6062	6085	6062	5963	5939	5937

Note: Sum of data from all provinces may not exactly equal national total figure due to rounding errors. Source: Agricultural Yearbook of China, various issues.

Appendix Table 2. Sweetpotato yield (ton/ha) by province, 1982-99

Province	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Beijing	2.5	2.5	2.9	3.4	3.3	3.9	3.9	3.9	3.9	4.0	4.7	4.1	5.3	4.8	5.2	4.8	4.6	4.6
Tianjin	3.3	3.8	4.0	4.1	3.7	4.2	3.2	4.4	4.0	4.0	5.0	5.3	4.3	6.0	4.3	3.7	4.4	2.9
Hebei	3.3	3.3	3.3	3.3	3.2	3.5	3.4	3.3	3.5	3.7	3.2	3.8	4.0	4.1	3.9	3.8	4.1	3.9
Shanxi	3.2	3.3	3.6	3.6	2.5	2.9	3.8	3.6	3.2	2.1	3.4	4.2	3.2	4.1	4.1	2.9	4.5	4.2
Inner Mongolia					1.7	2.1	0.9	1.4	2.5	2.3	2.3	2.7	2.3	4.0	6.7	2.6	6.1	3.4
Liaoning	2.5	3.0	2.9	2.2	2.5	2.2	2.8	1.5	2.5	2.4	2.8	3.2	3.2	3.4	3.7	3.6	4.1	3.7
Jilin	2.5	3.8	3.6	2.8	2.8	3.4	4.0	4.0	3.3	5.2	5.2	3.7	3.3	4.0	4.7	2.8	3.2	5.7
Heilong													3.2	3.4	3.4	5.0	4.6	3.3
Shanghai																5.3		5.8
Jiangsu	4.7	4.8	4.7	4.7	4.8	5.0	5.0	4.9	4.7	3.8	4.8	4.8	4.9	5.4	5.3	5.9	6.4	6.2
Zhejiang	5.4	5.7	5.7	5.5	4.8	5.4	5.0	5.2	4.6	4.8	4.9	4.2	4.7	5.2	5.4	5.2	5.4	5.8
Anhui	2.9	4.0	3.6	3.4	4.2	4.0	3.9	4.0	4.0	3.2	3.8	4.4	3.3	4.4	4.6	4.5	4.4	4.6
Fujian	3.8	3.5	3.8	3.7	3.0	3.7	3.5	3.7	3.8	3.9	4.0	3.8	4.3	4.3	4.5	4.7	4.9	4.8
Jiangxi	2.7	2.6	2.7	2.6	2.0	2.5	2.3	2.6	2.6	2.6	3.2	5.6	3.9	4.3	4.0	4.2	4.4	3.9
Shandong	4.6	4.6	5.7	5.3	5.2	5.9	5.2	4.2	5.5	5.3	5.1	6.7	5.7	6.0	6.6	6.9	7.1	6.6
Henan	2.4	3.6	3.0	2.7	2.3	3.0	2.7	3.2	3.4	3.3	3.4	4.3	3.9	4.1	4.6	3.6	5.0	4.8
Hubei	3.2	3.3	3.4	3.2	3.2	3.4	2.9	3.3	2.7	3.0	3.3	3.2	3.5	4.1	3.8	3.6	4.3	4.6
Hunan	3.2	3.4	3.2	3.0	2.7	3.0	2.8	3.0	2.4	2.8	2.4	3.0	3.5	3.6	3.1	3.6	3.6	4.1
Guangdong	2.4	2.3	2.4	2.5	2.4	2.7	2.7	2.8	3.0	3.2	3.0	3.1	3.4	3.6	3.7	4.0	4.2	4.7
Guangxi	1.2	1.1	1.0	1.0	1.0	1.0	0.9	0.9	1.0	1.0	1.2	1.6	1.6	1.6	1.7	1.8	1.8	2.0
Sichuan	2.9	3.3	3.2	3.3	3.1	3.6	3.0	3.2	2.5	3.2	3.4	3.5	2.9	3.2	3.7	3.2	3.6	3.7
Guizhou	2.6	2.7	2.8	2.1	2.5	2.8	2.1	2.4	1.8	2.8	2.9	2.6	2.7	2.5	2.7	2.5	2.5	2.8
Yunnan	1.8	2.5	1.8	2.0	2.1	1.7	1.7	1.7	1.7	1.6	1.5	1.5	2.1	1.8	2.3	2.2	1.9	2.0
Tibet					1.5								2.4					
Shaanxi	2.2	2.4	2.5	2.3	2.1	2.7	2.5	2.5	2.5	2.6	2.8	2.6	2.1	2.3	4.4	2.3	3.4	2.8
Gansu																		
Qinghai														2.9				
Ningxia	0.5																	
Xinjiang														5.0				
National total	3.2	3.5	3.5	3.4	3.2	3.6	3.3	3.3	3.3	3.4	3.5	3.7	3.5	3.9	4.1	3.4	4.2	4.2

Note: Sweetpotato is reported on a dry weight basis, by dividing fresh weight by 5. Source: Data are from Agricultural Yearbook of China, various issues.

Appendix Table 3. Sweetpotato production (1000 tons) by province.

Province	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Beijing	15	15	20	34	26	27	27	27	27	28	33	29	32	29	26	24	23	24
Tianjin	30	30	40	33	26	25	16	22	20	20	20	21	17	18	13	11	11	7
Hebei	1115	1155	1180	1206	1125	1195	1166	1111	1138	1163	953	1206	1138	1088	1039	973	993	949
Shanxi	120	130	160	165	113	140	184	172	158	95	164	223	170	212	228	140	234	229
Inner Mongolia	0	0	0	0	1	1	1	1	1	1	2	3	15	20	35	25	20	17
Liaoning	75	110	137	103	105	85	125	66	105	98	125	150	130	151	157	154	173	180
Jilin	10	15	25	17	11	17	20	20	20	26	26	26	20	28	28	17	18	33
Heilong	0	0	0	0	0	0	0	0	0	0	0	0	7	23	16	7	13	13
Shanghai	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.9	0	5
Jiangsu	1520	1520	1395	1336	1330	1319	1249	1203	1053	822	934	788	883	902	959	1002	1035	970
Zhejiang	740	750	715	646	557	637	566	613	557	573	550	587	465	584	615	598	634	709
Anhui	1965	2990	2470	2099	2772	2672	2759	2557	2595	1922	2193	2250	1759	2326	2322	2096	2090	2263
Fujian	915	800	835	805	661	824	784	866	930	993	1039	1217	1174	1211	1293	1356	1403	1392
Jiangxi	295	270	280	276	206	269	257	309	327	360	448	603	589	623	637	700	708	606
Shandong	4945	4670	5280	4373	4247	4784	4040	3220	4120	3684	3400	4409	3255	3316	3422	3325	3250	2764
Henan	2627	3450	2590	2086	1782	2329	2175	2452	2537	2309	2495	2298	2540	2860	3030	2258	2943	2946
Hubei	625	665	640	600	594	635	557	673	524	627	638	1050	699	809	815	707	928	1030
Hunan	955	965	865	808	710	820	768	845	708	883	735	975	1061	1078	931	1087	1092	1230
Guangdong	1505	1380	1400	1416	1386	1589	1542	1633	1773	1855	1682	1917	2177	2256	2284	2446	2555	2574
Guangxi	270	235	220	209	234	266	215	233	249	274	313	423	506	506	550	604	639	674
Sichuan	4050	4345	3910	3942	3820	4572	3824	4211	3319	4350	4530	4842	4038	4558	5188	4638	5192	5464
Guizhou	240	260	275	206	280	313	250	306	225	385	357	394	422	441	488	474	520	605
Yunnan	100	195	100	82	85	95	125	132	145	140	134	133	165	142	197	197	174	207
Tibet	0	0	0	0	3	0	0	0	0	0	0	0	4	0	7	0	0	0
Shaanxi	215	240	255	245	209	275	251	250	240	250	293	265	217	247	477	220	339	300
Gansu	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	0	0
Qinghai	0	0	0	0	0	0	0	0	0	1	0	0	0	0.2	0	0	0	0
Ningxia	20	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Xinjiang	0	0	0	0	0	0	0	0	0	0	0	0	0	46	1	0	0	0
National total	21915	24190	22795	20686	20033	22886	20904	20936	20771	20846	20955	22603	21494	23479	24761	20474	24988	25191

Note: Sweetpotato is reported on a dry weight basis, dividing fresh weight by 5. Sum of data from all provinces may not exactly equal national total due to rounding errors.
Sources: Agricultural Yearbook of China, various issues.

Appendix Table 4. Sweetpotato production in Sichuan province, China.

Year	Sown area (1000 ha)	Yield (kg/ha)	Production (1000 ton)	Year	Sown area (1000 ha)	Yield (kg/ha)	Production (1000 ton)
1931	388	1293	2511	1968	1135	2258	2555
1932	356	1341	2387	1969	1277	2693	3440
1933	468	957	2239	1970	1311	2408	3150
1934	404	1140	2306	1971	1321	1980	3610
1935	400	1373	2748	1972	1337	2400	3200
1936	398	1158	2302	1973	1392	3240	4515
1937	649	906	2941	1974	1329	2745	3645
1938	859	917	3935	1975	1325	2663	3525
1939	730	704	2570	1976	1285	2490	3200
1940	612	758	2320	1977	1397	3353	4685
1941	707	816	2936	1978	1568	3240	5030
1942	695	681	2366	1979	1573	3480	5475
1943	640	738	2363	1980	1483	3015	4480
1944	612	845	2585	1981	1419	2888	4100
1945	500	1083	2708	1982	1390	2914	4050
1946	557	891	2481	1983	1305	3330	4345
1947	558	1142	3182	1984	1226	3189	3910
1952	1155	1410	1625	1985	1207	3266	3942
1953	1185	1245	1485	1986	1230	3106	3820
1954	901	1455	1795	1987	1287	3552	4572
1955	1340	1688	2260	1988	1276	2997	3824
1956	1335	1808	2415	1989	1316	3200	4211
1957	1380	1808	2495	1990	1340	2477	3319
1958	1802	2100	3790	1991	1357	3206	4350
1959	1593	1980	3150	1992	1342	3376	4530
1960	1528	1560	2385	1993	1376	3519	4842
1961	1451	1635	2370	1994	1416	2852	4038
1962	1471	1635	2405	1995	1415	3221	4558
1963	1469	1890	2775	1996	1416	3664	5188
1964	1327	1545	2050	1997	1466	3164	4638
1965	1171	2205	2595	1998	1459	3559	5192
1966	1233	2468	3045	1999	1464	3732	5464
1967	1145	2183	2495				

Note: Sweetpotato is reported on a dry weight basis, dividing fresh weight by 5. Data are from Agricultural Yearbook of China, various issues.

Appendix Table 5. Private and social cost and profits of per hectare sweetpotato production in sample households, Sichuan, 1997.

		Private					Social				
	Quantity kg or Yuan	Price Yuan/kg	Total value Yuan	Tradable share %	Tradable Yuan	Non-tradable Yuan	Price Yuan/kg	Total value Yuan	Tradable share %	Tradable Yuan	Non-tradable Yuan
I. Revenue											
Product	4665	0.92	4292	100	4292	0	1.12	5209	100	5209	0
By-Product		1.00	675	0	0	675	1.00	675	0	0	675
Total			4967		4292	675		5884	89	5209	675
II. Variable capital cost			2358	73	1729	629		2561	75	1932	629
Seed	251	1.00	251	100	251	0	1.08	271	100	271	0
Fertilizer (pure N/P/K)	285	4.68	1335	100	1335	0	5.26	1500	100	1500	0
Manure	2455	0.12	300	0	0	300	0.12	300	0	0	300
Pesticide	0.22	18.18	4	100	4	0	20.43	4	100	4	0
Plastic	6	8.93	54	100	54	0	10.48	63	100	63	0
Other costs	8	1.00	8	50	4	4	1.17	9	57	5	4
Tax and depreciation	406.5	1.00	407	20	81	325	1.02	413	21	88	325
III. Labor cost	420	9.41	3951	0	0	3951	10.35	4346	0	0	4346
IV. Total Cost			6309		1729	4580		6907	28	1932	4975
V. Net return			-1342					-1023			

Note: A real exchange rate 11.18 (Yuan/US$) is used instead of the official exchange rate (8.29 in 1997).

Appendix Table 6. Private and social cost and profits of per hectare sweetpotato production in sample households, Shandong, 1997.

		Private					Social				
	Quantity kg or Yuan	Price Yuan/kg	Total value Yuan	Tradable share %	Tradable Yuan	Non-tradable Yuan	Price Yuan/kg	Total value Yuan	Tradable share %	Tradable Yuan	Non-tradable Yuan
I. Revenue											
Product	5289	1.04	5501	100	5501	0	1.23	6528	100	6528	0
By-Product		1.00	675	0	0	675	1.00	675	0	0	675
Total			6176		5501	675		7203	91	6528	675
II. Variable capital cost			2619	91	2389	230		2809	92	2579	230
Seed	710	1.00	710	100	710	0	1.05	747	100	747	0
Fertilizer (pure N/P/K)	204	7.26	1481	100	1481	0	7.90	1611	100	1611	0
Manure	375	0.12	46	0	0	46	0.12	46	0	0	46
Pesticide	2.75	24.00	66	100	66	0	26.53	73	100	73	0
Plastic	9	9.44	85	100	85	0	10.79	97	100	97	0
Other costs	3	1.00	3	50	2	2	1.17	4	57	2	2
Tax and depreciation	228	1.00	228	20	46	182	1.02	232	21	49	182
III. Labor cost	257	10.77	2767	0	0	2767	11.84	3044	0	0	3044
IV. Total Cost			5386		2389	2997		5853	44	2579	3274
V. Net return			790					1350			

Note: A real exchange rate 11.18 (Yuan/US$) is used instead of the official exchange rate (8.29 in 1997).