PN-ABM-656 71778

The mandate of the International Service for National Agricultural Research (ISNAR) is to assist developing countries in bringing about lasting improvements in the performance of their national agricultural research systems and organizations. It does this by promoting appropriate agricultural research policies, sustainable research institutions, and improved research management. ISNAR's services to national research are ultimately intended to benefit producers and consumers in developing countries and to safeguard the natural environment for future generations.

ISNAR offers developing countries three types of service, supported by research and training:

- For a limited number of countries, ISNAR establishes long-term, comprehensive partnerships to support the development of sustainable national agricultural research systems and institutions.

- For a wider range of countries, ISNAR gives support for strengthening specific policy and management components within the research system or constituent entities.

- For all developing countries, as well as the international development community and other interested parties, ISNAR disseminates knowledge and information about national agricultural research.

ISNAR was established in 1979 by the Consultative Group on International Agricultural Research (CGIAR), on the basis of recommendations from an international task force. It began operating at its headquarters in The Hague, the Netherlands, on September 1, 1980.

ISNAR is a nonprofit autonomous institute, international in character, and apolitical in its management, staffing, and operations. It is financially supported by a number of the members of the CGIAR, an informal group of donors that includes countries, development banks, international organizations, and foundations. Of the 18 centers in the CGIAR system of international centers, ISNAR is the only one that focuses specifically on institutional development within national agricultural research systems.

PN-ABM-656
79778

中国农业研究

Agricultural Research in China

Its Institutional Development and Impact

Shenggen Fan
Philip G. Pardey

August 1992

International Service for National Agricultural Research
Institute of Agricultural Economics, Chinese Academy of Agricultural Sciences
Center for International Food and Agricultural Policy, University of Minnesota

This project is jointly supported by the Rockefeller Foundation, ISNAR and CIFAP

Citation

Fan, S. and P. G. Pardey. 1992. Agricultural Research in China: Its Institutional Development and Impact. The Hague: International Service for National Agricultural Research.

AGROVOC Descriptors

agricultural policies; economic growth; expenditure; financing research; organization of research; productivity; public research; research policies; China

CABI Descriptors

agricultural policy; agricultural research; economic growth; government research; organization of research; productivity; research policy; China

ISBN 92 9118 007 6

Contents

List of Tables v

List of Figures vi

Acronyms and Abbreviations vii

Foreword ix

Acknowledgements xi

Introduction 1

1 Production Agriculture 3

1.1 Agricultural Resource Endowments 3
1.2 Agricultural Policies and Institutions 10
1.3 Agricultural Production and Trade Developments 12
1.4 Agricultural Productivity Patterns and Input Use 19

2 Institutional Evolution of Agricultural Research 29

2.1 Pre-Revolution Period 29
2.2 Early Post-Revolution Period (1949-1965) 30
2.3 Cultural Revolution Period (1966-1976) 31

3 The Contemporary Agricultural Research System 33

3.1 Organizational Structure 33
3.2 Funding Mechanisms 37
3.3 Coordination 38
3.4 Human Resource Management 39
3.5 University and Extension Activities 40

4 Quantitative Development and Impact of Chinese Agricultural Research 45

4.1 Quantitative Aspects of Agricultural Research 45
4.2 Accounting for the Impact of Agricultural Research 58

5 Concluding Remarks and Observations 67

References 71

Appendices 77

1 Regional Labor Productivity, Constant 1980 Yuan per Agricultural Worker 78

2 Regional Land Productivity, Constant 1980 Yuan per Hectare of Agricultural Land 79

3 R&D Organization Chart for China 80

4 Organizational Affiliations of Chinese Agricultural Research Institutes at the National Level, 1990 81

5 Sources and Flow of R&D Funds in China 85

6 Agricultural Research Personnel in China, 1949-88 86

7 Agricultural Research Expenditures in China, 1953-88 89

8 Yields of Principal Crops, 1949-90 91

9 Area Sown to Principal Crops, 1949-90 93

List of Tables

1. Regional Characteristics of the Natural Resource Base, 1989 6
2. International Comparisons of Land Resource Endowments, 1989 7
3. Population and Labor Force, 1950 to 1990 8
4. Regional Social and Economic Indicators, 1989 9
5. Regional Agricultural Production Growth Indices, 1965 = 100 14
6. Production of Major Agricultural Commodities, 1950 to 1990 15
7. Agricultural Trade, 1961 to 1989 17
8. Land and Labor Use in Agriculture, 1965 to 1990 24
9. Secondary Input Use, 1965 to 1990 26
10. Chronology of Major Institutional Changes within the Agricultural Research System since 1949 31
11. Quantitative Development of Agricultural Research, 1953 to 1988 46
12. Spending per Scientist, 1953 to 1988 48
13. Degree Status of Agricultural Researchers 49
14. Agricultural Research Intensity Ratios, Weighted Averages, 1961 to 1988 51
15. Vertical Structure of Agricultural Research Institutes, 1989 55
16. Regional Distribution of Agricultural Research Capacity, 1989 56
17. Quantitative Comparison of Agricultural Research and Extension, 1975 to 1988 58
18. Adoption of Hybrid and Improved Varieties, 1976 to 1986 60
19. Accounting for Growth in Agricultural Output, 1965 to 1989 65

List of Figures

1. Provinces and agricultural regions 4
2. Composition of agricultural production, 1949 to 1990 16
3. Induced changes in technology 20
4. Regional land and labor productivity, 1965 to 1990 21
5. Organizational structure of the agricultural research system 35
6. Organizational structure of the agricultural extension system 43
7. Agricultural research personnel and expenditures, 1953 to 1988 47
8. Commodity orientation of agricultural research and production, 1987 53
9. Regional distribution of national-level research institutes, 1990 57
10. Yield of principal grain crops, 1949 to 1990 61
11. Yield of principal cash crops, 1949 to 1990 62

Foreword

Sustaining growth in agricultural output to meet basic food requirements while accommodating the changing structure of demand for agricultural produce give rise to fundamental policy choices in all developing countries. These concerns take on a heightened priority in China with its large and still growing population and relatively limited agricultural land base. And the substantial and continuing domestic market reforms, including the increased integration of Chinese agriculture in world commodity markets, are leading to marked changes in the structure of demand for agricultural technologies. Clearly, the country's agricultural technology generation and transfer systems cannot be isolated from these broad-ranging, and in many respects quite radical, institutional changes.

A prerequisite to examining the reform options presently available to the Chinese agricultural research system is a comprehensive review of the nature and deployment of the system's existing resource base. The time-intensive character of the agricultural research process itself also points to the need for a historical perspective. Just as today's technological advances in agriculture are a consequence of past research endeavors, much of the impact of the present research effort will not bear fruit until some time in the future. Consequently, the reform options facing the agricultural research system must be seen as the strategic choices they represent as they shape the productivity gains to be had by the agricultural sector over the longer term.

This monograph represents a collaborative effort between the International Service for National Agricultural Research, the Institute for Agricultural Economics of the Chinese Academy of Agricultural Sciences, and the Center for International Food and Agricultural Policy of the University of Minnesota to develop a quantitative and institutional perspective on agricultural research in China. The large, institutionally disparate nature of the system poses substantial practical difficulties in assembling such data. The institutional volatility that has characterized China over the past several decades presents additional difficulties in developing a historical perspective on these matters. By drawing together a good deal of data from officially published material, cross-checked with insights gained from knowledgeable individuals and informal sources, the authors have been able to construct quantitative estimates that are in accord with informed views of China's agricultural research efforts.

Besides documenting the evolution of the research system, some analysis of interregional productivity differences and the sources of growth in Chinese agriculture is also included. The results demonstrate that agricultural research investments have made substantial contributions to agricultural output growth over the past several decades. It is hoped this monograph will facilitate more informed policy dialogue to ensure that agricultural research plays a vital role in sustaining this growth into the future.

Zhu Xigang
Director
Institute of Agricultural Economics, CAAS
Beijing

Christian Bonte-Friedheim
Director General
International Service for National Agricultural Research
The Hague

Harald von Witzke
Director
Center for InternationalFood and Agricultural Policy
University of Minnesota, St Paul

Acknowledgements

This research is jointly sponsored by the International Service for National Agricultural Research, the Rockefeller Foundation, and the Center for International Food and Agricultural Policy of the University of Minnesota. It has been executed in collaboration with the Institute of Agricultural Economics of the Chinese Academy of Agricultural Sciences.

Numerous individuals and institutes both within and outside China provided guidance and assistance in the process of researching and preparing this monograph. We are particularly grateful to Howard Elliott, Jørgen Delman, and Barry Nestel, who thoroughly reviewed and extensively commented on a draft of the manuscript. Additional and helpful comments were given by Kym Anderson, Christian Bonte-Friedheim, and Stanley Wood.

During our field work in China in October 1990, September 1991, and May 1992, many experts and government officials supplied valuable information on the nation's agricultural research system. Particular thanks go to Professors Niu Ruofeng and Zhu Xigang, as well as Liu Jiling and Sun Zhengyu, all from the Institute of Agricultural Economics of the Chinese Academy of Agricultural Sciences, for taking the time to discuss in detail the Chinese agricultural research system. Qian Keming provided excellent research assistance.

In addition, this project has benefitted from the substantive input of various other government agencies and research institutes. They include the relevant departments of the Ministry of Agriculture, the Ministry of Forestry, the Chinese Academy of Agricultural Sciences, the Chinese Academy of Forestry, the Chinese Academy of Fishery Sciences, the National Center for Rural Technology Development of the State Science and Technology Commission, as well as provincial departments, agricultural universities, and research institutes in Jiangsu and Heilongjiang provinces.

Vernon Ruttan and Bob Herdt also provided guidance and comments during the course of this study, for which we are grateful. A final series of thanks are due Fionnuala Hawes for her usual flair on the word processing and layout fronts, Wilhelmina Eveleens for her able research assistance, Cathy Wheat for her fine cover design, and Kathleen Sheridan for putting us right on editorial matters.

Shenggen Fan
Phil Pardey

The Hague

Acronyms and Abbreviations

AgGDP	agricultural gross domestic product
AgGPV	agricultural gross production value
BAU	Beijing Agricultural University
CAAM	Chinese Academy of Agricultural Mechanization
CAAS	Chinese Academy of Agricultural Sciences
CAF	Chinese Academy of Forestry
CAFS	Chinese Academy of Fishery Sciences
CAS	Chinese Academy of Sciences
CIFAP	Center for International Food and Agricultural Policy, University of Minnesota
CPC	Communist Party of China
FAO	Food and Agriculture Organization of the United Nations
GNP	gross national product
GPV	gross production value
IRRI	International Rice Research Institute
ISNAR	International Service for National Agricultural Research
JAAS	Jiangsu Academy of Agricultural Sciences
MOA	Ministry of Agriculture
MOF	Ministry of Forestry
MOMB	Ministry of Machine Building
MOWCP	Ministry of Water Conservation and Power
NATEC	National Agricultural Technical Extension Center
NCRTD	National Center for Rural Technology Development
NARS	national agricultural research system
NEAC	Northeast Agricultural College
NMB	National Meteorological Bureau
PRC	People's Republic of China
R&D	research and development
SSB	State Statistical Bureau
SSTC	State Science and Technology Commission
STCMA	Science and Technology Committee of the Ministry of Agriculture
STDMA	Science and Technology Department of the Ministry of Agriculture
SCATC	South China Academy of Tropical Crops
UNESCO	United Nations Educational, Scientific and Cultural Organization
ZAAS	Zhejiang Academy of Agricultural Sciences

Introduction

Contemporary rates of growth of agricultural production in China[1] have been impressive by historical and international standards. Despite some intervening periods of stagnant or declining performance, agricultural output grew at a long-run average rate of 4.2% per annum over the 1950 to 1990 period. This growth is the most rapid among the socialist (or former socialist) countries and is more rapid than for many less-developed countries during the same period (Fan 1991). In many respects agriculture is still the country's most important sector. In 1990 it accounted for 20% of gross domestic product and 60% of total employment, and with only 7% of the world's arable land, it sought to feed and clothe 23% of the world's population. Thus, the performance of this sector plays a pivotal role in ensuring not only national but global food security as well. But in spite of past successes, living standards, especially in rural areas, are still low, even when compared with some less-developed countries. Indeed, by the early 1980s China's leaders were calling for a quadrupling of the value of industrial and agricultural production by the end of this century, in order to improve the overall standard of living and prepare the ground for the development of the national economy during the next century.[2]

Much has been written about the economic impacts of the Chinese government's institutional reform efforts that began in December 1978. But comparatively little attention has focussed on the agricultural productivity (not simply growth) consequences of these reforms or the likely nature and sources of future productivity gains in Chinese agriculture. It is investment in capital, be it human, physical, or technological, that will play an ever-increasing role in shaping Chinese agriculture's long-run comparative advantage as the shorter-run gains from market reforms work their way through the system. For China to realize its development objectives, much will therefore be required of its agricultural technology generation system, the focus of our attention here.

The monograph is organized into five main sections. By way of introduction we begin with a brief review of the Chinese agricultural sector and the patterns of output, trade, and productivity growth therein. China is a large and diverse country, so differences among regions in their natural resource endowments, as well as social and economic conditions are substantial. In general, land-saving and labor-using technology has been developed and adopted, yet farming systems differ sharply among as well as within regions, even with the same level of technology. The biased nature of this technical change has shaped the pattern of productivity growth, with land productivity growing more rapidly than labor productivity. Agricultural research, responsive to the natural resource base as well as social and economic forces, has played a crucial role in inducing these technology and productivity growth patterns.

[1] Taiwan is not included in this study.

[2] This growth objective was set in September 1982 at the Twelfth Congress of the Communist Party of China (Liu et al. 1987). For some considered reflections on the likelihood of this outcome see Garnant (1988).

The historical evolution of the Chinese agricultural research system is reviewed in the second part. The present system was established in 1957, suffered much damage between 1967 and 1976 as a result of the Cultural Revolution, and is currently working to create a more integrated agricultural research system. Domestic political struggles and shifts in international relations with other countries, as well as the nature and pattern of the country's economic growth, helped determine the origin and development of the system.

The third part of this report describes the contemporary institutional structure of agricultural research. The current system has been characterized as a ministry model (Fang 1987, Shen 1990). However, agricultural research in China is organized in a variety of ministries or different ministerial-level units and is probably best thought of as a multi-ministry model. For much of the post-revolution period the system has been organized in a rather decentralized manner. The vertical linkages between different levels (national, provincial, and prefectural) are mainly professional, while horizontal linkages between institutes under different departments at the same level are generally weak.

The quantitative development and impact of agricultural research in China is discussed in the fourth part. Investment in agricultural research has grown considerably over the past 40 years. However, there have been marked, and in some instances quite volatile, fluctuations in the level of resources committed to agricultural research. This instability notwithstanding, the impact of agricultural research on production growth has been substantial. Yields for many crops have increased substantially since 1949 and the growth in total agricultural production has accelerated since 1965. We estimate that about 20% of this growth in agricultural production is attributable to investments in agricultural research.

In the final section we reflect on the research policy and organizational issues currently facing agricultural research in China. Securing continued political and financial support for agricultural research and deploying the available resources more judiciously will be essential if the national agricultural research system is to be further strengthened over the coming years.

Chapter 1

PRODUCTION AGRICULTURE

Variations both across and within countries in the quantity and quality of land, capital, technology, and climate, as well as differences in market and policy environments, give rise to observed patterns of agricultural production and productivity growth. Ratios of domestic resource endowments relative to those of the rest of the world also influence patterns of agricultural specialization and trade.[1] Conventional, neoclassical trade theory suggests that poor countries with little capital relative to land and labor tend to export agricultural products in exchange for manufactures. As capital (including the technologies embodied therein) is accumulated or flows in from abroad, labor tends to move off-farm and the share of primary agricultural production in total output and employment declines as manufacturing and service activities (including the farm input supply industries and the agricultural processing and marketing sectors) expand. If international prices remain unchanged, a country's export specialization gradually shifts from agriculture to manufactures.

This transformation is likely to begin at a lower level of capital per worker the lower a country's (agricultural) land endowment per worker — a situation that typifies a land-scarce, densely populated country such as China. Nevertheless there is scope for slowing the decline in a country's comparative advantage in agriculture if capital is used to substitute for land or labor in agriculture or if labor-saving technologies are generated that raise labor productivity faster in agricultural production than elsewhere in the economy. Government policies that subsidize agriculture can also act to slow the rate of decline in food self-sufficiency.

We begin this study of the nature and impact of agricultural research endeavors in China by reviewing briefly the country's agricultural resource endowments and its relevant institutional environment. The production, trade, and productivity consequences that flow directly from these aspects is then summarized in sections 1.3 and 1.4.

1.1 Agricultural Resource Endowments

A country's land and labor endowments represent fundamental but not necessarily immutable constraints to production agriculture. It is the relative as much as the absolute endowment of these primary factors — be they at the regional, national, or international level — that is relevant in this regard. So in order to adequately review both these aspects for a large and diverse country such as China, it is necessary that we disaggregate the national-level statistics to a manageable but revealing set of regions (figure 1) while also casting the aggregate statistics in an international context.

Land

In terms of area, China is the third largest nation in the world, with a land mass of 9.6 million square kilometers. But in agricultural terms it is a relatively land-scarce country. About 66% of the land area consists of mountains and only 10% of the total area is arable, only half the corresponding proportion of

[1] For a more detailed development of the ideas presented in this introductory section see Krueger (1977) and Anderson (1983 and 1990).

Figure 1: *Provinces and agricultural regions in China*

Legend: • provincial capitals; ····· provincial boundaries (provincial names in italic); —— regional boundaries.
Note: For details concerning the classification of provinces into regions see the note to table 1.

Southwest Asia and one-fifth that of South Asia (table 1). Most of China's western area is mountainous with high plateaus. In the south and southwest hills predominate, while it is only in the east that one finds low-elevation plains. The high altitudes in the mountainous areas and the resultant low temperatures severely limit the length of the growing season. Not only does this extremely cold weather place substantial constraints on existing cropping, forestry, and animal husbandry systems, but the precipitous slopes and shallow soils prevent any further expansion in the area farmed. The rough topography means that soil erosion is a constant threat to the ecology, while the construction of irrigation systems and the use of mechanized inputs are virtually impossible.

Soil types vary greatly throughout China. The drier northern and western regions are dominated by two soil types: the very shallow and poor mountain soils found on the Tibetan Plateau and the prairie, steppe, and desert soils in the regions of Xinjiang, Nei Monggol, as well as the Loess Plateau and parts of Northeast China. Eastern China is humid; its soils are generally podzols and are distinguished by the moisture and temperature regimes in which they developed. They form the most important agricultural soils in China, and although not especially fertile, they can generally be worked easily.

In most years, rainfall is abundant but distributed unequally among regions (table 1). Both the southern and eastern areas of China (including the south, southeast, southwest, and central regions and part of the north and northeast) lie in the path of monsoonal winds, so some areas are classified as wet and others as semi-wet. The wet region comprises 32% of the country. Irrigation in these areas is used only to flood rice paddies and not for dryland crops. The semi-wet region covers 18% of the country, where dryland crops grow without irrigation, although seasonal water deficiencies often occur. The wet and semi-wet regions combined comprise approximately half the country's total land area.[2] Semi-dry areas (including parts of the north, northwest, and northeast regions) comprise 19% of the total land area and experience crop yields that are low and unstable in the absence of irrigation. Dry regions (mainly in the northwest) extend over 31% of the total land area and are semi-desert in nature. In these desert areas agriculture is possible only with irrigation.

Most of the rain occurs in the summer months of June to August. Southern parts of the country receive around 40% to 50% of their annual total during these months and the northern areas around 60% to 75%. Most regions receive only 10% to 15% of their annual rainfall during the winter months of December to February.

Measures of China's land-endowment ratios relative to the rest of the world are shown in table 2. The Chinese per capita endowment of land used for short-cycle and, especially, tree crops (i.e., arable and permanently cropped land, respectively) is low by both more- and less-developed country standards. In an Asian context China is relatively well endowed with pastureland[3] but has little pasture per capita compared with the more-developed world, particularly relative to Australia and the Americas. The same is true for areas under forest and woodland. At face value these data suggest China has a comparative disadvantage in crop, extensive livestock, and timber production vis-à-vis the rest of the world and, except for extensive livestock and to some degree short-cycle crops, with respect to Asia. In fact, China's land scarcity is magnified when its land endowments are expressed per agricultural worker rather than simply total number of workers, given the country's relatively high proportion of workers in agriculture.

2 For the classification of wet, semi-wet, and dry regions see Chen and Hu (1983).

3 In absolute terms the area of land under pasture in China is roughly equivalent to that of the United States or Australia.

Table 1: *Regional Characteristics of the Natural Resource Base, 1989*

Region	Annual average temperature[a]	Annual precipitation[a]	Land: Total	Land: Arable[b]	Land: Arable percentage of total	Predominant soil types[c]
	(C°)	(*millimeters*)	(*million ha*)	(*million ha*)	%	
Northeast	6.7	623.9	79.9	16.2	20.3	Chernozem and black earth
North	13.2	442.2	90.5	28.5	31.5	Alluvial soil and dust-blown loess
Northwest	7.2	262.2	520.1	13.1	2.5	Steppes, desert and semi-desert lands
Central	16.2	1,654.9	56.5	9.2	16.3	Red and yellow podzolic soils
Southeast	16.1	1,332.2	35.8	11.0	30.7	Yellow podzolic soils
Southwest	15.7	967.2	112.6	11.0	9.8	Purple and brown soils
South	22.3	1,606.2	57.1	6.8	11.9	Acid red and yellow lateritic soils
National			952.5	95.7	10.0	

Source: Temperature and precipitation is from *China's Statistical Yearbook* (1990). Total agricultural land and arable land is from *China's Rural Statistical Yearbook* (1990).

Note: China currently has 30 provincial-level units (of which 22 are classed as provinces, five as autonomous regions, and three as municipalities), 336 prefectural-level units (including both prefectures and prefectural-level cities or municipalities) and 2,182 county-level units. For our purposes, the country is divided into seven regions according to agricultural characteristics: *northeast* – Heilongjiang, Liaoning, and Jilin provinces; *north* – municipalities of Beijing and Tianjin, Hebei, Henan, Shandong, Shanxi, and Shaanxi provinces; *northwest* – autonomous regions of Nei Monggol, Ningxia, Xinjiang, and Tibet; Qinghai and Gansu provinces; *central* – Jiangxi, Hunan, and Hubei provinces; *southeast* – Shanghai municipality, Jiangsu, Zhejiang, and Anhui provinces; *southwest* – Sichuan, Guizhou, and Yunnan provinces; *south* – Guangxi autonomous region, Fujian, Hainan, and Guangdong provinces.

[a] Temperature and precipitation statistics are those recorded for the following cities: northeast, Changchun; north, Beijing; northwest, Urumqi; central, Wuhan; southeast, Shanghai; southwest, Chengdu; and south, Guangzhou.

[b] Arable land refers to land under temporary crops (multiple-cropped areas counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens, and land temporarily fallow or lying idle. It excludes land under permanent crops.

[c] The classification of soils is taken from CAS (1980).

Table 2: *International Comparisons of Land Resource Endowments, 1989*

	Land per unit labor				Land per unit agricultural labor				Irrigated land as percent of A&PC[a]
	Pasture & rangeland	Arable land	Permanently cropped	Forest & woodland	Pasture & rangeland	Arable land	Permanently cropped	Forest & woodland	
	(hectares per '000 population)				*(hectares per '000 population)*				%
China	447	139	5	189	700	204	7	278	47.2
Indonesia	167	224	77	1,606	339	454	157	3,256	35.5
Thailand	27	655	108	491	41	1,009	166	756	19.1
Southeast Asia (8)[b]	92	274	106	1,086	196	582	225	2,309	26.3
South Asia (8)	122	515	14	294	188	793	22	453	30.2
LDC (excl. China) (127)	*1,560*	*609*	*75*	*1,970*	*2,826*	*1,103*	*136*	*3,569*	*17.4*
Australia	52,099	6,078	22	13,212	1,009,643	117,780	418	256,039	3.8
Canada	2,504	3,482	6	27,169	72,527	100,835	176	786,813	1.8
USA	1,975	1,537	17	2,404	81,165	63,153	684	98,790	9.5
Western Europe (8)	363	354	16	294	9,371	9,145	407	7,578	5.9
MDC (17)	*2,150*	*994*	*40*	*2,384*	*44,254*	*20,470*	*815*	*49,071*	*9.5*

Source: FAO AGROSTAT (1991).

[a] A&PC refers to the sum of arable and permanently cropped land.
[b] Bracketed figures represent number of countries in the region.

Leaving aside the possibility that differential levels of technology (particularly land-saving technologies) will affect China's comparative advantage in food and fibre production relative to the rest of the world, the level of and rate of change in its agricultural comparative disadvantage can be partially offset by investments in agricultural capital, especially that aimed at improving the quality of the agricultural land base. China's long history of investment in rural infrastructure, particularly irrigation facilities, has served to enhance the productive capacity of its agricultural land. Nearly one-half of the country's arable and permanently cropped land is irrigated (table 2). This is over two and one-half times higher than the corresponding areas under irrigation in the less-developed countries and five times higher than in the more-developed countries. It is even high by Asian standards where it is eclipsed only by Japan, which has around two-thirds of its arable and permanently cropped land under irrigation.

Labor

By any standards the size of China's labor force is immense (table 3). Since 1955 the total labor force has grown at an average annual rate of 2.9% to total 567.4 million by 1990. There was a slower rate of increase (1.7%) in agricultural labor over the corresponding period, so the share of the nation's workforce directly engaged in production agriculture has declined, at an accelerating rate over more recent years, from 83% in 1955 to 59% in 1990.

The distribution of the agricultural labor force throughout China is quite uneven (table 4). Just three regions (the north, southeast and southwest) account for over 60% of the nation's total and agricultural labor force. These regions, or parts thereof, encompass the most intensively cultivated areas within China, namely the North China Plain (part of the north region), the middle and lower Changjiang River Basin and the river delta (part of the southeast and central regions), and the Sichuan

Table 3: *Population and Labor Force, 1950 to 1990*

	Population		Labor		
				Agriculture[a]	
Year	Total	Rural	Total	Number	Percent of total
		(millions)			%
1950	552.0	490.3	180.8	-	-
1955	614.6	531.8	223.3	185.9	83.3
1960	662.7	531.3	258.8	163.3	63.1
1965	725.4	594.9	286.7	225.0	78.5
1970	830.0	685.7	344.3	278.1	80.8
1975	924.2	763.9	381.7	287.0	75.2
1980	987.1	795.7	419.0	298.1	71.1
1985	1058.5	807.6	498.7	303.5	60.8
1990	1143.3	841.4	567.4	333.4	58.8

Source: *China's Rural Economic Statistical Materials, 1949-86* (1989), and *China's Statistical Yearbook* (1991).

[a] Except for 1955 and 1970, labor in rural nonfarm industry is excluded. The resulting distortions in the 1955 and 1970 figures are small in that the percentage of total labor employed in rural industries, even by 1970, was probably minimal.

Basin (part of the southwest region). These three areas have relatively abundant precipitation, level topography, fertile alluvial soils, and navigable river systems. This is particularly true for those areas in the south that are served by the Changjiang River (Yangtze) and its several tributaries. In these areas are to be found China's major cities, including Shanghai, Beijing, Tianjin, Nanjing, Changdu, and Chongqing, which are the principal centers of urban demand for agricultural produce. Secondary population concentrations, with lower but still significant population densities, are found throughout the rugged uplands of much of south China.

By contrast, the rather harsh environmental conditions found throughout the Songliao River Basin in the northeast where the climate is colder and marshlands are extensive, along the Hexi Corridor in Gansu Province, and in the oases in Xinjiang Uygur Autonomous Region place natural constraints on the population densities in these areas. Likewise, in Nei Monggol, Qinghai, and Xinjiang in western China, where minority nationalities reside, the insufficient rainfall, temperature extremes, and poor soils limit agricultural development as well as population carrying capacities (Pannell and Ma 1983).

Table 4: *Regional Social and Economic Indicators, 1989*

Region	Population[a]		Labor		GPV[b]	AgGPV[c]
	Total	Rural	Total	Agricultural		
	(million)	*(million)*	*(million)*	*(million)*	*(billion yuan)*	
Northeast	97.9	55.3	43.9	15.6	362.9	29.6
North	301.5	246.2	148.8	85.9	784.9	92.1
Northwest	68.6	48.1	30.3	17.1	133.6	21.9
Central	149.6	121.8	73.5	47.6	309.8	47.5
Southeast	174.9	138.7	96.6	49.3	744.8	61.5
Southwest	175.5	152.3	92.5	68.5	261.8	46.5
South	137.1	115.9	67.6	40.5	366.5	42.2
National	*1,111.9*	*878.3*	*553.3*	*324.4*	*2,964.3*	*341.3*
	%	%	%	%	%	%
Northeast	8.8	6.3	7.9	4.8	12.2	8.7
North	27.2	28.0	26.9	26.5	26.5	27.0
Northwest	6.2	5.5	5.5	5.3	4.5	6.4
Central	13.5	13.9	13.3	14.7	10.5	13.9
Southeast	15.8	15.8	17.5	15.2	25.0	18.0
Southwest	15.8	17.3	16.7	21.1	8.8	13.6
South	12.3	13.2	12.2	12.5	12.4	12.4
National	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*

Source: China's Statistical Yearbook (1990) and *China's Rural Statistical Yearbook* (1990).

[a] Total national population includes military personnel while regional population figures do not.

[b] GPV denotes gross production value, which includes the production value of agriculture, industry, transportation, and so on.

[c] AgGPV denotes gross value of agricultural production, an aggregate of the value of crop, animal husbandry, forestry, and fisheries production. Off-farm rural industry (which includes power, machinery, coal, coke, petroleum, chemicals, building materials, forestry, food, forage, textiles, sewing, leather, paper-making, stationery, and arts and crafts) is excluded from agricultural production.

Apart from these unfavorable and inhospitable areas, it is the quality and deployment of the agricultural labor force, not just the quantity per se, that has had, and no doubt will continue to have, a large impact on agricultural development patterns throughout China. There is overwhelming evidence that enhancing the ability and information base of farmers, and rural populations in general, through investments in literacy, educational, and extension programs can have a profound and positive influence on the generation, adoption, and use of agricultural technologies, taken here in their broader sense to include agricultural farming practices in general (Schultz 1981). Such investments not only improve farmers' allocative abilities, whereby inputs are used more efficiently given prevailing levels of technology, but also enhance the capability of farmers to search and screen for new and potentially profitable technologies.

China's record on human capital investments, particularly with regard to rural education, has been reasonably good. Depending on the criteria used, literacy rates have been pushed up from around 20% to 40% at the time of the communist takeover in 1949 (Perkins and Yusuf 1984) to around 80% today (SSB 1987). While this is certainly a considerable feat, which few countries in a comparable income class can rival, Perkins and Yusuf (1984) raised questions about the economic significance of these data. If, as they presumed, most of those who were classified as literate could comprehend no more than 1,500 characters, then few such peasants are likely to obtain little more than a very limited understanding of a tractor repair manual or any of the myriad publications through which technical information is extended. However, casual evidence suggests that a lack of functional literacy in this sense may be more of a problem for older cohorts, with those educated in recent decades generally being capable of availing themselves of such information. This view is strengthened by the available data on primary school enrollment ratios that have been at or above 90% (even for most rural areas) for the past three decades and secondary school enrollments (including, presumably, high schools and technical vocational schools) that have risen from around 20% in the early 1960s to around 40% over more recent years. (Craig, Pardey and Roseboom 1991).

1.2 Agricultural Policies and Institutions[4]

Since the formation of the new republic, China has experienced a number of policy and institutional reforms that in some cases have involved abrupt dislocations of the country's economic, social, and political order. The official raison d'être for these changes was to promote rapid economic development and a more equal distribution of wealth, attain national food security, and move forward socialist or communist "ideals" (MOA and SSB 1989). But in practice, not all these purported objectives were realized.

The mode of production has been the target of repeated government-sponsored change. Large-scale land reform was one of the first priorities of the newly formed Communist government. Up until the 1949 Revolution there was a feudal system of land ownership with something in the order of 70% to 80% of the agricultural land being held by 10% of the landlords (MOA and SSB 1989). Most farmers were landless peasants who rented land, commonly at exorbitant rates, from these landowners. Soon after 1949 land was confiscated by the government, without compensation, and redistributed to peasant farmers.

Beginning in 1952, some small-scale peasant farmers voluntarily pooled their land and other resources into a cooperative mode of operation. This was soon followed by compulsory, government efforts to develop large collectivized operations, and by 1956 most agricultural production was done on a collec-

4 For additional commentary on the evolving institutional environment facing Chinese agriculture see Perkins (1988), Sicular (1988), Lin (1990) and World Bank (1991b).

tive basis. Under this system landownership was vested in the collective, which usually consisted of around 200 families. Within the collective, an individual's income was tied to the number of work points accumulated throughout the year in line with the amount of time, effort, skill and "political attitude" that was brought to one's collective work.[5] Home gardens on "private plots," constituting about 5% of all arable land at this time, were also farmed by households, the produce from which could be sold on free markets.

This collective system of production remained more or less in place until the late 1970s, although the size of the basic collective unit did vary substantially over time. At the height of the commune movement in 1958-59 the average communal unit had grown to 5,000 households covering 10,000 acres with food being allocated as much on the basis of need as on accumulated work points. Work on private plots was also prohibited at this time. But by 1962 the "production unit," a subunit of the commune consisting of only 20 to 30 neighboring families, had become the basic unit of operation and accounting. Decisions regarding farm operations, including the adoption of new technologies, were primarily made by unit leaders. Market exchanges of land between different production units in the collective system were outlawed.

At the outset the market-oriented rural reforms initiated in late 1978 were seen primarily as a means of freeing up rural trade fairs or "free markets" whose main function was to provide an outlet for produce grown on the private plots of farm households working in their spare time. But events rather quickly overtook these quite modest aims and have subsequently led to, among other things, a radical overhaul of the collective system of farm production and management, a relaxation of regional self-sufficiency requirements, and moves to liberalize and decentralize many factor and product markets that included significant increases in the prices paid for state-purchased farm produce. These new policies sought to move away from a lopsided stress on grain production by encouraging diversification of the rural economy as well as product specialization and crop selection that was more in accord with regional comparative advantage. Most important, they also sought to restore the primacy of the individual household as the basic unit of production and management in rural China. These institutional changes have demonstrably accelerated the rate of development of the Chinese agricultural sector. Studies by McMillan, Whalley, and Zhu (1989), Wen (1989) and Lin (1992) claim that a particularly large share of the growth in agricultural output is due to these institutional changes, an issue to which we return in chapter 4.

Although land in China remains under collective ownership, the household-based farming system, i.e., the "household responsibility system," that began to emerge in 1979 restored households as the basic unit of farm operations.[6] By 1983 virtually all the nation's collective teams had converted to this new system. Households now take out a lease from the collective for a plot of land which, at least in principle, can be subcontracted to other households if the original household migrates to other areas or jobs. In practice such transactions are uncommon, so land (and indeed labor) markets remain thin and only exist marginally around major cities.

Agricultural price policies have also had a substantial impact on agricultural production. In 1953 a system of production controls was introduced along with a series of demand management measures. These included a system of rationing and administered pricing coupled with a compulsory grain procurement program. In 1960 the procurement program was divided into a "basic-quota" and an "above-

[5] Lin (1988) gives an analysis of the economies of communal production systems as practiced throughout China at this time.

[6] Official recognition of the household responsibility system, in the form it now takes, was not actually forthcoming until late 1981.

quota" component whereby farm units made obligatory grain deliveries under both categories but a price premium was paid for above-quota grain. The amount of basic-quota purchase has remained essentially fixed since 1953, so most of the increase in procured grain has been in the above-quota category. On the heals of a bumper crop in 1984, this procurement system was briefly changed from a mandatory to a voluntary contract system at the beginning of 1985, whereby procurement quantities were determined by mutual agreements between individual farmers and the government. Given a variety of management problems as well as difficulties concerning the enforcement of contracts, the government switched to a negotiated (but in practice, mandatory) system by the end of 1985. Nevertheless, the proportion of output marketed outside this quota system appears to have increased for most commodities. And an increasing proportion of agricultural production is being sold at market rather than at managed prices. In 1986, an estimated 44% of all the farm produce sold in China was sold at market prices, compared with only 18% in 1984 (Sicular 1988).

Food-ration prices paid by consumers[7] increased only fourfold over the four decades since 1950, compared with an increase of nearly eight and one-half in food procurement prices paid to farmers (*China's Statistical Yearbook* 1991). Procurement prices increased in a stepwise fashion with substantive price jumps occuring in 1953, 1961, 1966, 1979, and 1985 and then annually from 1986 to 1989, after which they declined slightly. While higher procurement prices have played an important role in stimulating agricultural production and increasing farm incomes over the past several decades, the treasury costs of such a system have become substantial. Through this scheme, government subsidizes the consumption of agricultural commodities (a) by paying the difference between official procurement prices and official urban, retail (or ration) prices and (b) by subsidizing the importation, marketing, and processing of agricultural commodities. By 1987, the latest year for which relevant data are available, total price subsidies going to grain, cotton, oilseed, and meat products amounted to 9.7% of total government expenditures. The bill for these commodity subsidies alone was 1.2-fold higher than the total government expenditures on agriculture.[8]

Notwithstanding the increased role of the market in both production and postproduction agriculture, the sector continues to be influenced by a host of direct and indirect policy interventions. In addition to the administered pricing, rationing, and controlled distribution mechanisms that still apply to many agricultural inputs and outputs, there are a number of other measures — such as disaster relief payments, interest subsidies, and expenditures on infrastructure developments — that result in policy-induced transfers to and from producers and consumers alike. Producer subsidy equivalent (PSE) and consumer subsidy equivalent (CSE) measures are attempts to get summary indications of the overall level of support to the producers or consumers of a given commodity. They can be viewed as the payment to producers that would be required to compensate them for the loss of income resulting from the removal of a given policy measure, or the payment to consumers that would be required to compensate them for their change in expenditure if a policy measure were removed. Positive PSEs or CSEs indicate that the incomes of producers are higher and the expenditures by consumers are lower than they would have been in the absence of these policies. Recent

[7] Rationed goods include grains, edible oils, pork, and sugar.

[8] The reported government expenditures on agriculture for 1987 were 19.6 billion yuan (*China's Statistical Yearbook* 1991) and included agricultural production subsidies (separate from the consumer price subsidies discussed here, which are charged against the Ministry of Commerce budget); support for research, extension, and service agencies such as seed multiplication and veterinary stations; plus investments in agricultural infrastructure like irrigation, transport, and communications facilities.

estimates of these two measures for Chinese agricultural industries resulted in a pattern of negative PSEs and positive CSEs across a fairly broad set of agricultural commodities (Gunasekera et al. 1991). According to these estimates, producers of livestock products, rice, and sugar in particular were subject to significant levels of implicit taxation as a result of the government policies in place in 1986. While these measures are particularly sensitive to the reference border prices used to calculate them (and, relatedly, the exchange rates used to express these border prices in local currency units), they do suggest that on balance these government policies taxed producers and subsidized consumers, thereby transferring resources from producers and to consumers.

Developments within the farm input supply and output utilization and marketing sectors have complemented government efforts to reform production agriculture within China. As part of the overall industrialization strategy of the Great Leap Forward policies of 1958, the government fostered the development of rural industries throughout the countryside. In its early stages the program focussed on the simple processing of local produce and local repair and eventually manufacture of farm machinery, plus small-scale chemical fertilizer and cement plants. With fairly primitive technologies, these small-scale enterprises generally used locally available materials to satisfy the demand of nearby commune and brigade members. Developments along these lines slowed during the Cultural Revolution years but were revived as part of the economic reforms initiated in 1978. Since that time the growth in the rural nonfarm sector has been extremely rapid. Much of this growth has been in the privately or collectively operated enterprises, rather than the state-operated enterprises which tend to be concentrated in urban areas. As one indication of this growth, the share of nonfarm rural production in total rural (including agricultural) output increased from 31.4% in 1978 to 53.9% in 1990 (*China's Statistical Yearbook* 1991). Over the same period, the nonfarm sector increased its share of rural employment from less than 10% to 20.6%. Further growth in the nonfarm rural sector will continue to play a pivotal role in absorbing underemployed or surplus agricultural labor and thereby facilitate even further productivity growth in that sector.

1.3 Agricultural Production and Trade Developments

The value of aggregate agricultural output in China grew at a compound rate of 5% a year from 1965 to 1990 (table 5). Up until 1980 the annual rate was 4%. It then jumped to 8.1% for the years 1980 to 1985, but thereafter declined to (a still respectable) 4.7% per annum. While the agricultural boom of the early 1980s is largely ascribed to the market-oriented reforms within agriculture and the economy as a whole, An (1985) and Lardy (1985) singled out the increase in relative agricultural prices and the effective removal of quantity controls as being particularly important in this regard. They argued that both these measures had their principal effect by encouraging the greater use of yield-improving inputs. The fact that more recent rates of growth have returned to pre-1980 levels suggests that the growth-stimulating effects of this initial series of institutional reforms may well be largely exhausted.

Given the substantial regional differences in resource endowments noted earlier, it is not surprising that there were marked regional deviations from the pattern of growth at the national level. In three regions, the north, northeast, and southeast, agricultural output increased at a faster rate than the national average, while, somewhat unexpectedly, the central region (one of the major agricultural areas in China) and, perhaps not so surprisingly, the northwest and southwest regions (which account for the smallest share of agricultural output in the nation) had long-run rates of growth some 12% to 16% below the national average. Our attempt to account for these regional differences in output growth are reported in section 4.2.

Table 5: *Regional Agricultural Production Growth Indices, 1965 = 100*

Year	Region							National
	Northeast	North	Northwest	Central	Southeast	Southwest	South	
1965	100	100	100	100	100	100	100	100
1970	137	124	105	120	119	102	119	118
1975	192	174	139	155	152	120	132	153
1976	171	163	130	146	154	114	144	147
1977	173	162	123	146	145	123	155	148
1978	198	175	130	149	162	136	165	160
1979	190	190	131	173	191	149	158	173
1980	210	208	136	164	191	166	162	180
1981	216	218	145	178	210	175	171	192
1982	226	239	160	200	237	195	196	213
1983	273	273	173	204	241	209	203	230
1984	294	309	193	227	278	230	219	257
1985	270	318	215	241	292	237	242	267
1986	294	315	222	250	307	247	254	276
1987	307	342	233	261	318	258	276	292
1988	327	356	254	260	330	266	289	304
1989	301	375	262	273	334	276	311	313
1990	374	398	296	287	345	291	333	337
Growth rate[a]	%	%	%	%	%	%	%	%
1965-80	5.1	5.1	2.1	3.4	4.4	3.6	3.3	4.0
1980-85	5.1	8.9	9.5	8.0	8.9	6.8	8.5	8.1
1985-90	6.7	4.6	6.6	3.6	3.4	4.1	6.5	4.7
1965-90	*5.4*	*5.7*	*4.4*	*4.3*	*5.1*	*4.4*	*4.9*	*5.0*

Source: *China's Statistical Yearbook* (various issues), *China's Agricultural Yearbook* (various issues), *National Income Statistics, 1949-1985* (1987).

Note: Agricultural production is taken to be the gross value of agricultural production (AGGPV) measured in constant 1980 local prices. Rural industry (i.e., nonfarm) output is excluded from the estimates reported here.

[a] Compound annual growth rates.

The evolving pattern of production at the commodity level is shown in table 6. China's grain production has grown on average by 3.2% per annum over the past 40 years—some 1.1% faster than the growth in population over the corresponding period. Cash crop production (including cotton, oil crops, and fruits) has achieved notable success, generally exceeding the increase in food grain production. Over the longer run, increased grain production has come about largely through intensifying farming practices, i.e., by increasing yields rather than through a sustained increase in area sown. In fact the national rate of increase in grain yields averaged slightly over 3% per annum over the 1949-90 period, with the 113.5 million hectares sown to grains in 1990 being only marginal higher than the 110 million hectares sown in 1949.[9] By contrast, the growth in cash

[9] These end points mask the fact that the area sown to grains was quite volatile over the intervening years. It

Table 6: *Production of Major Agricultural Commodities, 1950 to 1990*

	1950	1960	1970	1980	1985	1990	Annual growth rates 1950-1990
			(*million metric tonnes*)				%
Rice[a]	55.1	59.7	110.0	139.9	168.6	189.3	3.1
Wheat	14.5	22.2	29.2	55.2	85.8	98.2	4.9
Corn	16.9[f]	15.5[g]	33.0	62.6	63.8	96.8	4.5
All grains[b]	119.7	123.2	213.3	291.9	353.1	418.8	3.2
Roots & tubers[c]	15.5	20.3	26.7	28.7	26.0	27.4	1.4
Cotton	0.7	1.1	2.3	2.7	4.1	4.5	4.8
Oil crops[d]	3.0	1.9	3.8	7.7	15.8	16.1	4.3
Fruits[e]	1.3	4.0	3.7	6.8	11.6	18.7	6.9
Pork, beef & mutton	2.2[h]	-	6.0	12.1	17.6	25.1	6.3
Aquatic products	0.5[i]	2.3[j]	3.1	4.5	7.1	12.3	8.6

Source: *China's Statistical Yearbook* (1991).

[a] In Chinese statistics, grain production data are reported in paddy-rice terms. To convert these data to the more standard milled-rice equivalent would require multiplying by the milling rate conversion factor of 0.7.

[b] Includes soybeans and coarse grains such as millet and sorghum as well as other unspecified grains.

[c] Roots and tubers are reported in "grain-equivalent" terms where one unit of fresh roots and tubers equals 0.2 units of grain.

[d] Includes peanuts, rapeseed, sunflower seed, sesame seed, linseed, and other oil crops.

[e] Includes apples, citrus, pears, grapes, bananas and other fresh fruits.

[f] 1952 data. [g] 1961 data. [h] 1949 data. [i] 1949 data. [j] 1962 data.

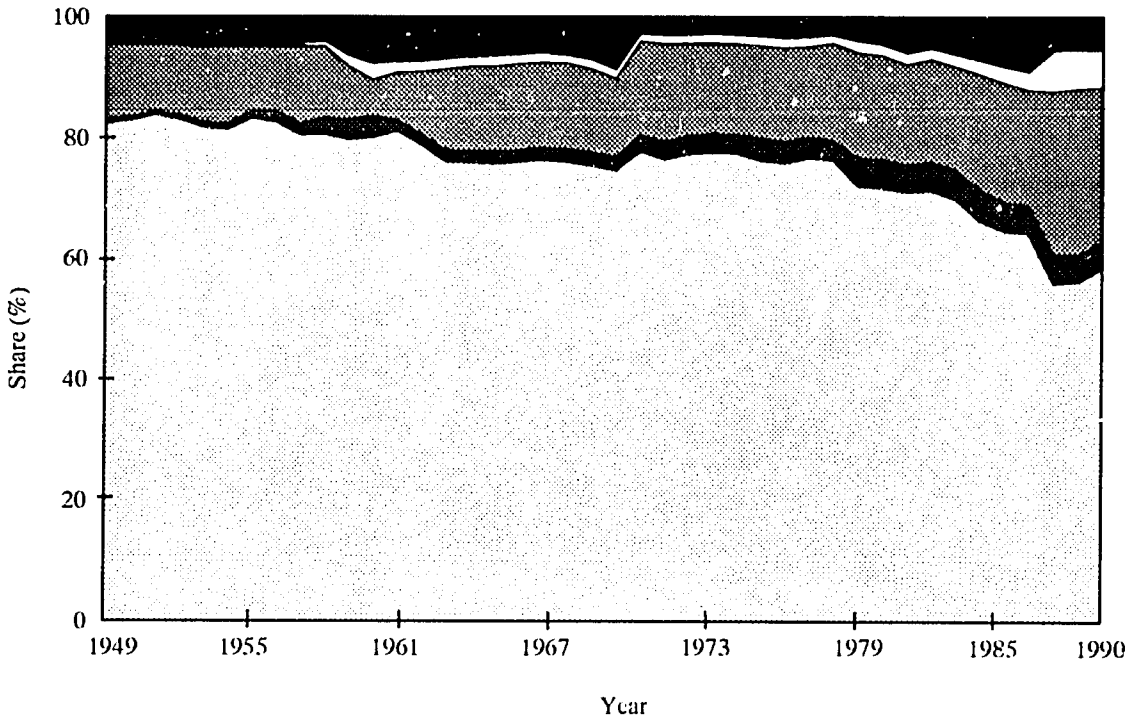
crops has resulted from both intensifying and extensifying farming practices, i.e., through the increase of both yields and sown area (up from 12.5 million hectares in 1954 to 21.4 million hectares in 1990, with much of this growth occurring in the past decade). The performance of the animal and fishery sectors has been even more impressive than that of the crop sector, achieving growth rates between 6% and 8% per annum from 1950 to 1990.

These cross-commodity differences in the rate of output growth gave rise to marked shifts in the structure of agricultural production and trade. Livestock products now account for more than 25% of the total value of agricultural output, more than double their share back in 1949 (figure 2). Forestry and fish products account for a smaller but similarly increasing share in the value of production. These changing patterns of production are no doubt a response to shifts of demand into income-elastic fruit and vegetable, livestock, and feed grain products that has followed from the rapid growth in per capita income over the past 25 years, as well as China's increased level of participation in international agricultural product markets.[10] This switch to higher-valued

increased markedly throughout the 1950s to peak at 136 million hectares in 1956. It declined to around 120 million hectares by the early 1960s where it remained more or less until 1978; thereafter, it declined fairly steadily over the ensuing decade, only to grow in the subsequent two years for which data are available (appendix 9).

[10] Given the widespread use of crop residues, industrial and, especially, household by-products, and wastes as well as green manures for livestock feed, it is difficult to get accurate measures of the trends in feed-grain consumption. Nevertheless, per capita grain consump-

Figure 2: *Composition of agricultural production 1949-1990*



Legend: crop; forestry; livestock; fisheries; other.

crops and livestock products is precisely what occurred in earlier decades elsewhere in East Asia as incomes grew (Anderson 1990).

As a corollary to the rapid rise in the manufacturing share of exports over the past several decades, the share of exports accounted for by agricultural, forestry, and fisheries products has declined markedly. They accounted for over one-half of the value of exports in the late 1960s but less than 20% by the late 1980s. Agriculture's share of the value of trade in agriculture, forestry, and fishery products declined from 99% in the early 1960s to about 70% in more recent years (table 7). In a normal production year China has maintained its status as a net exporter of fishery products and shifted from a net importer to a net exporter of agricultural products, while at the same time becoming a net importer of forestry products. Although over time the state increased procurement prices for major agricultural products, these prices were still low relative to nonagricultural prices. Furthermore, relative grain prices have been maintained at levels well below those received for cash crops. Given these widening disparities in grain versus cash crop prices, the total area planted to grain crops contracted by 1.15 million hectares in 1988 compared with the previous year, when the government relaxed its policies aimed at "stabilizing" the area farmers planted

tion has more than doubled since 1949, with most of this increase coming from the use of feed grains in livestock products. The main sources of feed, particularly for pigs and poultry, are grains (including potatoes), grain by-products, and, to a more limited extent, protein meals such as fish meal, meat and bone meal, cotton seed meal, oil seed meal, brewers' wastes, etc. (World Bank 1987 and 1991b).

Table 7: *Agricultural Trade, 1961 to 1989*

	Imports					Exports					Net Imports				
	1961-63	1969-71	1979-81	1986-88	1989	1961-63	1969-71	1979-81	1986-88	1989	1961-63	1969-71	1979-81	1986-88	1989
						(millions 1980 US dollars)									
Agriculture, fisheries, and forestry[a]	2,453	2,103	8,025	11,176	na	1,751	3,215	5,018	10,708	na	702	-1,113	3,007	467	na
Agriculture	2,352	1,859	6,837	7,755	11,594	1,667	2,841	4,116	9,281	10,645	685	-982	2,721	-1,526	949
Forestry	99	219	1,177	3,352	4,185	82	31	542	678	757	167	-99	720	2,675	3,427
Fisheries[b]	na	na	12	68	na	na	na	360	749	na	na	na	-347	-681	na
Livestock[c]	137	96	422	1,287	1,576	223	517	857	1,557	1,627	-87	-421	-394	-269	-51
Cereals[d]	1,413	869	3,027	2,249	3,944	329	483	407	735	717	1,084	385	2,869	1,514	3,227
Wheat	1,142	743	2,155	1,566	2,879	27	1	1	2	2	1,115	742	2,392	1,562	2,878
Rice	31	2	37	72	319	294	475	385	219	117	-263	-473	-331	-147	203
						(percentage of world total)									
	%	%	%	%	%	%	%	%	%	%					
Agriculture, fisheries, and forestry	1.74	1.25	2.74	2.77	na	1.35	2.10	1.78	2.91	na					
Agriculture	2.05	1.44	3.03	2.66	3.36	1.58	2.40	1.90	3.51	3.39					
Forestry	0.45	0.69	2.24	4.10	3.96	0.42	1.12	1.07	0.90	0.76					
Fisheries	na	na	0.08	0.22	na	na	na	2.43	2.61	na					
Livestock	0.61	0.37	1.03	2.15	2.14	1.06	2.08	1.98	2.81	2.37					
Cereals	7.51	4.48	7.81	6.85	8.95	1.91	2.79	1.09	2.46	1.78					
Wheat	11.02	8.19	12.63	9.71	13.56	0.29	0.01	0.01	0.01	0.01					
Rice	1.12	0.07	1.00	1.81	5.75	11.08	17.01	8.12	6.02	2.27					

Source: All data from FAO AGROSTAT (1991), except fishery data which was taken from *China's Statistical Yearbook* (1990) and *FAO Yearbook, Fishery Statistics* (various issues).

Note: Preconverted data reported in current US dollars. Deflated to 1980 base using World Bank's agricultural GDP deflator. The index for the 1960-87 period was taken directly from the diskette version of the *World Tables* (1989-90). The 1988 and 1989 figures were forecast using a logarithmic regression over 14 years (1974-87) wherein the IMF GNP deflator and a time trend were used as independent variables.

Table 7: *Agricultural Trade, 1961 to 1989 (Contd.)*

[a] Derived by summing the individual agricultural, forestry, and fishery components of this table. For the 1961-63 and 1969-71 periods, the fishery data used in forming this aggregate unavoidably includes Taiwan, which amounted to $2.2m of imports and $1.7m of exports in 1961-63 and $24.6m of imports and $56.9m of exports in 1969-71. See note b for additional details.

[b] Fishery data for 1980-88 was taken directly from *China's Trade Materials* (1989). The FAO fisheries series (a total of seven fishery commodity groups) was used to derive backcasted fishery estimates. The FAO data for the pre-1971 years include Taiwan and are therefore inconsistent with the more recently available data and have not been reported here.

[c] Livestock data reported here are the sum of meat (fresh, dried, meal, and prepared), animal fats, butter, cheese, lard, milk, wool (greased and degreased), and live animals traded (cattle, pigs, and sheep and goats).

[d] Includes wheat, rice, barley, maize, rye, oats, millet, and sorghum. In this instance roots and tubers are excluded, although they are traditionally included in Chinese grain statistics.

to specific grain crops.[11] This was approximately equivalent to a loss of 4.3 million tons of grain and accounted for 79% of the total decrease in the national grain output in that year. Compounding the decline in hectarage was a marginal decline in the yields for major grain crops (appendix 8) due to natural calamities such as a serious spring freeze in the Huang-Huai, Jiang-Huai regions and Sichuan Province, summer drought throughout much of the country, and unusually high temperatures in the Yantze and Huaihe valleys. Agricultural output, and in particular rice production, declined to the point that China switched from a net (and in fact major) exporter to a net importer of agricultural products (especially rice) in the following year. Wheat continues to dominate the country's food import bill, accounting for 70% of all grain imports and nearly a quarter of all agricultural imports.

1.4 Agricultural Productivity Patterns and Input Use

In thinking about the factors that influence observed patterns of change in production and productivity, Alston and Pardey (1991) found it useful to characterize economizing responses according to their length of run such that

a. short-run choices are made concerning total input use and input combinations for a given technology (i.e., factor use decisions);
b. intermediate-run choices are made concerning the choice of technology from the existing set of technologies (i.e., adoption decisions);
c. longer-run choices are made concerning investments in R&D and new technologies (i.e., research decisions).

[11] This course of events caused the government to reinstate its oversight and "guidance" with regard to the area planted to grain crops after 1988.

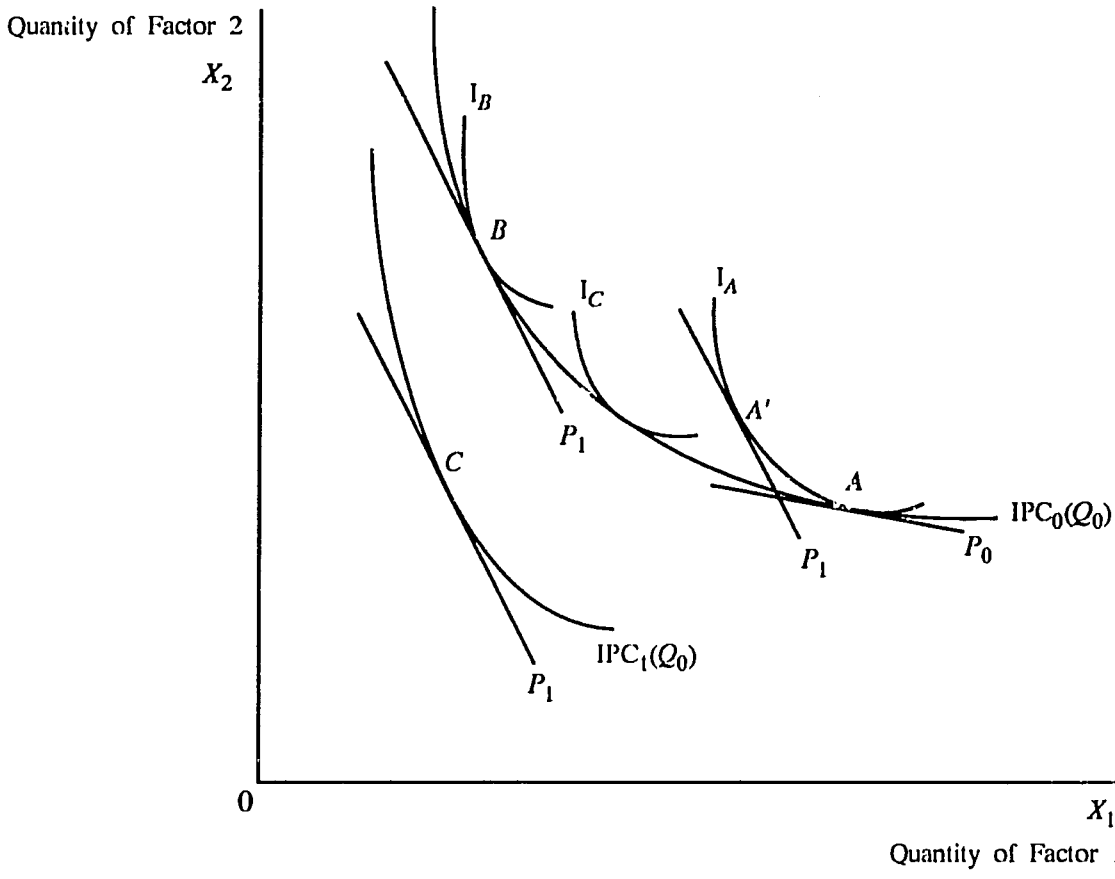
These ideas are represented schematically in figure 3.[12] In this diagram, initially output is at Q_0 and all of the curves are isoquants for this quantity. The isoquants labeled I_A, I_B, and I_C refer to different technology choices from the available set defined by the innovation possibilities curve IPC_0, which could be used to produce Q_0.[13] Suppose equilibrium is established at point A. With relative prices indicating relative factor endowments, changes over time in relative factor scarcities will lead to short-run responses concerning technology use that result in a movement around I_A from A to A'. Intermediate-run responses (holding output constant) entail search and screening activities by farmers that lead to the adoption of different technologies and a move to point B.

In the longer run these demand-side influences concerning technology use are complemented by supply-oriented decisions about R&D investments. The technological innovations that may follow will in turn shift the innovation possibilities curve from IPC_0 to IPC_1 and induce subsequent decisions on technology use that invoke a move to a new equilibrium point C.

[12] This diagram (and the ideas underlying it) relates closely to those of Hayami and Ruttan (1971, 1985) and Thirtle and Ruttan (1987). The isoquant here represented as an "innovation possibilities curve" using Thirtle and Ruttan's terminology (which they attribute to Ahmad 1966) corresponds to Hayami and Ruttan's "meta-production function."

[13] Ahmad (1966, p.347) defined the innovation possibilities curve as the "envelope of all the alternative isoquants (representing a given output on various production functions) which the businessman expects to develop with the use of the available amount of innovating skill and time (assumed constant throughout this analysis)." This definition leaves vague the distinction between available technology (held constant along the *IPC*) and new technology (different between *IPC*s). The distinction in figure 3 is between technology that is available without additional R&D (along the *IPC*) and technology that requires additional R&D investment (among *IPC*s), with each *IPC* corresponding to a different R&D budget.

Figure 3: *Induced changes in technology*



Source: Alston and Pardey (1991).

There are a number of reasons this factor-scarcity view of technical change may not correspond closely with observed behavior. In market economies, distortions in factor as well as product markets can result in a pattern of relative factor prices that in the short, intermediate, and (in some instances) even longer run bear little resemblance to underlying factor endowments (de Janvry and Deither 1985; Alston and Pardey 1991). While centrally planned economies commonly operate with distorted relative prices, it is also the case that factor markets are often missing or incomplete in such economies.

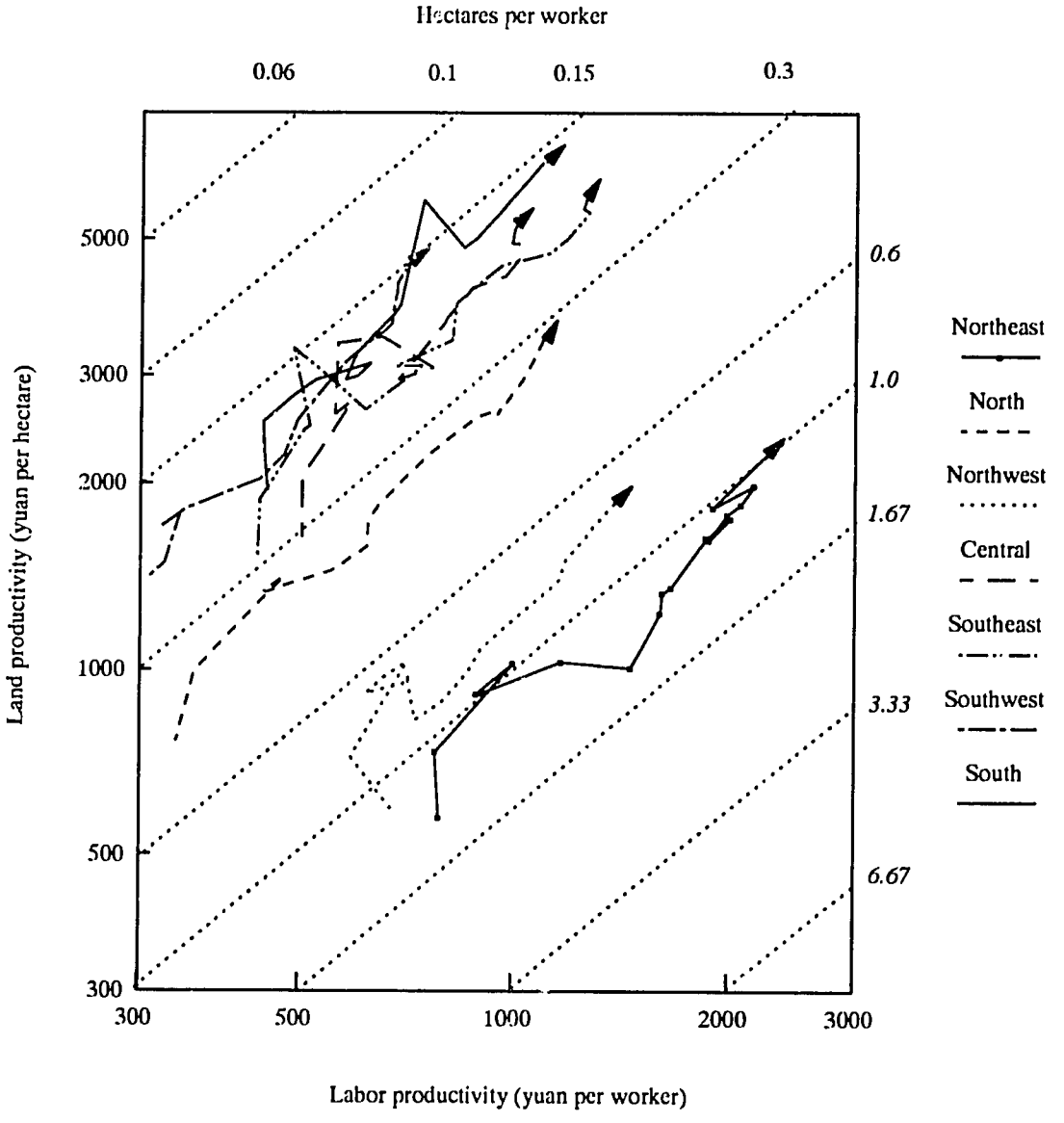
In China, as we noted earlier, land markets are still rudimentary, while labor and capital markets remain quite distorted in spite of the institutional reforms that have taken place over more recent years. Notwithstanding these market imperfections, recent empirical work by Lin (1991c), using provincial-level data, and by Fan and Ruttan (1992), using aggregate national data, suggests that the contemporary pattern of Chinese agricultural development is broadly consistent with the factor-scarcity version of the induced-innovation model. In this case, central planning appears to substitute, albeit imperfectly, for missing or imperfect factor markets in ways that preserve the factor-saving bias of technology innovation and choice that would be expected of a market economy with similar resource endowments.

Regional patterns of land and labor productivity are presented diagrammatically in figure 4 and in tabular form in appendices 1 and 2. The land variable is the total hectares of land in agriculture as measured by area sown to crops plus the sown-area equivalent of grass-

lands. The labor variable is a person-year-equivalent measure of the workers engaged in agricultural production, while the agricultural output estimate explicitly excludes off-farm value-added in agriculture in order to more closely match the coverage of the input variables. The dark arrows indicate the path of these two productivity measures, and the diagonals indicate constant factor ratios. A productivity path that crosses such a diagonal from right to left indicates a decrease in the number of hectares per worker. The longer a productivity path, the greater the percentage change in productivity.

China's measured level of labor productivity in agriculture is low compared with that of

Figure 4: *Regional land and labor productivity, 1965-1990*



Source: Appendices 1 and 2.

many other developing or (former) socialist countries (Wong and Ruttan 1988), a situation that is consistent with the country's exceptionally low land-to-labor ratio.[14] However, from 1965 to 1990 the growth rate of China's labor productivity was rather high despite a tendency for land area per unit of labor to decrease (appendices 1 and 2). The growth rate was 3.7% per year from 1965 to 1990—2.7% prior to the reforms that began to have an impact in 1979, 7.7% from 1980 to 1985, declining to 3.3% per year from 1985 to 1990. For the country as a whole, the rate of growth in land productivity averaged about 5.4% per annum from 1965 to 1990—4.4% prior to 1980, 8.5% from 1980 to 1985, and 5.3% over the following five years. It is noteworthy that land productivity grew more rapidly than labor productivity, indicating a general tendency to adopt land-saving and labor-using technologies throughout the country.

On closer inspection, however, there are considerable differences across regions, both in the levels of these partial productivity measures and their paths over time. The highest measured output per hectare occurs in the south and southeast, and the lowest in the northeast and northwest. Output per worker is highest in the northeast and lowest in the central region. There has been a persistent and reasonably strong positive correspondence between rates of increase in land and labor productivity. Over the longer run both productivity measures grew most rapidly in the north and southeast and most slowly in the southwest and northwest. In more recent years it is the south and northwest regions that have shown the largest land and labor productivity gains, while the central and southwest regions experienced the smallest gains in both productivity measures.

Using similarly regionalized productivity data for US agriculture, Craig and Pardey (1990) showed that over the 1949-85 period, spatial variation in the average productivity of labor narrowed more rapidly than that of land, even after differences in the mix (or quality) of land and labor across states had been accounted for. Since land is completely immobile across states and is not nearly as mobile intersectorally as labor, it is not surprising that land productivity still remains variable even within one country. On the other hand, because regional labor markets are increasingly integrated within the US, it is to be expected that, over time, significant differences in the marginal product of labor will be eroded. In such economies, with well-functioning factor markets, workers in all regions will leave agriculture largely in response to opportunities outside the sector (Kislev and Peterson 1982), thereby enabling interregional differences in returns to agricultural workers to be eliminated.

At least at the level of spatial aggregation used for this study, there is no clear evidence that regional differences in either land or labor productivity within China have converged over time. In most cases, those regions with relatively low land productivity in the mid-1960s showed no propensity to catch up with the more productive regions over the ensuing two and one-half decades. Nor was there a systematic tendency to close the gap with regard to regional labor productivity differentials. While two of the regions did manage to do so, two more maintained their labor productivity differential with respect to the northeast — the region that had consistently outperformed all other regions in this regard since 1965 — while the remaining two actually lost ground. Given the essentially regional rather than national character of labor markets in China and the continuing (although increasingly muted) intersectoral rigidities in the nation's labor markets, this lack of convergence in regional labor productivities is not so surprising.

Careful interpretation of these partial productivity measures requires some recognition

[14] This follows because a labor-productivity ratio (Q/L) can be partitioned into two components, a land-to-labor ratio (A/L) and a land-productivity ratio (Q/A) so that $Q/L = (A/L)(Q/A)$.

of problems with mismeasured and omitted variables, as well as limitations of the measures themselves. Clearly land and labor endowments cannot tell the whole story when there is the possibility of substituting other inputs for these primary factors of production. While it is difficult to imagine a perfect substitute for land, there are many ways to alter the productivity of any given unit of land through complementary inputs such as fertilizers, modern seeds, pesticides, irrigation, and both physical and human capital. The same purchased inputs can also augment the productivity of labor.

In order to gain richer insights into the sources of economic growth, "total" rather than partial productivity indices are often constructed, since they allow one to account for the role played by all measurable inputs. However, regardless of the input coverage of productivity indices — be it a single input as in the case of the partial productivity measures reported here or a more comprehensive set of inputs as with a total factor measure — describing and comparing the evolution of productivity over time or across regions poses the same methodological problems. Of particular importance is the need to disaggregate inputs in order to account for quality differences, as occurs across different types of agricultural land (e.g., arid pastureland versus irrigated cropland) or classes of agricultural labor (e.g., well-educated farmers versus unskilled hired labor). Star (1974) showed that if heterogeneous inputs are disaggregated, the unexplained growth in output will be reduced if higher-priced inputs are increasing faster. One is safe in using aggregated inputs only if all inputs are growing at the same rate or are perfect substitutes for one another. Under the behavioral assumption that inputs are paid in proportion to their marginal products, Star's results imply that growth rates of either partial or total factor productivity will be reduced if the faster-growing inputs are higher-quality inputs. These analytical results have a direct bearing on the partial productivity measures reported here. Data limitations meant we had no option but to use preaggregated land and labor measures, thereby giving rise to partial productivity measures that subsume the impact of land and labor quality differentials.

Over the past 25 years the number of workers in Chinese agriculture has increased across all regions and averaged 1.2% per annum nationally (table 8). At the same time, the total area under agriculture rose at an annual rate of 0.4% per annum, although it contracted in the north and northwest, the former region having experienced the most rapid increase in land and labor productivity growth of any part of the country. Consistent with the land rather than the labor productivity bias of Chinese agricultural development, land-to-labor ratios declined for all regions, especially the northwest where 1965 land-to-labor ratios of 1.32 hectares per worker were over twice the national average.

There has been a concomitant and especially rapid increase in the use of modern inputs by Chinese agriculture since 1965 (table 9). With application rates of 180 kilograms per hectare, Chinese farmers still rely heavily on manurial fertilizers. This level of use represents a 30% increase over the rates that prevailed 25 years earlier, compared with a 12-fold increase in the rate of chemical fertilizer applications.[15] The marginal gains from additional manurial fertilizer use appear to be diminishing (Fan 1991) but still worthwhile from a farmer's perspective. Nevertheless, continuing development of the nonfarm (input-supply) sector as witnessed over the past decade, coupled with an increase in the opportunity cost of farm labor, are likely to result in further but moderating substitution of

[15] By comparison, fertilizer use increased, on average, by ninefold in the less-developed countries and only twofold in the more-developed countries. China's 1981-85 average application rate was 167 kg per hectare, compared with corresponding less- and more-developed country averages of 54 and 119 kgs per hectare respectively (Craig, Pardey and Roseboom 1991).

Table 8: *Land and Labor Use in Agriculture, 1965 to 1990*

	Year	Region							National
		Northeast	North	Northwest	Central	Southeast	Southwest	South	
Land [a]	1965	16.08	43.01	16.45	20.43	20.84	17.16	12.90	146.87
(million hectares)	1970	16.08	43.05	16.61	20.43	20.84	17.16	12.90	147.08
	1980	16.96	41.04	16.12	20.94	21.88	18.98	14.06	149.98
	1990	16.22	41.50	13.00	21.07	21.59	20.55	14.38	148.41
Labor [b]	1965	12.52	72.91	12.42	34.47	42.20	43.19	30.12	247.83
(million workers)	1970	17.40	85.53	14.87	41.48	49.81	52.92	36.33	298.34
	1980	12.88	82.22	14.95	41.67	51.77	56.58	38.01	298.08
	1990	16.17	89.06	17.60	48.64	50.49	70.23	41.24	333.36
Land/Labor	1965	1.28	0.59	1.32	0.59	0.49	0.40	0.43	0.59
(hectares per worker)	1970	0.92	0.50	1.12	0.49	0.42	0.32	0.36	0.49
	1980	1.32	0.50	1.08	0.50	0.42	0.33	0.37	0.50
	1990	1.01	0.47	0.74	0.43	0.43	0.29	0.35	0.45

Source: *China's Statistical Yearbook* (various issues), *National Agricultural Statistics for 30 Years, 1949-1979* (1979).

[a] Area sown to crops plus the sown-area equivalent of grasslands.
[b] Workers engaged in agricultural production.

chemical fertilizers for (labor-intensive) manurial fertilizers.

There are marked regional disparities in the rates of application of both chemical and manurial fertilizer. Chemical fertilizer distribution has long been used by government as an instrument of state policy with respect to crop production. The goal had been to maximize national benefits of fertilizer application by favoring certain areas, generally those with a high (natural) yield potential in priority crops and those with better irrigation facilities.

With just under half its arable land irrigated, China is second only to Japan in this regard. And the 58% increase in irrigated area over the past 25 years is only part of the story. An even more dramatic threefold increase in power-irrigated area — which translates to an eightfold increase in the horsepower used for irrigation per worker in agriculture — indicates that the quality of irrigation systems has improved significantly.[16] As a consequence, the increased proportion of arable land under irrigation will be an understated measure of the increased use of irrigation services to the extent that it omits these substantive quality improvements.

But even these shifts in factor proportions are eclipsed by the ratios of nonirrigation horsepower per worker, which has increased by a factor of 34-fold since 1965. Much of this machinery has been used for plowing, harvesting, threshing, and transportation operations, with repair service facilities and, in the case of smaller machinery, production facilities being provided by local rural industries. In part this increased use of mechanized inputs reflects the government's well-known ideological or policy bias toward a capital-intensive development strategy (Fan and Ruttan 1992).

To sum up, the evolving patterns of land and labor productivity in Chinese agriculture have been influenced by shifts in the intensity of use and quality of the land and labor inputs themselves, as well as a marked increase in the level and intensity of the use of other inputs. Our attempts to distinguish the separate influences of each of these inputs on the growth of agricultural output in China since 1965 are reported in section 4.2.

[16] Converting from gravity-fed, windmill, or manual irrigation systems to mechanized irrigation systems can increase yields by increasing the reliability and timely delivery of irrigation water.

Table 9: *Secondary Input Use, 1965 to 1990*

	Year	Region							National
		Northeast	North	Northwest	Central	Southeast	Southwest	South	
Chemical Fertilizer[a]	1965	6.5	9.4	3.6	15.8	21.0	11.5	44.1	14.3
(kg per hectare)	1980	74.7	87.4	23.9	82.4	116.8	83.0	113.4	84.6
	1990	149.6	180.2	100.0	170.0	225.0	139.5	234.5	174.5
Manurial Fertilizer[a]	1965	88.4	92.7	218.3	112.4	109.7	210.2	157.5	130.9
(kg per hectare)	1980	96.5	113.9	252.7	121.8	107.0	243.3	162.1	147.9
	1990	103.3	140.8	320.8	160.0	128.1	288.1	214.8	180.4
Total Irrigated Area[b]	1965	5.1	20.9	33.7	65.8	49.6	29.4	58.4	31.3
(% arable land)	1980	12.9	49.2	37.1	66.8	68.3	38.7	58.6	44.8
	1990	18.5	52.3	42.1	74.8	76.0	40.1	64.2	49.5
Power Irrigated Area	1965	-	-	-	-	-	-	-	7.7
(% arable land)	1980	8.8	39.9	6.9	29.8	55.9	6.9	13.8	25.3
	1990	13.0	43.5	11.9	30.3	60.2	8.0	12.5	28.4
Nonirrigation Power[c]	1965	0.22	0.03	0.13	0.02	0.02	0.006	0.02	0.025
(hp per ag worker)	1980	1.40	0.44	0.82	0.35	0.41	0.17	0.36	0.42
	1990	1.99	1.08	1.47	0.60	1.03	0.35	0.81	0.88
Irrigation power	1965	0.03	0.03	0.02	0.05	0.05	0.01	0.03	0.03
(hp per ag worker)	1980	0.34	0.43	0.28	0.20	0.25	0.10	0.10	0.25
	1990	0.38	0.59	0.24	0.23	0.26	0.07	0.11	0.29

Table 9: *Secondary Input Use, 1965 to 1990 (Contd.)*

	Region							
	Northeast	North	Northwest	Central	Southeast	Southwest	South	National
	(compound annual growth, 1965-1990)							
	%	%	%	%	%	%	%	%
Chemical Fertilizer	13.4	12.5	14.2	10.0	10.0	10.5	6.9	11.1
Manurial Fertilizer	0.7	1.8	1.6	1.5	0.6	0.3	1.3	1.3
Total Irrigated Area	5.3	3.7	0.9	0.5	1.7	1.2	0.4	1.9
Power Irrigated Area	-	-	-	-	-	-	-	5.4
Nonirrigation Power[d]	9.3	15.9	10.1	14.5	17.9	17.5	16.0	16.3
Irrigation Power	10.7	12.7	10.5	6.3	6.8	8.1	5.3	9.5

Source: *China's Statistical Yearbook* (various issues), *China's Agricultural Yearbook* (various issues), *China's Rural Statistical Yearbook* (various issues), *National Agricultural Statistics for 30 Years, 1949-1979* (1979).

[a] Fertilizer is measured in pure nutrient terms while land area represents arable land. Data on chemical fertilizer use was compiled in standard gross weight units then converted to its elemental nutrient equivalent using the following percentages: 20% for ammonium sulphate, 18.7% for super phosphate, and 40% for potassium sulphate. Manurial fertilizer includes animal, human, and crop wastes, green manures, and water plants. These data were derived using the procedures detailed in Fan (1990).

[b] Irrigated areas include level land with a water source and a complete set of irrigation facilities to lift and move water adequate for irrigation purposes in a normal year.

[c] Nonirrigation power includes power used for agricultural practices such as cultivating, spraying, harvesting, drafting, and animal husbandry, as well as the power used by forestry and fishery machinery. These data exclude a draft-animal component.

[d] We regressed nonirrigation horsepower at the national level against corresponding tractor numbers and a time trend for the 1962-80 period. Given the strong correspondence between tractor numbers and nonirrigation horsepower, we used this information to estimate the rate of growth in nonirrigation power. This growth rate was in turn used to calculate the nonirrigation horsepower estimate for 1965 given in the upper half of this table.

Chapter 2

INSTITUTIONAL EVOLUTION OF AGRICULTURAL RESEARCH

The organization and functioning of a national agricultural research system is best seen within the context of the broad social, economic, and political forces at work within a society. The theory of induced institutional change as described by Ruttan (1978) argues that such change is responsive not only to social and economic forces, but also to technical changes. Over the past 40 years, mainly in response to radical political upheavals, there have been substantial fluctuations in the organization of agricultural research in China, as well as the level of resources committed to it. This section outlines the historical evolution of the agricultural research system in China and shows how political factors helped shape and indeed continue to influence the organization and functioning of the system.

2.1 Pre-Revolution Period

Despite the country's long history of agriculture, it was the beginning of this century before China moved to develop specialized agricultural research institutes. The first agricultural experimental station was established in Baoding, Hebei Province, in 1902. The Ministry of Agriculture, Forestry and Commerce set up an agricultural experiment station as a central government agency in Beijing in 1906. The station supported a number of research activities in areas such as agriculture and forestry, sericulture, animals, plants, and livestock (CAAS 1987).

Beginning in 1928 the nationalist government established the central, northeast, north-China and southwest agricultural experiment stations, while some provinces under nationalist rule (notably Jiangsu, Zhejiang, and Sichuan) also established their own agricultural improvement research institutes (Lu 1985). For example, a sericulture station, a cotton seed station, the Bureau of Entomology, a rice and wheat station, a horticultural station, a livestock breeding station, and a tea production improvement station were established in Zhejiang province (ZAAS 1983). The National Experimental Institute for Agriculture was founded in 1931 by the central government.

Agricultural research within the universities dates back to 1914 when Jinling University (in Nanjing) began selecting improved wheat varieties. Dongnan University, Nantong University, and Guangdong University were also engaged in research on the control of cotton pests.

During these early stages, the organizational structure of the agricultural research system was similar to the national-prefectural agricultural research system of Japan (Hayami 1975). It was a decentralized, cooperative system composed of both national and local agencies. By 1949 there were a total of 1,600 research staff and workers in the country, which included 470 technical personnel. Nevertheless, the organization of agricultural research was still at a primitive stage, and there were few agricultural research institutions at the provincial level (Lu 1985).[1]

[1] For further details on the early history of the Chinese agricultural research system see Guo and Cao (1989).

Previous Page Blank

2.2 Early Post-Revolution Period (1949-1965)

Immediately following the formation of the People's Republic of China in 1949, the government gave more serious attention to the development of the nation's capacity to generate science and technology. The Chinese Academy of Sciences (CAS), which undertakes basic research across a wide range of sciences, including biology, zoology, and soil science, was established in 1949. In 1952 the old agricultural research institutions were reorganized into two professional research institutes (veterinary science and sericulture) and seven agricultural research institutes — one each in the north, northeast, east, central, south, southwest, and northwest of China —, corresponding to the seven administrative regions of China at the time. By 1952 the technical personnel numbered about 1,000 and some comprehensive agricultural experimental stations had been established in 18 provinces, municipalities, and autonomous regions (Lu 1985). In 1955, mid-way into the first Five-Year Plan (1953-1957), a coordinating committee for agricultural research was established. The committee's mandate was to examine programs on agricultural research, organize relevant technical personnel to cooperate in research, and appraise research achievements.

The Chinese Academy of Agricultural Sciences (CAAS), along with academies of agricultural sciences in each of the 29 provinces, municipalities, and autonomous regions were established in 1957. It was at that time that agricultural research in China could be said to take on the characteristics of a simple yet functioning system. CAAS was not only a national agricultural research institution operating across a range of disciplines, but it also served as an academic center for agricultural research in China. Agricultural research institutes in the seven regions were under the jurisdiction of CAAS. The administrative structure of the system was highly centralized and in essence was transplanted from the Soviet model of that period. The purported rationale of this centralization was to enable China to catch up with the more advanced countries in the fields of science and technology. But, in 1958, the system was decentralized and the administrative (and funding) functions of the seven regional agricultural research institutes were transferred to their respective provinces. The decentralization was motivated by a desire to promote stronger links between research and production.

The period during the Great Leap Forward (1958) and the Anti-Rightist Campaign (1959) was a particularly unsettling time within China. Many research activities were transferred to the rural areas. For example, two-thirds of CAAS personnel and one-third of the research institutes were moved to rural areas or disbanded. There was a tendency for cadres at various levels to strive for overambitious research objectives and to inject a degree of arbitrariness in the work schedules set for agricultural researchers (SSTC 1986). A three-year period of readjustment was initiated in 1961 and resulted in a more realistic and stable pattern of development in the national agricultural research system. Moreover, during 1962 many of the personnel and research institutes that had been relocated to rural areas were returned to the locations they held prior to the Great Leap Forward. The Science and Technology Bureau of the Ministry of Agriculture was set up in 1963 to foster the development of agricultural science and technology and to promote a recovery in agricultural production levels from the disaster of the previous three years. The bureau supported scientific research, extension and technical equipment divisions, as well as a general office. The mandate of the bureau included verifying and coordinating key plans of agricultural research and extension above the provincial level and coordinating agricultural research and extension in general, as well as research on agricultural science and technology policy. In the same year, the Ministry of Agriculture appointed 49 experts from various research insti-

Table 10: *Chronology of Major Institutional Changes within the Agricultural Research System since 1949*

Year	Major Events
1952	Establishment of Agricultural Research Institutes in seven regions, i.e., northeast, north, east, central, south, southwest, and northwest.
1955	Establishment of Coordinating Committee for Agricultural Research.
1957	Establishment of the Chinese Academy of Agricultural Sciences. Agricultural Research Institutes in seven regions placed under the jurisdiction of CAAS.
1958	Seven regional research institutes were handed over to the respective provinces where they were located.
1960-61	One-third of CAAS institutes were moved to rural areas or disbanded, and its total staffing level declined by 70%. It took until 1962 before CAAS began to recover from this situation.
1963	Establishment of the Science and Technology Bureau of the Ministry of Agriculture. The bureau suffered much damage during the Cultural Revolution and was renamed the Science and Technology Department in 1982.
1964	Establishment of the South China Academy of Tropical Crops.
1970-72	CAAS was disbanded and most institutes and staff were once again moved to rural areas.
1978	Reestablishment of CAAS and the Chinese Academy of Forestry. Establishment of the Chinese Academy of Fishery Sciences.
1983	Establishment of the Scientific and Technology Committee of the Ministry of Agriculture.
1985-	Reform of the scientific and technology system.

Source: Compiled by the authors from various Chinese documents.

tutes and universities to form the Science and Technology Committee (STCMA and STDMA 1989). The committee provided advisory services to the ministry regarding agricultural science and technology issues.

To facilitate communication between the research institutes and the farming community some agrotechnical extension stations were established in the early 1950s. By 1956, 16,466 stations had been established with 94,219 staff (STCMA and STDMA 1989). When communes were formed in 1957, the funding, management, and operation of these stations were transferred to them. But, after 1960, when serious crop failures deprived communes of financial capacity, the network dissolved. At the behest of the Ministry of Agriculture, the extension stations were reconstituted and consolidated in 1961-62.

2.3 Cultural Revolution Period (1966-1976)

Agricultural research during this period sought to pursue a practical problem-solving approach, and many resources and scientific personnel were once again relocated to rural areas. The system suffered much damage and the consequences of these actions continue to affect it even today. For example, the total staff at CAAS decreased from 7,500 to 620 in 1970 (STCMA and STDMA 1989). A so-called "open-door" research policy was put into effect at all administrative levels, including the institutes of the academies of agricultural sciences, along with thousands of field-testing groups in provinces, counties, communes, brigades, and agricultural production teams throughout the country. This policy required

that a major part of research be done in the field where the problems facing production agriculture were directly observable. It also required that peasants and farmers participate directly in the research work. This grassroots participation among scientists in the various research institutes, as well as university faculty and students, sought to mobilize the research system around the production problems at hand rather than reflect the position, academic training, or prestige of the researchers involved. But, as a consequence, many agricultural researchers to this day have little or no formal training in their disciplines. Some are high school graduates who developed their research skills on the job.

Little systematic, controlled, replicated experimentation was conducted at this time. The approach to research was to move to rural areas and learn from the peasants. Neither in the normal educational curriculum or the many informal training programs undertaken within the multilevel, research-extension network was there training in formal research methodology involving controls or the use of statistical testing procedures (Stavis 1978). A positive aspect of agricultural research during this period was that new technologies could, in principle if not in practice, be rapidly translated into "action programs". Since the research was primarily associated with problem solving, and generally implemented at the local level, a direct relationship between research and popular-participation programs was encouraged (IRRI 1978).

A four-level network of agricultural research agencies below the prefectural level was formed in the early 1970s to extend new techniques to the field. The network had corresponding agricultural research and extension organizations at each of the four levels, including an agricultural research institute, an extension station, a high-yield seed station, a plant protection station, and a soil and fertilizer station at the county level; an agricultural scientific station, and a livestock and animal station at the commune level; an agricultural scientific team at the brigade level; and a research group at the production team level.

Chapter 3

THE CONTEMPORARY AGRICULTURAL RESEARCH SYSTEM

A national agricultural research system in its broadest sense includes all those organizations and institutions in a country that carry out research in various fields of the agricultural sciences. Those institutions are often diverse and may be distributed among the various ministries of the government, parastatal bodies, faculties of agriculture and other science faculties in the universities, and in the private sector where there are close links with agribusiness. One of the distinguishing characteristics of the agricultural research system in China is that it is dominated by public research conducted mainly in national and provincial academies, prefectural institutes of agricultural sciences, and agricultural universities. Private agricultural research is minimal. Such a structure is consistent with the country's socialist nature.

National agricultural research systems are often classified according to their mode of organization and structure. In contrast with the integrated research, extension, and education model of the United States, the autonomous or semi-autonomous publicly or privately supported research model of Great Britain (Ruttan 1982), and the agricultural research council model that is typical of some Asian countries such as India, Pakistan, and Bangladesh (Jain 1989), China's agricultural research system is best classified as a multi-ministry model.

3.1 Organizational Structure

The Chinese agricultural research system presently consists of research institutes at three different levels of government, i.e., national, provincial and prefectural. Related county-level activities deal with technology-transfer issues, such as the demonstration trials, farmer education, and other extension-related work that is described briefly in sections 3.5 and 4.1.

Research at the National Level

We begin this section with a brief discussion of how general science and technology in China is organized and where the agricultural research system fits within the overall science and technology system.

At present, the State Science and Technology Commission (SSTC) is the most comprehensive organization devoted to the coordination and management of civilian science. Functionally, the commission is at the apex of the hierarchy of research institutes, although administratively it interfaces with them only indirectly via ministries (Tang, T. 1984).[1] The mandate of SSTC is to (a) implement the state's R&D policies, (b) create, implement, and supervise R&D plans (annual and long term), (c) coordinate activities of the agencies carrying out major R&D projects, (d) evaluate major R&D achievements, incentives, and creative innovations and promote their application, (e) educate, train, and manage personnel engaged in R&D, (f) allocate R&D budgets and provide R&D equipment, (g) draft and propose R&D-related legislation, regulations, and instruments to the national People's Con-

[1] For details of the relationship between commissions and ministries related to science and technology in China see appendix 7.

gress, and (h) organize scientific and technological exchanges with other countries (Maruyama 1990). Another important agency within the central government is the State Planning Commission. The commission is responsible for the allocation of central government funds, including science and technology funds.

Below the commissions are the ministries and special agencies. One such agency, CAS, is a national research complex engaged mainly in basic research, including biology, botany, genetics, physiology, entomology, virology, zoology, and soil science. There are also a series of research institutes or academies that are directly controlled by the respective ministries under the State Council. These institutes are mainly engaged in applied research and technology development. Agricultural research at the national level is conducted mainly within academies and institutes under the Ministry of Agriculture, complemented by the research efforts of the various institutes under the administrative control of other ministries (figure 5). CAAS is administered by the Ministry of Agriculture and is the principal national-level research agency within the Chinese agricultural research system. It operates over 30 national commodity, resource, and disciplinary research institutes located throughout the country. Its research program takes a leadership role on issues of national significance, such as the development of hybrid rice varieties within China. The main tasks of CAAS, as described by Lu (1985), its president at the time, are

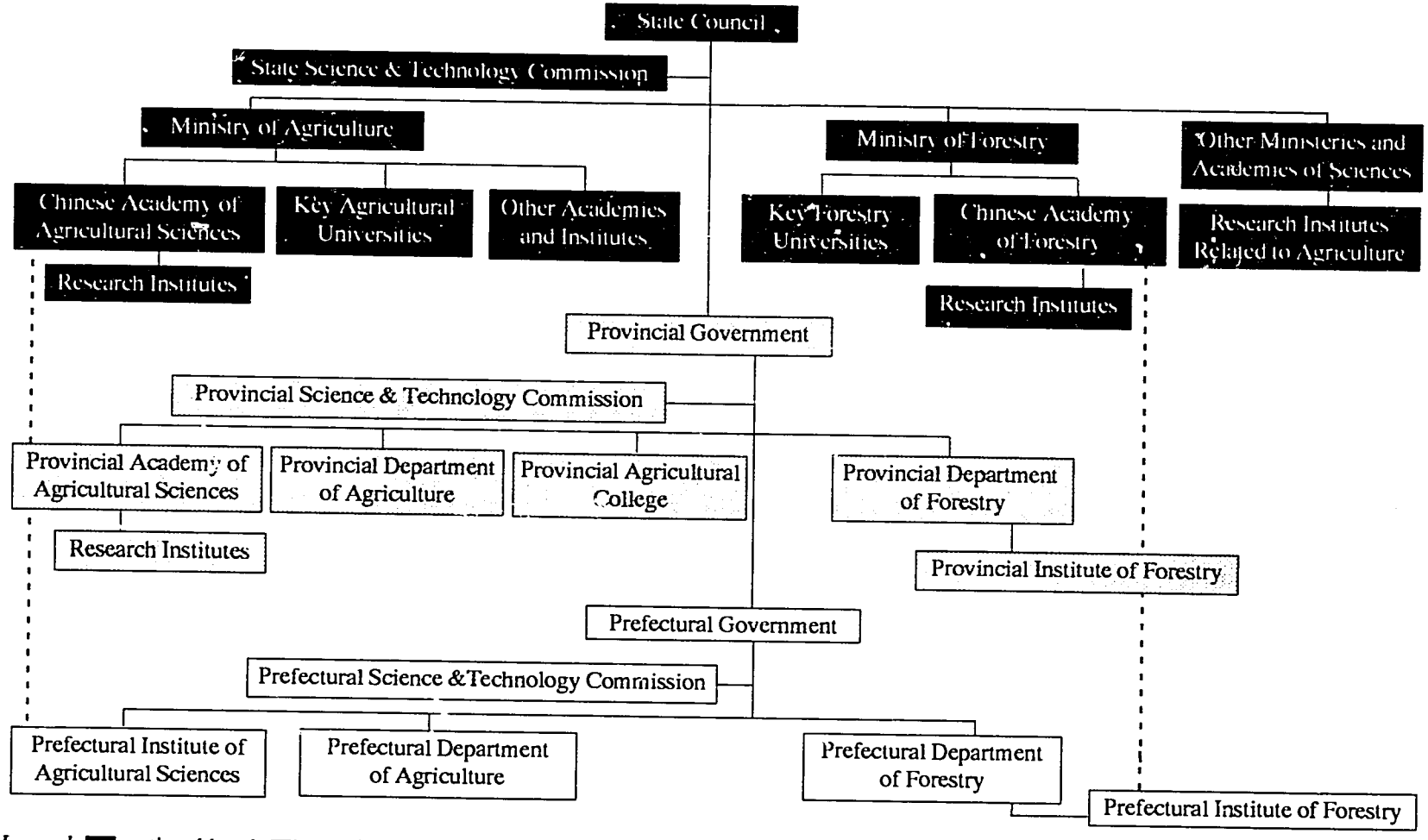
a. to undertake both basic and applied research in agriculture, primarily aimed at solving problems that have significant economic value in the nation's agricultural sector, and to provide scientific ways and technical means so as to continuously raise national agricultural production;
b. to strengthen fundamental research, to exploit new techniques and methods in various fields, and to train research personnel so as to constantly improve agricultural research work;
c. to coordinate the national research program;
d. to edit and publish agricultural periodicals and other works, organize academic activities, and carry out international exchanges and collaboration in order to keep abreast of developments in the agricultural sciences and technology at home and abroad.

As of 1991, CAAS operated 37 research institutes (or centers), a graduate school, and a publishing unit. There were over 10,500 staff members working for the academy, of whom around 5,000 were classified as technical personnel (20% of whom are senior scientists), 800 as administrators, and about 4,700 as support staff.

China has a separate ministry and academy for forestry. The Chinese Academy of Forestry (CAF) was established in 1958 and was integrated into CAAS in 1970. When the Ministry of Forestry was separated from the Ministry of Agriculture in 1978, CAF was reconstituted. The academy has eight research units, four of which are in Beijing and four located elsewhere in the country (CAF 1990). CAF supports 5,051 staff, of whom 1,230 are technical staff. Research undertaken by the academy covers all issues of basic and applied research and development related to forestry. Of the eight professional institutes under CAF (see appendix 4), four develop improved production technologies and forest management systems and two focus on post-harvest technologies related to the timber and chemical industries. There is also a socioeconomic institute as well as an information institute that acts as a clearing house for scientific information related to forestry research.

The Chinese Academy of Fishery Sciences (CAFS), founded in 1978, is administered by the General Bureau of Fishery Production of the Ministry of Agriculture. It currently supports 18 of its own research units and 3,400 staff (1,847 are technical staff) who are involved in both basic and applied research as well as fishery technology development. More

Figure 5: *Organizational structure of the agricultural research system*



Legend: ■ national level; □ provincial level; □ prefectural level; —— administrative linkage; ----- professional linkage.

Source: Compiled by the authors.

specifically, these institutes work in areas such as fish genetics and breeding, physiology, nutrition, and fish biology for both marine and freshwater environments. CAFS also does some limited research on fresh fish preservation and processing technologies and has several institutes that focus on fishing machinery and vessel design.

After the initiation of the "four modernization" policy[2] in the 1970s, the Chinese Academy of Sciences (CAS) established five agricultural research institutes. In contrast to the research institutes of CAAS and the provincial academies of agricultural sciences, both of which are organized on a commodity or disciplinary basis, the CAS agricultural research institutes take an integrated rural development approach. They select several counties as test sites and undertake research based on analyses of the natural resources, renewable energy, pollution abatement, mechanization, farming systems, and socioeconomic aspects of the region's agricultural sector.

Other agricultural research institutions at the national level include the South China Academy of Tropical Crops, the Agricultural Environment Protection Institute, and the Biogas Institute (under the Ministry of Agriculture) and the Institute of Water Construction (under the Ministry of Water Conservancy and Power [MOWCP]).[3] In addition, the Bureau of State Farms and Land Reclamation under the Ministry of Agriculture also has its own set of research institutes which focus on production problems arising in the large state farms located principally in the northeast, northwest, and south.

A high proportion of the agricultural research carried out by the Ministry of Agriculture agencies reviewed above is directed toward production agriculture. But, if China continues to develop as it has over the past decade, then the demand for agriculturally related technologies will increasingly move off-farm. Further increases in the use of off-farm inputs in agriculture, such as fertilizers, pesticides, and machinery, will stimulate increased demand for new technologies and know-how aimed at the input supply sector. Rising per capita incomes are resulting in a rapid increase in the demand for processed agricultural products that will in turn stimulate the demand for post-harvest technologies related to the storage, processing, packaging, and marketing of agricultural produce. At present China's research capacity in input supply and, particularly, post-harvest technology is embryonic. The limited research that is underway in the post-harvest area focuses largely on food-processing technologies and is under the jurisdiction of the Ministries of Light Industry and Commerce. There is an Institute of Agricultural Mechanization Sciences that is jointly under the Ministry of Machine Building (MOMB) and the Ministry of Agriculture that conducts research on agricultural mechanization issues[4] while the Ministry of Chemical Industry performs some limited research related to the fertilizer and pesticide industries.

Research at the Provincial and Prefectural Levels

Upon establishment around 1958, the provincial academies functioned as branches of CAAS. But since the Cultural Revolution, they have all been placed under the jurisdiction of their respective provincial governments. The provincial agricultural academies conduct research that is targeted more to their provincial circumstances. They are linked to the national institutes through a series of collaborative programs, with the leadership, in rice breeding for example, located at the national centers. Jiangsu Academy of Agricultural Sciences (JAAS) is in many respects a typical provincial

[2] Involving the modernization of agriculture, industry, national defence, and science ar. technology.

[3] For further details on the national level research institutes see appendix 4.

[4] In 1979 the Ministry of Agriculture established its own Institute of Agricultural Engineering and Design that carries out research on agricultural engineering and mechanization, some of which appears to overlap with the work of the MOMB.

academy. It currently has a staff of 1,256 at its headquarters, among whom there are 746 scientists and technicians (JAAS 1987). The major missions of JAAS are

a. to conduct research on scientific and technological problems vital to plant and animal production in Jiangsu province;
b. to manage and coordinate agricultural research activities throughout the province;
c. to conduct research on national priority programs and to act as the regional coordinator for cooperative research programs assigned or entrusted to the academy by national institutions.

Currently, JAAS headquarters has 14 research institutes, which include food crops, soil and fertilizer, plant protection, animal husbandry and veterinary science, feed and food, agrobiological genetics and physiology, agricultural modernization, application of atomic energy in agriculture, and information for agricultural science and technology. It is often the case that the provincial academies also conduct a certain amount of basic research in addition to applied research in agriculture.

At the prefectural level, the emphasis is more on applied and adaptive research and development. The principal research entity is the prefectural agricultural research institute, which is generally administrated by the prefectural government, although there are three provinces (namely, Jiangsu, Shanxi, and Heilongjiang) where prefectural institutes are under the provincial academies of agricultural sciences. Research at the prefectural level is important, given the relatively large size of a prefecture within China. The research performed at this level has been fruitful and has led to the release of many new varieties. Taihu Institute of Agricultural Science (in Jiangsu) is a representative example. Its prime missions involve breeding improved cultivars of japonica rice; developing new wheat and rape varieties that combine improved quality characteristics with enhanced yield potentials and pest and disease resistance; developing improved, cost-saving, crop production systems; analyzing the potential for commercializing the local agricultural sector with emphasis on the postproduction uses of agricultural production; and exploiting the distinctive features of traditional plant and animal products to meet the demands of liberalized domestic markets and export trade. The institute consists of seven research divisions, namely, crop breeding, crop cultivation, plant protection, soil and fertilizer floriculture, animal and poultry production, and agricultural development.

3.2 Funding Mechanisms

The State Planning Commission finalizes the annual budgets for all ministerial spending at the national level. It also authorizes the disbursement of central government funds to the various ministries as well as to the SSTC. The SSTC is in turn responsible for allocating the science and technology funds at its disposal to the various agricultural and nonagricultural ministries and national research agencies such as CAS and (to a limited extent) CAAS. At these upper levels of government, the allocation procedures are largely driven by precedent and political considerations. Within the respective ministries and agricultural research agencies (e.g., CAAS), there are presently no formally established or especially transparent mechanisms for setting research priorities and allocating funds accordingly. As a practical matter, a good portion of the financial resources are allocated in line with the number of research personnel, while in many cases project-based funds are allocated on the basis of informal, subjective criteria, with precedent and personal relations also playing a role.

Funding mechanisms at the provincial and prefectural levels parallel those at the national (or, in Chinese parlance, state) level. Some national funds flow down to local government agencies, in some instances from the national- to provincial-level institutes in support of collaborative research activities. But government financing within China is highly decentralized

so the funds available to provincial and prefectural planning commissions are principally generated through locally administered, public financing instruments (e.g., taxes on industry and commerce, as well as agricultural [land] taxes and resource extraction taxes).

Funding support for most research institutes consists of both core and project funds. Core funds are mainly used for salaries and are allocated to various organizations by central and local finance departments at the various levels of government, on the recommendations of their counterpart Science and Technology Commissions. Project funds are allocated in accordance with the research program specified in the five-year plan. Every year the state also allocates a certain share of project funds for new emerging issues. But these project funds are not disbursed automatically on the basis of any formula. When the preliminary planning document becomes available, different national and provincial institutes submit research proposals to the Science and Technology Commission and their counterpart agricultural department. Budgetary allocations are then made following a conference in which the budget, the quality of the proposals, and the capacity of the organization proposing the research are assessed (UNESCO 1985).

In addition, according to their production interests, agribusinesses will allocate monies in support of agricultural research. Research institutes also generate some funds by providing services to other units or by fulfilling research tasks entrusted to them. Part of these earnings may be retained for use as science and technology research funds by the research units that generate them (SSTC 1989). The source of funds and their relative importance in an institution's funding base varies depending on the particular institution and region involved. Guangdong Academy of Agricultural Sciences, for instance, receives 70% of its funding from its provincial government, 17% from national, provincial, and lower-level ministries and S&T bodies, and 13% from sales of products (Ruttan 1985).

In recent years, governments at various levels have reduced the amount of core funds made available to the research institutes. They have encouraged the institutes to apply for funds from various domestic and international donor agencies and foundations and to undertake joint research projects with international research centers and foreign countries (SSTC 1989). One of these domestic funding agencies is the National Natural Science Foundation. It was established in 1986 and provides funds for basic research, including the agricultural sciences.[5]

3.3 Coordination

Much of the agricultural research designed for generating new technologies to increase agricultural production calls for a multidisciplinary approach. This is particularly true of commodity research programs where plant breeders, agronomists, pathologists, entomologists, and others must often be brought together in a highly complementary relationship. Countries that are characterized by a great deal of agroecological diversity may find it cost-effective to mobilize their limited scientific and other resources by establishing a small number of national stations to do the more advanced technology-generating research and a chain of regional stations located in different parts of the country that are involved mainly in adaptive research working in close collaboration with the extension service. An important function of the national research system is to coordinate the work of those two types of stations and to forge interinstitutional links (Jain 1989).

The SSTC has a primary role in coordinating civilian research and development activities across the science and technology units operating throughout all government agencies. Given this broad mandate, its impact on agricultural research per se is relatively indirect, with its influence felt primarily through the

[5] For more details concerning the National Natural Science Foundation see Li (1990).

priorities that are established in the process of formulating the country's five-year plans.

Within the Ministry of Agriculture is a Science and Technology Department. Its mandate is focussed more on issues related solely to research and development within the Ministry of Agriculture, which enables it to play a more effective role in efforts to coordinate research at the national level. But it has a less direct role as a coordinating mechanism at the subnational level. Its coordinating role is realized principally through the five-year planning cycle for science and technology developments related to crop production, fisheries, and animal husbandry. The Ministry of Forestry also has a department for science and technology that coordinates all research activities within the ministry.

At present, however, research institutes under the various ministries and research programs operate somewhat independently. As a result, the linkages among institutes under different ministries are generally weak. At the provincial level, ties between provincial departments of agriculture, provincial research academies, and colleges and universities are also often weak or nonexistent. Where close cooperation exists, it is often fortuitous or stems from personal contacts. While the vertical structure from the local to the national level is relatively effective, institutional cooperation along horizontal lines needs strengthening if China is to make the best use of its limited finances, equipment, and trained personnel. To cite an example, in Nanjing, the Nanjing Agricultural University, Jiangsu Academy of Agricultural Sciences, and Nanjing Agricultural Mechanization Research Institute operate separate facilities within a short distance of each other but with little coordination of effort. The result of this institutional isolation is an excessive duplication of research effort. Coordination of research projects and communication of research results among entities working on similar problems would contribute to more focussed, better-quality research.

Wugong Agricultural Research Center, established in 1978, was the first coordinating institution for agricultural research in China whose principal duties are to coordinate agricultural research in different institutes based in Wugong and affiliated with the various ministries.[6] Institutes under the coordination of the Center include the Northwest Agricultural University, Shaanxi Academy of Agricultural Sciences, Northwest Forestry College, Institute of Water and Soil Conservation of CAS, and some units affiliated with FAO. The center itself employs only 70 staff members but coordinates the efforts of 1,500 individuals located throughout the various institutes. Based on state and local government assignments, the center chooses appropriate scientists from coordinated institutes to form research groups for special projects. It also signs agreements with the national and local governments and contracts with scientists regarding the objectives of projects, expenditures, and other facilities. Whether this serves as a model for use in other parts of the country is open to question since it has not been replicated elsewhere in China to this time.

3.4 Human Resource Management

Prior to the Cultural Revolution, there were elite institutions that provided sound education and training in the agricultural sciences. Those who benefitted from this training, along with Soviet-trained and some Western-trained scientists, are serving as China's current leaders of science and technology in agriculture (Suttmeier 1989).

But there was a severe deterioration in the quality of the domestic training given to agricultural scientists during the Cultural Revolution, the effects of which are still evident within the research system today. In addition, the isolation of Chinese scientists during this period from changes and advances elsewhere

[6] For further details see *China's Agricultural Yearbook* (1986).

in the world — particularly in terms of training opportunities and the free exchange of staff and information — compounded this decline in the quality of research personnel. Furthermore, the instrumentation and equipment used by agricultural research institutes were not updated during that period. This points to the need for a professional development program to retrain researchers on the job in order to develop scientific and technical skills within the system.

There are other factors related to human resource management, such as planning, retirement, selection, and staffing (including post assignment and transfer), which determine the way in which personnel are deployed throughout the system. Usually, personnel are assigned to posts by state and local government agencies, and once assigned, any attempt to transfer is often met with insurmountable obstacles. These personnel management mechanisms are consistent with the country's mode of centralized planning. However, the resulting assignments may not be particularly appropriate, and in many instances, staff are placed in jobs for which they are unsuitable (Tang, T. 1984). Fortunately, new reforms are being initiated to encourage direct contacts between employment units and educational institutions. As part of these reforms, the managers of research institutes may be called upon to take more active roles to ensure that their staff are rationally distributed. Attention to other management processes such as job analysis and performance appraisal could also help managers to achieve this objective.

The reward structure facing agricultural scientists directly affects the quality of personnel in the system. In China, as in many other public research systems, scientists are employed in accordance with standard civil-service regulations, which provide no explicit linkages between an individual's scientific productivity and the compensation they receive. With transfers to jobs either within or outside of the system being difficult, one of the principal effects of such a compensation system is to dampen the incentives for research personnel to work efficiently. Moreover, for those thousands of Chinese students and scientists trained in the agricultural sciences over recent years throughout the United States, Canada, Japan, Australia, and Europe, the opportunity costs, in both professional and pecuniary terms, of returning to China under these conditions are high. Few appear willing to return voluntarily if the present situation prevails. In seeking to counter such attrition, the system may look to reforming compensation (including salary and benefits such as housing, spouse employment, awards for scientific achievement, etc.) as well as other aspects of reward such as developing career paths for researchers.

The system is also facing the prospect that large number of senior managers will retire during the next five years or so. These managers will be replaced to a large degree by those who received their basic training during the Cultural Revolution. A management development program is needed to maintain leadership quality throughout the system.

3.5 University and Extension Activities

Research Activities at Universities

A distinctive aspect of the agricultural research system in China is that research is institutionally separated from education. Although the Chinese Academy of Agricultural Sciences and the key agricultural universities both fall under the administrative jurisdiction of the Ministry of Agriculture, there is no functional link between them. This contrasts sharply with the US land-grant system, which involves integrated educational, research, and extension activities. China's agricultural university system was adapted from the Soviet model in 1952. Under this system, agricultural universities and colleges were established as entities separate from the comprehensive[7] universi-

[7] They give instruction in and perform research across a wide range of nonagricultural disciplines.

ties. Traditionally their main task has been to teach, although their research functions have been reinforced somewhat in recent years.

There are seven key agricultural universities in China — namely, Beijing, Nanjing, South China, Shenyang, Central China, Southwest, and Northwest Agricultural Universities — that are administered by the Ministry of Agriculture. They place more emphasis on research and have stronger contingents of research personnel than provincial agricultural colleges. Beijing Agricultural University (BAU), one of the most eminent agricultural universities in China, has defined the following five fields of research as its priorities (BAU 1989);

a. regional development programs;
b. basic and applied research on breeding in agriculture, including rice, wheat, cotton, corn, vegetables, laying hens, and lean-meat pigs;
c. agrobiology, physiological biochemistry of animals and plants, biological nitrogen fixation, genetic engineering, protein engineering, etc.;
d. integrated pest and disease management;
e. technology development, including atomic applications in agriculture, etc.

From this list, it is obvious that applied research, technology generation, and technology transfer are dominant. In fact, applied agricultural research accounts for 70%, basic research only 20%, and research for new technology generation around 10% of the university's research portfolio (BAU 1989).

Provincial colleges devote most of their research efforts to applied research and technology extension. For example, Northeast Agricultural College (the provincial college of Heilongjiang Province) has established six research institutes dealing with agricultural biology, animal science, animal and poultry diseases, agricultural engineering, agricultural product processing, and agricultural bioengineering. The mandate of these institutes is to generate new production methods and extend new technology (NEAC 1989).

While agricultural universities and colleges within China have relatively well-trained personnel, only 22% of the scientific and technical staff at the universities in 1986 were classified as full-time equivalent researchers (SSTC 1987).

University research funds come almost entirely from project grants and contracts with the national, provincial, and lower levels of government units. Research results have been substantial despite insufficient funds and the generally poor quality of equipment. However, the lack of research resources at universities and colleges affects not only the current research effort but also the quality of training received by students who constitute the cadre of future researchers.

Linkages with Extension

The National Agricultural Technical Extension Center (NATEC), a parastatal established in 1982 under the Ministry of Agriculture, is the principal agricultural extension agency at the national level. It is concerned mainly with the formulation of government policies that relate to extension, designing national extension programs and conducting nationwide information exchange and training activities. Although NATEC is the top governmental institution responsible for coordinating all extension activities at the national level, its work has been oriented toward crop production and its coordination power is weak with respect to forestry, fishery, and livestock extension. Fishery and livestock extension is in the hands of the Fishery Product Bureau and the Livestock and Veterinary Bureau, respectively, under the Ministry of Agriculture. Forestry extension is under the jurisdiction of the Ministry of Forestry. There is an office within the respective agricultural departments that perform duties at the provincial and prefectural levels that mirror those of the NATEC at the national level. Similar to the

national level, forestry, fishery, and livestock extension is separated from the provincial agricultural extension center that focusses on crop production, although there have been efforts to merge these agencies under the different government departments (figure 6).

In addition to the institutional fragmentation of the extension system itself, the horizontal linkages between research and extension are particularly weak, especially at the provincial and prefectural levels. At the provincial levels, extension is mainly the responsibility of the extension centers under the provincial departments of agriculture and forestry, while research is conducted at the provincial academies of agricultural sciences and provincial agricultural colleges. The lack of coordination that stems from this institutional fragmentation often leads to unnecessary competition for resources and duplication of effort between research and extension. Fortunately, the importance of these linkages is being increasingly recognized and has resulted in some projects to promote "triple A" linkages, i.e., linkages among agricultural research, agricultural extension, and agricultural education. Such projects have been funded by national and local governments in Jiangsu, Sichuan, Liaonin, Beijing, Hunan, and Fujian, for example (STCMA and STDMA 1989). Research institutes and universities are usually responsible for the research components of these projects, while extension organizations take the lead in technology demonstration and extension activities.

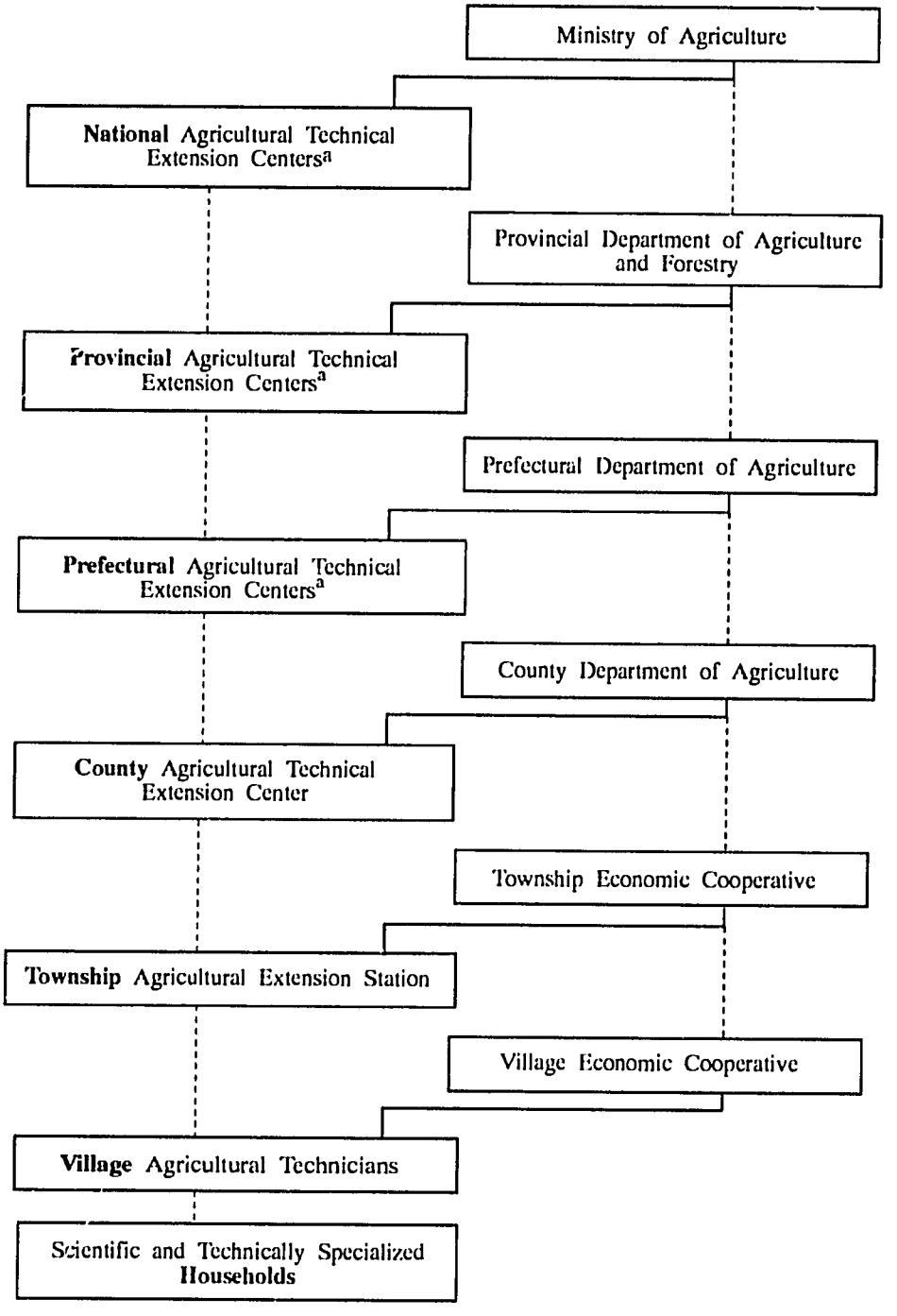
Extension effectively becomes operative at the county level, which has been designed as the focal point for developing China's agricultural technology-transfer system. County-level extension structures are similar to those at the national, provincial, and prefectural levels. Beginning in 1979 the Ministry of Agriculture, with the assistance of local governments, has made substantial efforts to integrate extension more effectively at the county level. County agricultural extension centers have been established in more than 1,000 (or one-third) of the counties in China (STCMA and STDMA 1989). These agricultural extension centers include what had previously been cultivation stations, seed stations, plant protection stations, soil and fertilizer stations, and agricultural technical extension schools. Some 200 livestock extension centers have also been established, based on the previous veterinary stations, livestock improvement stations, and grasslands stations.

Prior to the market reforms of the late 1970s, the extension system at its lowest level was an operational entity within the commune system that served the production teams within each commune. Because production decisions were highly centralized, decisions regarding technology delivery and adoption could be effected by administrative order, and in some respects this was a very effective mode of operation.

Following the market reforms, production has been increasingly decentralized, so the extension system must now service 170 million family farms rather than the 6.6 million production teams in the commune system (Conroy 1987). Under this situation, agricultural technical service companies (semiofficial governmental agencies) have been created based on the previous agricultural technical stations at the township level (the commune level in the old system), and an agricultural technology responsibility system that parallels the household responsibility system has been introduced (STCMA and STDMA 1989). The overall objectives of these changes are to rebuild the extension system in a way that link the remuneration of extension staff to the effectiveness of the extension services they provide. Extension staff sign contracts with farmers, or local governments, that link remuneration to results and define the economic rights and responsibilities of all parties to the contract.

Following the demise of the commune system, several farming households within each village were identified as scientifically and technically specialized. They carry out simple trials and demonstrations assigned to them by

Figure 6: *Organizational structure of the agricultural extension system*



Legend: —— administrative linkage; - - - - professional linkage.

Source: Compiled by the authors.

[a] National, provincial and prefectural centers include crop extension centers, plant protection centers, soil and fertilizer centers, and livestock centers.

local agricultural technicians. These households are often given special access to resources, such as training, technical guidance, and new seeds, and in return provide locally accessible information about the on-farm performance of new agricultural technologies.

Chapter 4

QUANTITATIVE DEVELOPMENT AND IMPACT OF CHINESE AGRICULTURAL RESEARCH

4.1 Quantitative Aspects of Agricultural Research[1]

Research Personnel and Expenditures

The development path along which China embarked in the early 1950s drew heavily in both form and practice from the prevailing Soviet style of central planning and economic development. In those early years the approach taken was more of an industry- rather than agriculture-led development strategy although it seemed well accepted that the application of science and technology to all sectors was an integral part of the overall development process. To this end, the national government actively promoted the establishment of a number of agricultural research institutes during the first five-year plan (1953-57). While levels of investment in agricultural research were quite modest, averaging 37.3 million 1980 yuan or just 82.8 million 1980 PPP dollars per annum, they grew at an annual rate of 65% over this five-year period (table 11).

This was followed by the Great Leap Forward, in which the government sought to jump start the development process through the mass mobilization of people and financial resources in large public works endeavors. As a consequence of these policies, the investment levels by the central government throughout the Chinese economy ballooned to unrealistic and unsustainably high levels, with expenditures on agricultural research increasing more than twofold in just three years beginning in 1958. The ensuing policy readjustments, instigated in 1961, reduced 1962 agricultural research expenditures to less than 50% of those prevailing just two years earlier (figure 7).

From this lower level, public investment in agricultural research in China steadily increased until the Cultural Revolution began in 1966. Research expenditures again contracted sharply during the first few years of the Revo-

[1] Earlier attempts to generate quantitative estimates of the resources committed to agricultural research in China are to be found in Boyce and Evenson (1975), Stavis (1978), Billgren and Sigurdson (1979), Berner (1979), Judd, Boyce and Evenson (1983), and Pardey and Roseboom (1989). Based on our own estimates, reported in detail in appendices 6 and 7 and summarized in tables throughout this section, these earlier efforts are all fraught with problems, which in some instances are substantial. The data given by Pardey and Roseboom come closest to the estimates reported here although their China aggregates did not include a university component and they incorrectly scaled down the personnel figures taken from SSTC (1986) on the mistaken belief that these data included county-level personnel who are generally engaged in extension-like rather than research endeavors. In addition to the problems of accessing Chinese statistics, was the major difficulty of ensuring that the institutional coverage and definitions used to compile the reported data were compatible with internationally accepted standards. The more recently available data — used to benchmark the estimates reported here — are consistent with the data reported in SSTC (1986) that was compiled on the basis of an autumn 1985 survey which adopted the standard definitions and concepts used by UNESCO when compiling R&D statistics.

Table 11: *Quantitative Development of Agricultural Research, 1953 to 1988*

	1953-57	1958-60	1961-65	1966-76	1977-85	1986-88
Research personnel			*(full-time equivalents)*			
Research institutes	-	-	6,966	11,118	27,207	43,421
Universities	193	363	504	503	3,051	7,351
Total	-	-	*7,470*	*11,621*	*30,258*	*50,772*
Research expenditures			*(millions 1980 yuan per year)*			
Research institutes	35.2	252.6	214.8	326.9	668.5	849.3
Universities	2.1	3.3	4.7	5.1	27.8	52.4
Total	*37.3*	*255.9*	*219.5*	*332.0*	*696.3*	*901.7*
Research expenditures			*(millions 1980 PPP dollars per year)*			
Research institutes	78.1	560.0	476.2	724.8	1,485.2	1,886.9
Universities	4.7	7.3	10.5	11.4	58.7	116.4
Total	*82.8*	*567.3*	*486.7*	*736.2*	*1,543.9*	*2,003.3*

Source: Authors' calculations based on data reported in appendices 6 and 7.

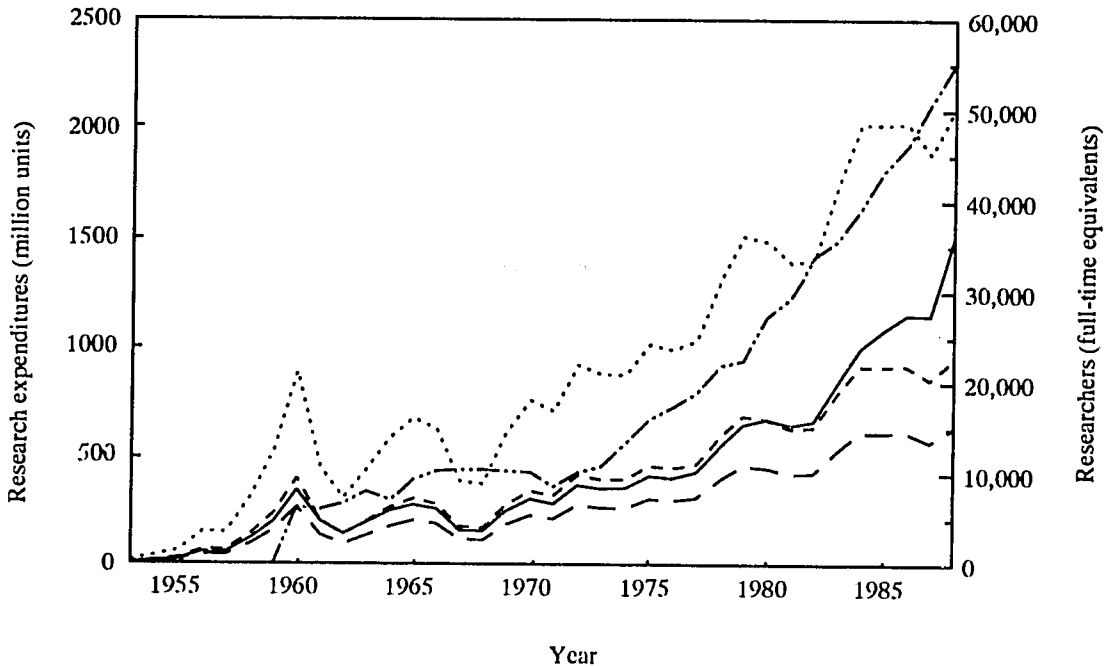
lution and the growth in research personnel that was evident in earlier years ceased. Indeed, as previously discussed, many researchers were redeployed from their research laboratories to rural locations where they worked as "barefoot researchers," often spending much of their time as manual rural laborers (Perkins and Yusuf 1984). While this had the merit of bringing researchers into direct contact with the practical problems confronting peasants engaged in production agriculture, there was widespread abandonment of the scientific principles of research throughout this period. This was clearly detrimental to the development of science-based agriculture.

It took until 1972 before the system returned to a more stable and balanced pattern of growth. Particularly since 1979, the central government has made a fairly sustained effort to strengthen the nation's agricultural research capacity, with the number of personnel increasing at a steady rate of 9.1% per annum and real expenditures at 4.8% per annum over the ensuing decade. By the mid-1980s, the latest year for which comparative figures are available (Pardey, Roseboom and Anderson 1991), the Chinese system alone accounted for 44% of the less-developed world's agricultural researchers and 39% of its research expenditures.

A salient characteristic of the national agricultural research system in China is that the research capacity vested in the universities, particularly in terms of levels of funding, is quite limited. Certainly the universities' share of the nation's commitment to agricultural research has increased substantially since the educational reforms that were instigated some 10 years ago. But by the late 1980s, universities still accounted for only 15% of the system's full-time equivalent researchers and 8% of its expenditures (table 11).

Expenditures per scientist for those working in the research institutes has declined by a third in real terms since the early 1960s and at a rate that has accelerated in more recent years (table 12). Their contemporary levels of research support averaged just under 20,000 1980 yuan per year, which, nevertheless, is about twice the level of support accorded sci-

Figure 7: *Agricultural research personnel and expenditures, 1953-1988*



Legend: —— current yuan; - - - - constant yuan; ..... PPP USD; – — atlas USD; -—·-- personnel.

entists working in the universities.[2] Moreover, this downward trend is consistent with that observed for other less-developed countries over the same period, although it runs counter to the widespread move toward more capital-intensive research systems (in both human and physical terms) among the more-developed countries.

Evaluating these figures on spending per scientist in international terms is confounded by the need to express these data in some common currency unit. There are two more-readily available options. The first is to convert 1980 yuan into 1980 Atlas dollars using the World Bank's Atlas exchange rate. This gives average spending per scientist for the 1985-89 period of just over $12,000. One of the major difficulties with using this Atlas convertor is that it is based on exchange rates that are managed official rates not market rates. In this instance the official 1978, 1979, and 1980 rates used to construct the Atlas convertor were substantially overvalued compared with the prevailing unofficial (black market) rates, thereby understating the *volume* of resources going to agricultural research relative to those obtained using unofficial, "market" rates.

Fortunately an alternative convertor is available that tries to address some of the limitations of using either official or market exchange rates for this purpose. It is a synthetic exchange rate called a purchasing power parity (PPP) developed under the auspices of the International Comparisons Project. The dollar

[2] The term *researcher* used here includes only scientists and engineers. Consequently, these figures on expenditures per researcher include not only the direct salary and fringe benefits of a researcher but also the related operational, support staff, and ancillary expenditures (on such things as education, housing, health, and subsidized food services) in support of these professional staff.

Table 12: *Spending per Scientist, 1953 to 1988*

	1953-57	1958-60	1961-65	1966-76	1977-85	1986-88
Expenditure per researcher			*(1980 yuan per year)*			
Research institutes	-	-	30,835	29,403	24,570	19,560
Universities	10,880	9,090	9,325	10,139	9,110	7,128
Total	-	-	*29,388*	*28,569*	*23,012*	*17,754*
Expenditure per researcher			*(1980 Atlas dollars per year)*			
Research institutes	-	-	20,499	19,544	16,370	13,030
Universities	7,250	6,060	6,230	6,759	5,768	4,747
Total	-	-	*19,534*	*19,000*	*15,302*	*11,831*
Expenditure per researcher			*(1980 PPP dollars per year)*			
Research institutes	-	-	68,360	65,192	61,354	43,456
Universities	24,350	20,110	20,833	22,664	19,240	15,835
Total	-	-	*65,163*	*63,351*	*51,026*	*39,457*

Source: Authors' calculations based on data reported in appendices 6 and 7.

aggregates that result from using PPP convertors are likely to yield more realistic international comparisons of the volume of resources committed to agricultural research.[3] At 41,000 PPP dollars per year, the contemporary level of real spending per Chinese scientist is on par with researchers working in other Asian NARSs. However, while these levels of spending for the Chinese and Asian NARSs are broadly comparable, the Chinese figure has been on a downward trend since the early 1960s, while the Asian figure has remained fairly stable, despite large increases in the number of scientists working in these systems.

While the Chinese agricultural research system dwarfs all other public-sector systems — in fact it is even four times larger in researcher terms than its nearest developing-country rival, India — the number of researchers with formal scientific qualifications is quite meager. Only 5% to 6% of its researchers hold a postgraduate degree compared with 60% to 70% in other less-developed Asian NARSs (table 13). Even in Chinese terms the agricultural scientific community fares badly in this regard. The share of scientists and engineers with PhDs across all sectors averaged 0.4% in 1988 (SSTC 1989), which is double the corresponding percentage for agriculture. Those holding MSc degrees were 5.1% for all sectors and 4.6% for agriculture. This state of affairs is no doubt a legacy of the industry-led development strategies of the 1950s and 1960s and the anti-intellectual climate of the Cultural Revolution years. It is to be expected that over the next few years this situation will redress itself somewhat with the expected influx of graduates into the research system from the surge of enrollments in

[3] PPPs attempt to get a broader measure of relative currency values by comparing the relative cost in local currencies of a detailed basket of traded and nontraded goods and services. They have the major advantage that they are not driven by policy shifts in exchange rates or by sudden swings in financial transactions. They also capture the price of nontradables (while exchange rates are based only on a basket of *traded* goods and services) such as the labor, land, and facilities components that constitute a large share of national research budgets. See Pardey, Roseboom and Craig (1992) for more discussion on this issue.

Table 13: *Degree Status of Agricultural Researchers*

Country	Year	PhD	MSc	Other[a]	Total	Percent of total		
						PhD	MSc	Other
						%	%	%
China[b]	1988	93	2,146	44,410	46,649	0.20	4.6	95.2
	1989	-	-	-	-	0.27	5.7	94.0
Bangladesh[c]	1986	131	732	289	1,152	11.4	63.5	25.0
Indonesia[c]	1989	179	463	1,537	2,179	8.2	21.2	70.5
Malaysia[c]	1983	171	358	318	847	20.2	42.3	37.5

Source: Based on data reported in *Statistical Materials on Agricultural Science and Technology, various years* (1989, 1990) and appendix 6 for China; Pardey and Roseboom (1989) for Bangladesh and Malaysia; and Pardey, Eveleens, Abdurachman and Wood (1992) for Indonesia.

[a] Generally includes researchers holding a BSc degree or its equivalent.

[b] Degree status of scientist and engineer equivalents from Ministry of Agricultural system (i.e., excluding forestry) are reported in *Statistical Materials on Agricultural Science and Technology, various years* (1989, 1990). These percentages were applied to the corresponding scientist and engineer estimates from appendix 6 to estimate the number of degree holders.

[c] Bangladesh data include all but the university component of the national system, Indonesia data include the Agency for Agricultural Research and Development, while Malaysia data include Malaysian Agricultural Research and Development Institute plus forestry, fisheries, palm oil, rubber, and veterinary research institutes.

China's agricultural universities during the late 1970s and early 1980s.

Agricultural research intensities (ARIs) that express expenditures on public-sector agricultural research as a proportion of agricultural product are commonly used to measure the support to NARSs. But to determine whether observed levels of investment in agricultural research are in any sense optimal or "appropriate" is an especially difficult exercise. Governments use a multitude of policy instruments in their efforts to shape the development of the agricultural sector. In the case of China, the government continues to directly set the prices received by farmers and paid by consumers for a contracting but still economically significant group of staple food and clothing commodities, while simultaneously pricing and controlling the distribution of off-farm inputs such as fertilizer, machinery, and pesticides. At the same time, government invests in a host of rural "public" goods such as education, transportation, communication, and irrigation infrastructure in addition to nurturing the country's agricultural research and extension system. All of these initiatives have direct, and in some instances substantial, budgetary implications, making it clear that agricultural research represents but one of a myriad of competing claims on the public purse. At a minimum, a clear understanding of the specific efficiency, equity, and security objectives being sought and the relative cost-effectiveness of alternative policy instruments in achieving these objectives is a prerequisite to evaluating the appropriateness of any portfolio of policy options.

Assessing the cost-effectiveness of a country's agricultural research program is in itself a tall order. The appropriate scale and scope of a NARS in terms of its commodity, type-of-technology, site, and problem focus is

derived from the size as well as the technological and socioeconomic diversity of the agricultural sector it seeks to serve. If agricultural research were subject to significant economies of size and economies of scope, then it would not be necessary for research costs to rise in proportion to the size and diversity of the agricultural sector. But, the site-specific nature of many agricultural technologies places a limit on the degree to which research results targeted for one locale can be transferred to another. This is particularly true for crops, such as soybeans, that are especially sensitive to day length, but it is perhaps of less concern when transferring crop management technologies and the like for, say, irrigated rice systems where some of the natural variation in the plant's production environment has been ameliorated. Likewise, there is a limit to which research inputs, such as personnel, glasshouses, and computer facilities, can be shared across different lines of research, making economies of scope possible when it is necessary to have experimental sites widely dispersed across a large country such as China.

Alston and Pardey (1991) examined the links between the size of the agricultural sector and levels of investment in agricultural research for a sample of 83 countries over the 1961-85 period. They found a significant income effect, with the elasticity of ARI ratios with respect to GDP per capita being 0.65. As a country's income level grows, it shows a greater propensity to support agricultural research. They also found (after accounting for differences in income levels, agricultural trade intensities, the level of protection accorded the agricultural sector, and so on) that the total elasticity of agricultural research expenditures with respect to agricultural output was 0.43, even though the total elasticity of the ARI ratio with respect to agricultural output was negative (-0.51). Thus, when other things such as per capita income levels are held constant, agricultural research expenditures do not rise proportionately with agricultural output, so ARI ratios (which measure the size of research expenditures relative to agricultural output) in fact shrink as the agricultural sector expands. These two offsetting tendencies (that is, one of increasing ARIs due to increasing per capita incomes versus shrinking ARIs associated with an expanding agricultural sector) have impacted China over the past several decades. By all accounts, per capita incomes have grown rapidly[4] and, as detailed earlier, real agricultural output is now 3.4 times larger than it was just a quarter of a century ago.

Naturally other factors, not least the significant political and institutional upheavals that have occurred in the recent past, have influenced the ARI ratios we observe for China since the early 1960s (table 14). In fact, China's investment in agricultural research in relation to AgGDP was relatively high in the early 1960s in comparison with other less-developed countries. Even during the Cultural Revolution in the second half of the 1960s, China maintained a respectable official level of investment in agricultural research. Between the late 1970s and early 1980s, however, the Chinese agricultural research-intensity ratio dropped considerably and, for the first time in this period of observation, fell below the less-developed country average. In line with the empirical evidence just presented, the rapid growth in per capita GDP throughout this period would lead to increased ARI ratios. But, in China's case, this tendency has been offset by the exceptionally high rate of growth (6.5% per annum) in AgGDP that occurred in the post-1980 period. Thus the decline in ARIs

[4] In constant yuan terms, real GDP per capita rose at an annual rate of 7.8% over the 1980-89 period, to a 1989 level of US$350 per capita according to World Bank (1991a) estimates. The difficulty of getting local currency prices for goods and services that are comparable in type and quality across countries makes dollar-denominated aggregates such as these questionable. This is particularly true for a country such as China where a large number of prices are still subject to state control or influence. Kravis (1980) uses purchasing power parity measures to derive a 1980 estimate of $700 per capita, while Perkins (1988) makes an informed guess for 1985 of $500.

Table 14: *Agricultural Research Intensity Ratios, Weighted Averages, 1961 to 1988*

Region/income group[a]	1961-65	1966-70	1971-75	1976-80	1981-85	1986-88
	%	%	%	%	%	%
Region						
China	0.42	0.32	0.40	0.48	0.40	0.39
Sub-Saharan Africa (37)[b]	0.26	0.39	0.42	0.51	0.49	-
Asia & Pacific, ex. China (15)	0.14	0.18	0.22	0.29	0.32	-
Latin America & Caribbean (26)	0.30	0.44	0.46	0.56	0.58	-
West Asia & North Africa (13)	0.28	0.49	0.50	0.48	0.52	-
Less-Developed Countries (92)	0.24	0.29	0.34	0.41	0.41	-
More-Developed Countries (18)	0.96	1.29	1.41	1.60	2.03	-
Total (110)	*0.48*	*0.60*	*0.65*	*0.72*	*0.76*	-
Income						
Low (30)	0.22	0.21	0.27	0.36	0.35	-
Lower-middle (28)	0.24	0.33	0.35	0.39	0.40	-
Middle (18)	0.25	0.44	0.46	0.49	0.57	-
Higher-middle (18)	0.27	0.38	0.44	0.52	0.55	-
Higher (16)	1.08	1.44	1.57	1.78	2.23	-
Total (110)	*0.48*	*0.60*	*0.65*	*0.72*	*0.76*	-

Source: Appendix 7 for China data and Roe and Pardey (1991) for remainder.

Note: Agricultural research intensity ratios, as defined here, measure agricultural research expenditures as a percentage of AgGDP. Averages are weighted by the respective country's share of aggregate AgGDP.

[a] Countries assigned to income classes based on 1971-75 per capita GDP averages where *Low* represents < $600; *Lower-middle*, $600-1500; *Middle*, $1500-3000; *Upper-middle*, $3000-6000; and *High*, > $6000.

[b] Bracketed figures represent number of countries in regional and income group totals.

over more recent years did not stem from a contracting or stagnating level of agricultural research expenditure; its principal origins are likely to be found in the high rate of growth in agricultural output during the 1980s spurred in large measure by the institutional reforms within the agricultural sector (Fan 1991).

Commodity Orientation

One of the more important policy and management dimensions of a NARS is its overall commodity orientation. In thinking about this issue, the congruence rule has been used widely as a crude procedure for research resource allocations. By this method research is funded in proportion to the value of production. To do this, funds are allocated so as to equate research intensities — research investment per value of output in gross or value-added terms — across areas. This approach has minimal, but still non-negligible, requirements for information. It will maximize the total economic benefits for society to be gained from a portfolio of research investments when, among other things, all projects or programs are subject to the same per unit research (or knowledge) production function.[5] Unfortu-

[5] In other words the average per unit cost savings that farmers ultimately achieve when adopting the technologies or new knowledge produced by research are equalized across different lines of research.

nately, the full conditions for this to be true are unlikely to be fulfilled. Some production problems are harder to solve than others and the rate of uptake of new research findings or technologies can vary markedly across commodities. A more explicit analysis of the flows of benefits and costs from alternative projects and programs would be required if these factors were to be included in a more complete assessment of the priorities a system places on its various commodity programs. Nevertheless, in the absence of such information, the congruence rule is a useful point of reference when reviewing a system's investment strategy.

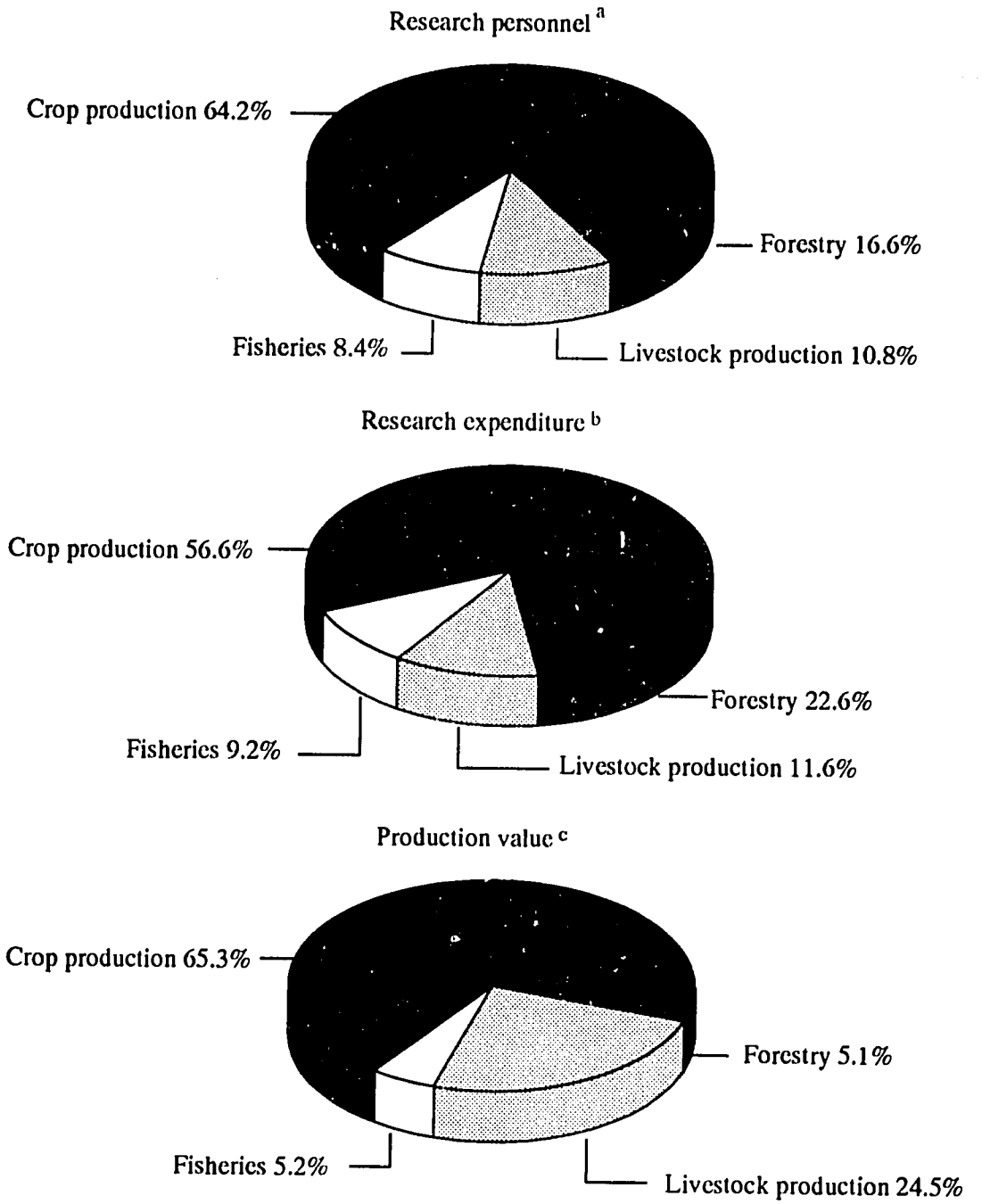
However, it is presently the case that even the data required to compile commodity-level congruence ratios for China's NARS are not available. Dissecting aggregates for research personnel or expenditures along individual commodity lines is far from simple. In addition to the practical difficulties of assembling data for such a large and institutionally disparate system such as China, there are several conceptual difficulties as well. For example, some agricultural research is either targeted to multiple crop or commodity environments or has secondary impacts that go beyond the targeted commodity. While research institutes tend to categorize information by problem area or commodity aggregates, universities usually provide information by disciplined that cannot readily be allocated on a commodity basis. What is currently available are data on research personnel and expenditures for the national, provincial, and prefectural institutes (excluding universities), disaggregated to the level of the broad commodity aggregates given in figure 8.

Based on these congruency ratios, there appears to be a substantial overinvestment in forestry research (when compared with the measured value of forestry production[6]) and a marginal overinvestment in fisheries research, with a corresponding underinvestment in crop and livestock research.[7] But one needs to be circumspect about drawing any such policy conclusions from these congruency rules alone. In particular, while these relativities suggest that China grossly overinvests in forestry research in relation to other production sectors, the extent to which this may be so cannot be ascertained simply on the basis of these data. There are additional measurement and interpretation concerns that need clarification before such a conclusion can be drawn, aside from the reservations already expressed. One such issue, which is of particular importance here, concerns the correspondence in coverage between the research expenditure and output measures. The *value-added* measure of output available in this instance is a value aggregate based on quantities of agricultural commodities and producer prices that, in principle, are both measured in "farm-gate" terms. This contrasts with *gross* output aggregates that are formed using quantity and price data often measured well beyond the farm-gate level. Such output measures include an off-farm cost component that in the case of wood products can be substantial. China's forestry research program invests a significant amount of resources in developing new and improved processing technologies and wood-based products. This gives rise to mismatched relativities when expressing expenditures on forestry research relative to a value-added (farm-level) measure of forestry output. This will bias upward the congruency ratio for forestry compared with those for crops, livestock, and fisheries, where a preponderance of the

[6] It is important to note that the forestry output measure used here does not take into account the nontimber services of forests. Although these services can be valued (Graham-Tomasi 1990a,b), in the present discussion it is only relevant to do so to the extent that forestry research is addressing these aspects.

[7] Moreover, the value shares for these broad commodity aggregates mask a good deal of variation at the commodity level. For example, while rice accounts for 26% of the value of total crop and livestock output in 1986 (measured in local market prices), wheat, corn, and pork account for 14%, 9%, and 17%, respectively, of the total (Gunasekera et al. 1991). The congruency rule would argue for allocating to corn and pork combined the same share of research resources allocated to rice research.

Figure 8: *Commodity orientation of agricultural research and production, 1987*



Source: China's Agricultural Statistical Materials (1987), *China's Forestry Yearbook* (1988), and *Statistical Materials on Agricultural Sciences and Technology* (1987).

[a] Research personnel and expenditures for mechanization and agricultural reclamation are excluded.

[b] Research expenditures for forestry represent total funds available to the various research institutes. The difference between expenditures and funds available is quite small.

[c] The production value of rural (off-farm) industries and sidelines (e.g., hunting, collecting wild plants, craft industries) is excluded.

research has an on-farm, primary-production orientation.

Taking congruence ratios — which normalize research expenditures on contemporaneous output measures — at face value also glosses over the dynamics between research expenditures and output. Research usually leads to an increase in the stock of knowledge or an improvement in technology, which in turn generates a stream of benefits that continues until the new technology or knowledge is superseded or becomes obsolete. But for research to realize its growth-promoting impact takes some time given the lags in the research processes itself and the further lags in the uptake of new ideas and new technologies. In this way *current* output levels in part reflect the successes (or failures) of *past* research investments. Whether present research expenditures will have a similar impact on future levels of output is one of the central questions to be addressed when contemplating a research investment decision and an issue on which congruence ratios, ipso facto, shed no light. Moreover, other factors such as income- and population-driven shifts in demand can alter future research benefit streams, thereby having a direct bearing on research investment decisions. In the Chinese case, for example, crop production has accounted for a declining share of the total value of agricultural production since 1949, while the livestock, fishery and forestry shares have grown considerably (figure 2). To the extent that the underlying demand-side influences that helped shape these observed production patterns continue in the future, it can be wholly appropriate to spend a higher than congruent share of current research expenditures in areas other than crop production.

Administrative cum Regional Structure of Research

A distinguishing characteristic of the Chinese agricultural research system is that the size, quality, and orientation of its research institutes vary considerably across administrative and regional boundaries. Over one-half the country's agricultural research institutes and one-third of its research personnel are administered at the prefectural level, while national-level institutes account for just 5% of the nation's institutes and 12% of its research personnel (table 15). As a consequence, there is a marked disparity in the average size of the institutes — ranging from 101 scientists per institute at the national level, through provincial-level institutes with half this number, to prefectural-level institutes averaging just 16 scientists per institute. These trends are paralleled by differences in the financial and technical support given to scientists working at these various administrative levels. Scientists at national-level institutes are provided with an average of 0.28 technical support staff each. There are 0.48 technical staff per provincial-level scientist and 0.77 technical support staff per prefectural-level scientist. At 30,451 yuan per scientist per year, the national average spending per scientist for 1989 is in line with the time-series data in table 12. But, largely in accord with the ratios of support staff per scientist, spending per scientist for those working in national-level institutes is 16% below the country-wide average and 9% above it for those scientists working at the prefectural level.

These data are generally consistent with the notion of larger, more scientist-intensive institutes at the national level focussing on pre-technology, less site-specific research. They are complemented by the provincial- and prefectural-level institutes, which are generally smaller, less scientist-intensive and involved in more localized, adaptive kinds of research. To discern whether this deployment of resources is optimal in any sense would require access to far more detailed information than is presently available on the specifics of the research programs being carried out by these various agencies.

Much the same can be said concerning what is known about the regional development of research resources throughout China. Figure 9

Table 15: *Vertical Structure of Agricultural Research Institutes, 1989*

	Administrative level			
	National	Provincial	Prefectural	Total
Number of institutes	56	423	620	1,099
Total staff engaged in S&T[a]	10,720	45,899	32,302	88,924
Scientists and engineers	5,676	17,827	10,161	33,664
Technical support staff	1,603	8,575	7,793	17,971
Other support staff	3,444	19,497	14,342	37,289
Research expenditures (*current million yuan per year*)	144.9	528.8	351.2	1,025.1
Scientists and engineers per institute	101	42	16	31
Research expenditure per staff engaged in S&T (*current yuan per year*)	13,513	11,521	10,872	11,528
Research expenditure per scientist or engineer (*current yuan per year*)	25,543	29,665	33,088	30,451

Source: *Statistical Materials on Agricultural Science and Technology, 1989* (1990).

Note: These data only pertain to the nonuniversity institutes within the Ministry of Agriculture research system (including national, provincial, and prefectural levels) and thereby exclude research activities under the ministeries of forestry, water conservation and power, and machine building (see appendix 4 for details).

[a] *Total staff engaged in S&T* include research personnel (i.e., scientists and engineers plus technical support staff as defined in appendix 6) as well as other support staff such as laboratory workers, and workers directly involved in implementing field trials and the like. Ancillary staff, such as drivers, security guards, cafeteria staff, plus affiliated hospital and school staff that provide health and education services for institute personnel and their childern, are explicitly exluded. The total number of research and ancillary staff employed by the Ministry of Agriculture research system in 1989 was 125,276.

gives the location of all national-level institutes (including those of CAAS, CAF, CAFS, and SCATC), which are predominantly found in the eastern part of the country. Broadening the institutional coverage to include institutes administered at the provincial and prefectural levels, it is evident that the research institute, personnel, and expenditure shares for each region are roughly congruent with the corre sponding agricultural output, population, and arable land. But there are some notable exceptions (table 16). In terms of their congruency with AgGPV for instance, the northeast and northwest regions appear to substantially overinvest in agricultural research, while the north and, to a lesser degree, the southwest regions underinvest in research. However, in a vein similar to the earlier discussion of commodity congruence, to do justice to a consideration of spatial congruence requires a more thorough assessment of issues such as the site-specificity of each region's program of research and the degree to which new technologies and knowledge developed in one region can potentially spill over to another (Pardey and Wood 1991).

Table 16: *Regional Distribution of Agricultural Research Capacity, 1989*

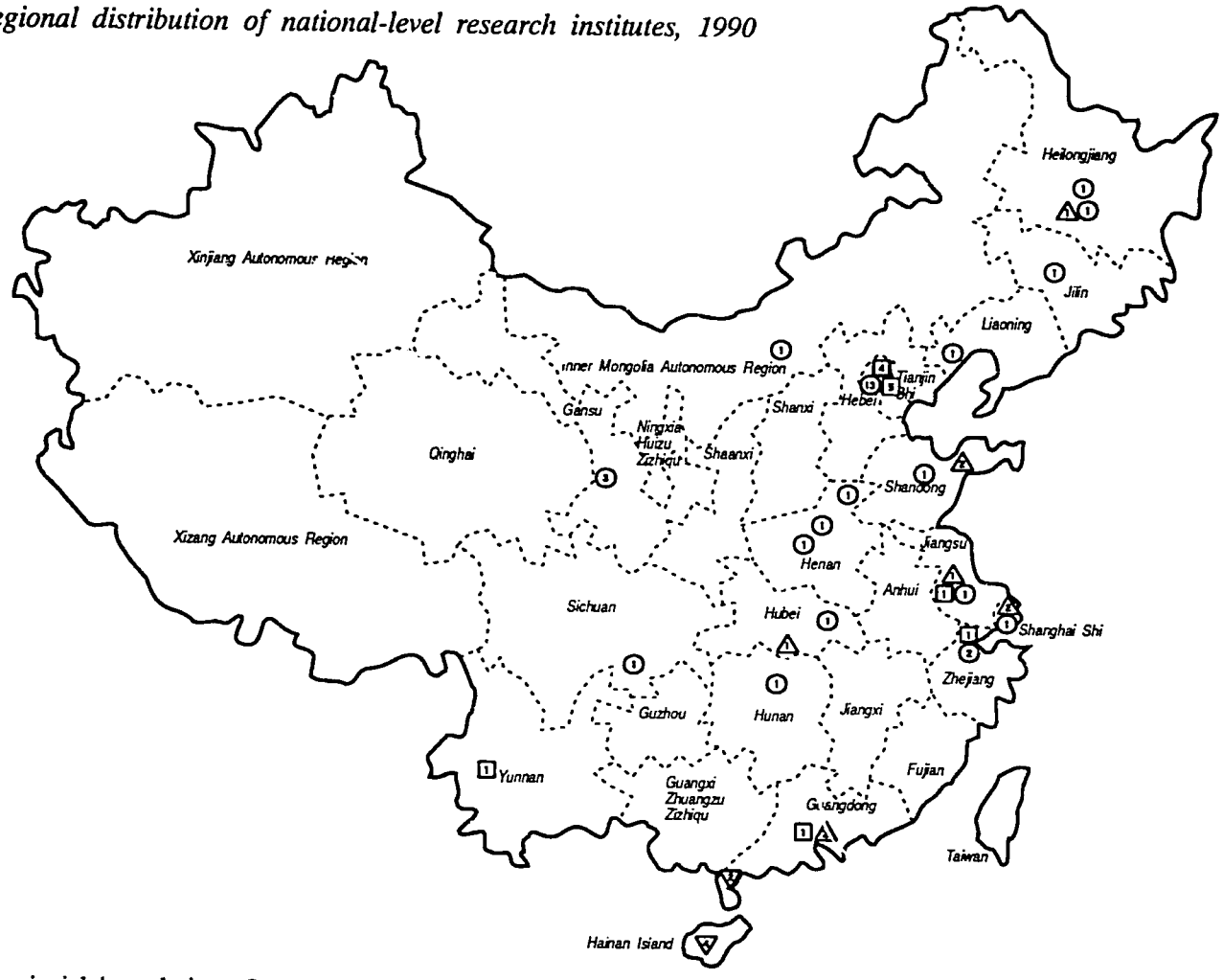
	Region						
	Northeast	North	Northwest	Central	Southeast	Southwest	South
Number of research institutes	135	208	167	128	114	145	146
Research personnel *(scientists & engineers)*	5,011	7,149	4,279	2,669	3,883	3,402	3,336
Research expenditures *(millions current yuan)*	84.0	97.2	68.5	79.7	96.7	57.7	82.6
AgGPV *(billions current yuan)*	29.6	92.1	21.9	47.5	61.5	46.5	42.2
Rural population *(millions)*	55.3	246.2	48.1	121.8	138.7	152.3	115.8
Arable land *(millions of hectares)*	16.2	28.5	13.1	9.2	11.0	11.0	6.8
	(Share of national total)						
	%	%	%	%	%	%	%
Number of research institutes	12.9	19.9	16.0	12.3	10.9	13.9	14.0
Research personnel	16.8	24.0	14.4	9.0	13.1	11.4	11.2
Research expenditures[a]	14.8	17.5	12.3	14.1	17.1	10.2	14.6
AgGPV	8.7	27.0	6.4	13.9	18.0	13.6	12.4
Rural population	6.3	28.0	5.5	13.9	15.8	17.3	13.2
Arable land	17.0	29.8	13.6	19.6	11.5	11.5	7.1

Source: Tables 1 and 2, *China's Agricultural Statistical Materials* (1988), *Statistical Materials on Agricultural Science and Technology, 1989* (1990).

Note: See table 15.

[a] 1987 data.

Figure 9: *Regional distribution of national-level research institutes, 1990*



Legend: ---- provincial boundaries; ○ numbers of CAAS Institutes; □ numbers of CAF institutes; △ numbers of CAFS institutes; ▽ numbers of SCATC institutes.

Source: Compiled by the authors

Extension

Complementing the nation's agricultural research endeavors is a national extension system that in 1987 had just over 300,000 employees, of whom 193,300 were classified as professional and technical support staff (table 17). The available data suggest that the number of professional extension workers declined markedly in recent years as the institutional reforms of the system (see section 3.5) took hold. And spending per extension worker is only 40% of that accorded researchers.

A good many of the professional extension staff working at the national, provincial, and prefectural levels spend most of their time in administrative, policy formulation, and management activities. It is at or below the county level, where 93% of the professional staff are located, that most of the technology demonstration and training activities are carried out.[8] As with research, an overwhelming majority of extension activities are oriented to crop production. In 1987, 75% of the state-employed extension professionals working in agriculture (i.e., excluding forestry and fisheries) focussed on agronomic, plant protection, and soil management issues, 6.3% on horticultural problems, and only 2.5% on livestock-related matters.

4.2 Accounting for the Impact of Agricultural Research

Measuring the impact of agricultural research is often handicapped by the paucity of suitable data. This problem is no less serious in the case of China. There are relatively abundant data on

[8] Only 7% of the nation's extensionists work at or above the prefectural level. County-level units account for 42% of the country-wide total, district-level agencies around 16%, and township-level units about 36%. Around two-thirds of the township-level extensionists are employed by the state while the remainder, who are generally lacking in formal professional training, are employed by the collective or township government (*China's Agricultural Statistical Materials, 1988*, 1989).

Table 17: *Quantitative Comparison of Agricultural Research and Extension, 1975 to 1988*

	Research			Extension		
Year	Staff[a]	Expenditure[b]	Expenditure per staff	Staff[a]	Expenditure[b]	Expenditure per staff
		(1980 million yuan)	*(1980 yuan)*		*(1980 million yuan)*	*(1980 yuan)*
1975	26,491	455.1	16,800	-	931.2	-
1980	44,290	667.5	15,070	174,950	719.7	4,290
1985	65,408	909.1	13,900	190,740	836.5	3,770
1986	76,325	912.5	11,960	-	735.4	-
1987	82,716	847.7	10,250	193,300	786.5	4,070
1988	85,068	945.0	11,110	150,390	-	-

Source: Appendix 6 for research data, and Swanson, Farner and Bahal (1991) and *China's Agricultural Statistical Materials, 1988* (1989) for extension data.

[a] Includes all professional and technical support staff. Extension staff other than for 1987 were derived from data reported in Swanson, Farner and Bahal (1991). The figure for 1987 is taken from *China's Agricultural Statistical Materials, 1987* (1988).

[b] The current yuan data reported in Swanson, Farner and Bahal (1991) was deflated using the same procedure as used for deflating research expenditures. See appendix 6 for details.

crop production and the use of inputs but rather less on technology dissemination and very little on the costs of research for different commodities or geographic regions. Data on the new varieties adopted as well as the yield trends of principal crops are used to give some indication of the output and impact of China's agricultural research program. This section closes with a more detailed accounting of the growth consequences of the nation's agricultural research program.

Generation and Adoption of Improved and Hybrid Varieties

While there has been a wide spectrum of technologies flowing from China's agricultural research program, we restrict our focus here to the varietal improvement aspects of these research endeavors, the outputs that are a tangible and important indicator of research successes.

In 1949, the area under improved varieties throughout China was no more than 0.7 million hectares, about 0.6% of total sown area (STCMA and STDMA 1989). China initiated a large-scale varietal improvement program that was given a high priority in the nation's 1951-55 Agricultural Research Plan. The focus of this program was to collect and select high-yielding varieties and to improve the yield performance of existing varieties, particularly for rice, wheat, and cotton (STCMA and STDMA 1989). In 1956 Chinese scientists began breeding dwarf indica varieties that had high yield potential, were responsive to fertilizer, and were relatively resistant to lodging and disease. With adequate fertilizer and water, on-farm yields of 5 to 6 tons per hectare were realized, comparable to those of the dwarf rice variety IR-8 developed at IRRI seven years later (Wittwer et al. 1987). This research effort continued to have a high priority in the 1956-67 Agricultural Research Program and the 1963-72 Agricultural Research Development Strategy. In its early phases, this line of work sought to evaluate and characterize all existing varieties, as a basis for developing improved conventional varieties of rice, wheat, cotton, corn, millet, potatoes, and oil-bearing seeds with well-developed resistance to pests, diseases, and lodging. During this period, dwarf rice varieties such as pearl dwarf, Jiangnan dwarf, early Jiang dwarf, and over 30 other improved rice varieties were developed and released. New wheat varieties with resistance to stem and stripe rust, such as Bima 1 and Nanda 2419, were also developed and planted in large areas, substantially reducing the yield losses associated with earlier varieties (table 18).

In addition to the conventional breeding strategies just noted, China also began its own hybrid corn breeding program in the 1950s. The area planted to hybrid corn varieties steadily increased from 55% in 1965 to around 70% by the mid-1980s. Hybrid breeding programs for sorghum, rice, wheat, cotton, oil bearing seeds, millet, and vegetables also got underway in the 1960s. During the middle of the 1970s, a three-line system for breeding rice hybrids was developed to solve self-pollination problems. The first line is a cytoplasmic male-sterile maternal or A-line plant. The second is a maintainer or B line, in which plants pollinate the male-sterile line and make it productive, but the progeny or offspring are still male-sterile. The third is a fertility-restorer line that is the paternal line or rice plant that pollinates the male-sterile line and restores the plant's ability to produce seeds with strong hybrid vigor. Since 1980, the area under hybrid rice has increased rapidly and now constitutes about 40% of the area planted to rice. Similar achievements have also been made in wheat, millet, sorghum, and hybrids of other crops. Within China, there is now greater emphasis placed on hybrids as opposed to conventional plant breeding for most crops.

During the periods spanned by the fifth (1976-80) and sixth (1981-85) five-year plans, concerted efforts were made to establish a truly national network for breeding, testing, producing, and disseminating high-yielding varieties. The more basic aspects of the country's breed-

Table 18 *Adoption of Hybrid and Improved Varieties, 1976 to 1986*

	Hybrid			Improved					
	Rice	Corn	Sorghum	Rice	Wheat	Soybeans	Cotton	Peanuts	Oil crops
	(percent of total area planted with crops)								
1976	0.4	-	-	-	-	-	-	-	-
1977	6	-	-	-	-	-	-	-	-
1978	13	-	-	-	-	-	-	-	-
1979	15	65	55	80	85	60	75	70	45
1980	14	69	57	85	90	56	80	75	50
1981	15	72	60	90	92	70	82	80	55
1982	17	75	60	92	93	75	85	85	60
1983	20	60	54	48[a]	71[a]	44[a]	86[a]	51[a]	[a]
1984	27	-	-	-	-	-	-	-	-
1985	26	73	46	46[a]	77[a]	47[a]	83[a]	53[a]	48[a]
1986	28	71	-	-	-	-	-	-	-
1987	34	-	-	-	-	-	-	-	-
1988	41	-	-	-	-	-	-	-	-

Source: *Forty Years of Chinese Agricultural Science and Technology* (1989) for data prior to 1979 and *Forty Years of Chinese Agriculture* (1989) for the remainder.

[a] After 1983 only those areas exceeding 6,667 hectares (100,000 mu) in each sampling frame were recorded in the data on area under improved varieties. As a consequence, part of the reported decline over recent years in this area is probably a statistical artifact. But the shift from a collective to a decentralized farming system has had a direct impact on technology delivery systems (see section 3.5) and the incentives of individual farmers (versus collectively managed production systems) to use new technologies.

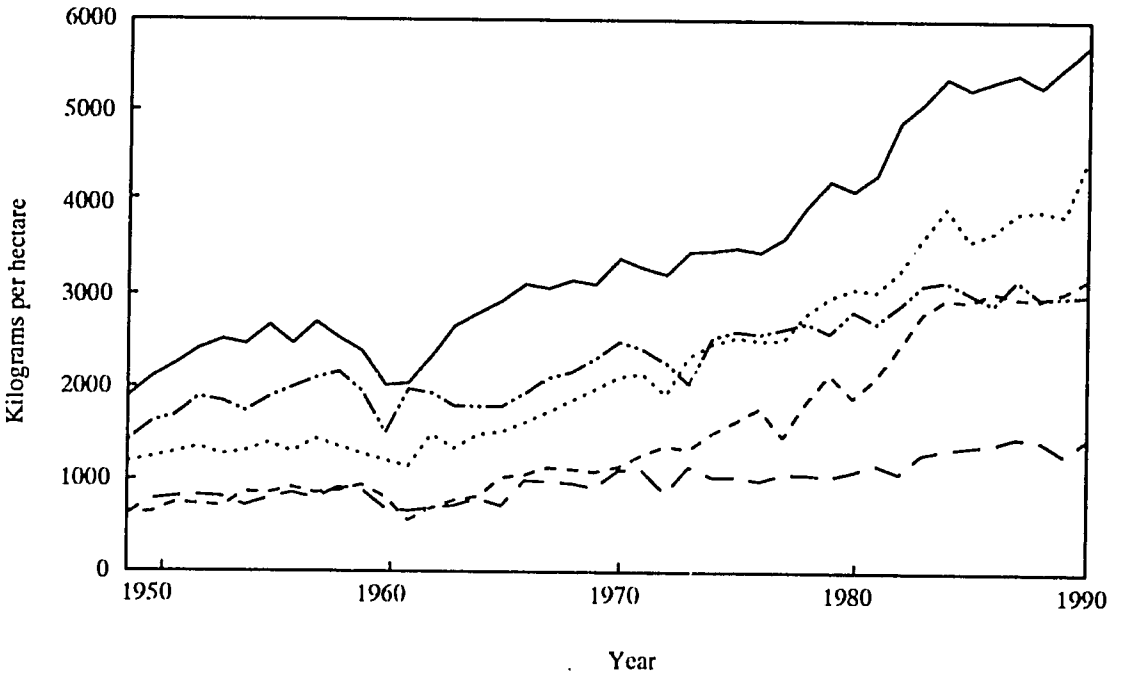
ing program are now focussed at the national and, in some instances, provincial institutes, while seed multiplication activities are concentrated at the county level. A formal procedure for evaluating and recommending new varieties at both the national and provincial levels has also been put in place. The idea here is to foster a division of labor and research focus in which the gradient from basic to applied and adaptive research runs from the national- to lower-level agencies. These institutional changes have also sought to encourage a more direct link between those agencies generating new seed technologies and the seed companies that have responsibility for seed multiplication, varietal demonstration, and seed supply.

Yield Trends

Growth in crop yields is a commonly used indicator of the effects of agricultural research on productivity. Yields per hectare since 1949 for selected major crops are presented in graphical form in figures 10 and 11. But yield increases reflect the influence of many factors other than agricultural research, such as the increased use of conventional inputs like fertilizer, labor, and pesticides. Agricultural research not only improves the quality of these conventional inputs but also generates new technologies (e.g., new varieties) and management practices that directly contribute to observed increases in yields.

At 4% and 3.3%, respectively, the average rate of growth of wheat and corn yields for the

Figure 10: *Yield of principal grain crops, 1949-1990*



Legend: —— rice; - - - - wheat; ..... corn; – — soybeans; .—..– potatoes.

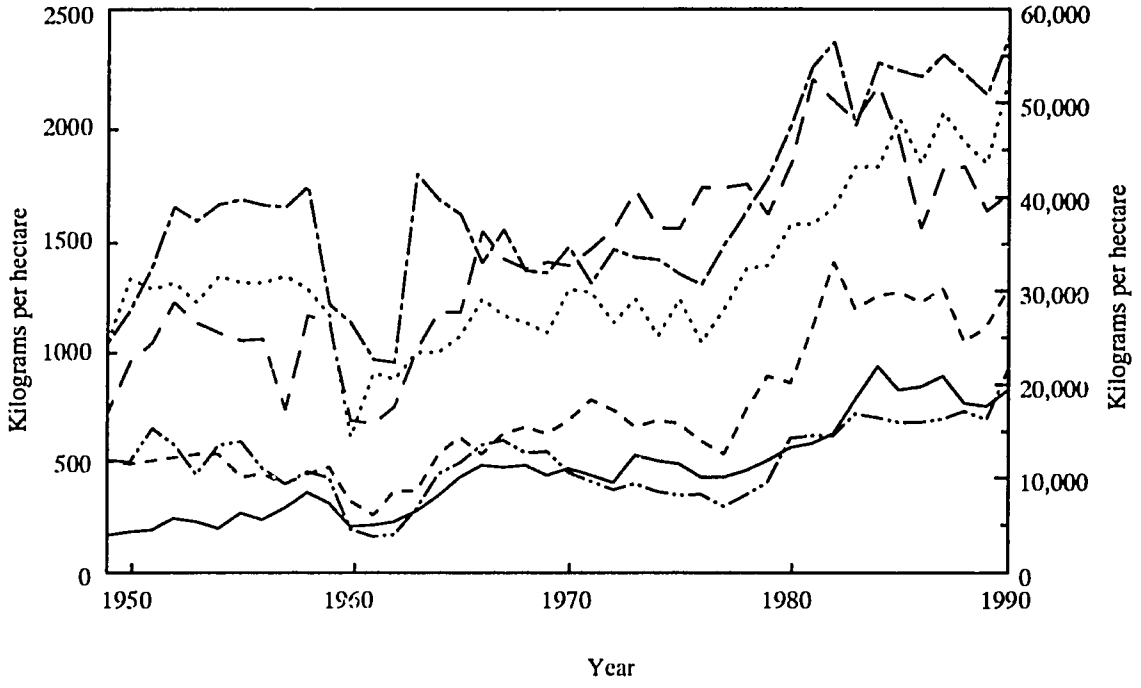
Source: See appendix 8.

post-1949 period has been impressive (appendix 8). The growth in rice yields fell from their immediate post-revolution rates of 5.2% per annum to just 2.8% per annum for the past decade to give a post-1949 average annual rate of growth of 2.7%. Although the area sown to rice, wheat, and particularly, corn has also grown substantially since the early 1950s (see appendix 9), the total area planted to grains has fallen, due largely to the more than 50% decline in the area sown to coarse grains such as millet and sorghum.

Both contemporary and longer-run yield increases for cash crops have generally been larger than those just noted for food crops (appendix 8). Moreover, the area sown to cash crops has nearly doubled over the past 40 years. An exception is cotton, which, despite yield gains averaging 4% per annum, covers the same area now as it did in the early 1950s but with intervening periods (particularly in the early 1980s) of higher than average area.

Positive yield trends may be an indication of research successes but there are several factors that can confound such an interpretation. As previously mentioned, the increased use of conventional inputs, even in the absence of research-induced technical change, will usually give positive yield responses. Our attempts to disentangle the growth-promoting effects of research from more conventional sources of output growth are reported in the following section. A more subtle issue relates to the effects of maintenance research that seeks to replace or replenish the yield gains achieved through prior research investments. Clear examples arise with pesticides or resistant varieties that are made absolete by the development of new chemicals or new resistant varieties and which depreciate as pests

Figure 11: *Yield of principal cash crops, 1949-1990*



Legend: ——— cotton; - - - - rapeseed; ..... peanuts; – — · tobacco; ·—··— sugar beets; ·——·— sugarcane.

Source: See appendix 8.

Note: Right-hand scale applies to sugar beets and sugarcane.

evolve to resist the chemicals or overcome the natural resistance of plants. To evaluate maintenance research that succeeds in preventing yields from falling, the appropriate comparison is not between current and previous yields but rather between current yields and what yields would have been otherwise.

Sources of Production Growth

While the rapid increase in the use of conventional inputs such as labor, capital, energy, irrigation infrastructure, and, especially, fertilizer (section 1.4) has contributed markedly to the growth in agricultural production, it represents only part of the story. The prima facie evidence suggests that improvements in allocative efficiency — arising in large measure from improvements in the quality of the agricultural labor force and a series of quite radical economic reforms — plus the productivity gains coming from the development and use of new agricultural technologies have also made important contributions. Statistically decomposing agricultural growth into its respective parts is a challenging but potentially fruitful line of enquiry.

The approach we took was to express aggregate agricultural output, Y, as a function of conventional inputs including land, labor, fertilizer, power, and area irrigated — denoted by X_i, i=1,...,5 — and a research investment variable, X_i=X_6. Also included were a set of regional dummy variables, D_g, g=2,...,7, presumed here to represent regional differences in social, economic, and natural endowments, and a time-specific dummy D_I,

capturing the effects of the post-1979 economic reforms. To keep the estimation exercise tractable, while still preserving a reasonable degree of flexibility, we chose the following functional form:

$$lnY_{jt} = \alpha_0 + (\alpha_1+\alpha_2 t)t + \sum_{i=1}^{6}(\beta_{1i}+\beta_{2i}t)lnX_{ijt}$$

$$+ \beta_l D_l + \sum_{g=2}^{7} (\beta_g+\beta_{lg}D_l) D_g + e_{jt} \qquad (1)$$

where provinces are denoted by j=1,..., 29, and annual observations for the years 1965, 70, 75, ..., 89 are denoted by t=1,6,11,...,24.

In this instance output is the value of agricultural production measured in 1980 local prices where agriculture is defined in a broad sense to include crop, livestock, forestry, and fisheries production. The land variable is taken to be land in agriculture as measured by area sown to crops plus the sown-area equivalent of grasslands. The labor variable is a person-year equivalent measure of the workers engaged in agricultural production, fertilizer inputs are a pure-nutrient equivalent estimate of the chemical and manurial fertilizers used in agriculture, the power variable is an aggregation of total machinery horsepower plus draft animals measured in "horsepower equivalents," while the irrigation variable is an estimate of the total irrigated area in agriculture.[9]

Investments in agricultural research eventually add to the stock of useful knowledge, which in turn leads to productivity gains in agriculture. But the production of new knowledge and technologies is a complex, risky, and time-intensive process. For instance, the lags between investing in research and developing new knowledge and agricultural technologies depend on a host of factors, not least of which are the commodity, scientific discipline, and research problems under consideration. There are further lags in the uptake of these new technologies and often site-specific variation in their productivity effects. Search, screening, and selection activities on the part of farmers, commune leaders, or whoever and the availability and effectiveness of extension services all play a role in this regard. Linking research investments directly to changes in an aggregate measure of agricultural output, as we do here, is clearly a reduced form specification but one that does enable us to examine quantitatively the productivity effects of research. Temporal and spatial differences in educational levels, extension activities, commodity mix, and the like, which also contribute to the measured growth of the agricultural sector, are subsumed in the time and dummy variables included in equation 1. This particular specification has the attractive feature of allowing the impact of research on agricultural output to be conditioned by these other variables through time. Moveover, it does this in a way that skirts some of the problems with multicollinearity and degrees of freedom that are associated with more general forms of the production function.

One of the thornier problems to resolve when including a research variable in an aggregate production function concerns the choice of an appropriate lag structure. Studies using long-run US data suggest that the productivity effects of agricultural research can persist for upwards of 30 years (Pardey and Craig 1989). There is some evidence that substantially shorter lag lengths may be appropriate for China, especially for the post-1965 period under study here. Stone (1990a) notes that some of the regional research systems in China move research on varietal improvement, at least for wheat and rice, through development, testing, and registration procedures and on to seed production and extension in just three to five years. In these more advanced regions, major varieties may well turn over every two to three years, with a national average of just twice this rate. Given that only the more applied and adaptive types of research performed at the provincial and prefectural levels are captured by the research variable in equation 1, the

[9] A more complete description of the data used here and their sources is given in Fan and Pardey (1992).

lag until research begins to have an impact on output may be relatively short and it may also take substantially less time before the research is either obsolete or fully depreciated. With this in mind,[10] we included a research variable that was a deflated, weighted sum of past research expenditures r_{t-i} given by

$$X_{6t} = \sum_{i=1}^{7} w_i r_{t-i} \qquad (2)$$

where the weights are defined as $w_1 = w_7 = 0.05$, $w_2 = w_6 = 0.1$, $w_3 = w_5 = 0.2$ and $w_4 = 0.3$. Given the unavoidable uncertainty concerning the structure of this lagged relationship, some sensitivity analyses were performed in which both the lag length and its form (as represented by the weights placed on the lagged research expenditures) were varied. This indicated that neither the qualitative nor quantitative details reported below were appreciably altered as a consequence.

To account for the separate contribution of each input (including research) to production growth in agriculture, the first derivative of (1) with respect to t was taken so that for each region g the rate of growth in total production can be expressed as

$$\partial lnY_t/\partial t = \sum_{i=1}^{6} \beta_{kt}\partial lnX_{it}/\partial t + \sum_{i=1}^{6} lnX_{it}\partial\beta_{kt}/\partial t$$

$$+(\beta_I+\beta_{Ig}D_g)\partial D_I/\partial t + \partial A_t/\partial t \qquad (3)$$

where

$$A_t = \alpha_0 + (\alpha_1 + \alpha_2 t)t + e_t \text{ and } \beta_{kt} = \beta_{1i} + \beta_{2i}t$$

The first term, $\Sigma\, \beta_{kt}\partial lnX_{it}/\partial t$, measures the effect of increased use of inputs on production growth. It is the sum of growth rates in inputs weighted by the relevant production elasticities. The impact of agricultural research on production growth is identified through this term. The second term, $\Sigma lnX_{it}\partial\beta_{kt}/\partial t$, captures the impact of biased technological change through its influence on the technical coefficients of production; a positive sign on this term indicates that biasing technology in this way enhances output. The third term, $(\beta_I+\beta_{Ig}D_g)\partial D_I/\partial t$, reflects the region-specific effects of institutional change on production growth, and the last term, $\partial A_t/\partial t$, captures the influences on output growth not already accounted for. This includes such things as neutral technological change plus region-specific differences in the quality and intensity of factor use, weather, and the like. Since our primary purpose is to measure the relative contribution of agricultural research on production growth, it is convenient to treat terms two and four as residual effects. Dividing each of the terms in equation 3 by $\partial \ln Y_t/\partial t$ and setting the left-hand side equal to 100 we can then interpret each of the right hand side terms as measuring the percentage contribution of each factor to regional and national production growth. The results of this calculation are presented in table 19.

For the whole country, agricultural output grew at an annual average rate of 4.9% over the 1965 to 1989 period. Fertilizers contributed most, accounting for 21% of this growth. The shift towards more energy-intensive production systems, that came with increased levels of mechanization throughout Chinese agriculture, accounted for about 12% of the growth in output. While the number of workers in agriculture grew by 1.6% per annum over the 1965-89 period (table 3) their low marginal products meant that only 3.4% of the growth in output could be attributed to labor. Land also made negligible contributions to growth over this period. The improvements in technical and allocative efficiency stemming from the series of institutional and economic reforms that got underway in the late 1970s accounted for 14% of the nation's growth in agricultural output. Our results suggest that the expansion of irri-

[10] Some Chinese research on this point (CAAS 1986) was also taken into account in the specification used here.

Table 19: *Accounting for Growth in Agricultural Output, 1965 to 1989*

	Region							
	Northeast	North	Northwest	Central	Southeast	Southwest	South	National
	%	%	%	%	%	%	%	%
Labor	2.9	1.8	4.8	4.7	1.9	6.6	3.4	3.4
Land	- 0.5	- 1.0	- 0.9	- 1.5	- 0.8	- 0.8	- 0.2	- 0.9
Fertilizer	23.7	22.8	10.6	26.4	23.4	22.3	21.7	21.3
Power	7.0	12.6	13.3	8.8	7.5	15.3	13.3	11.8
Irrigation	11.0	7.0	1.3	- 0.5	2.4	2.5	0.03	3.3
Research	30.2	8.6	14.4	19.8	35.2	23.3	19.6	19.8
Institutional change	14.2	18.6	16.1	- 7.4	10.2	12.6	- 1.7	13.8
Residual	11.2	29.5	40.5	49.7	20.2	18.3	43.6	27.6
Production growth[a]	100 (4.7)	100 (5.7)	100 (4.1)	100 (4.3)	100 (5.2)	100 (4.3)	100 (4.8)	100 (4.9)

Note: Production elasticities used in accounting for output growth are averages, i.e., $E_i = 1/2(E_{i1} + E_{in})$, where E_{i1} and E_{in} denote production elasticities of input i at year 1 and n, respectively.

[a] Bracketed figures represent annual rate of change of agricultural output.

gated area over this period has not contributed to the growth in agricultural output to the degree that might have been expected. But, as was evident from the data in table 9, much of the improvements in irrigation came about through an increase in the infrastructural aspects of irrigation (in particular, the mechanization of many irrigation facilities) rather than a growth in irrigated areas per se. Part of this infrastructural effect is likely to be captured by the power variable included in this study.

Despite the substantial growth effects arising from the increased use of purchased inputs such as energy, fertilizer, and irrigation services, agricultural research has accounted for almost 20% of the growth in Chinese agricultural output since 1965. Significantly, the growth promoting effects of research — and also many of the other inputs discussed here — were not uniformly felt throughout the country. Over one-third of the increase in agricultural output in the southeast stemmed from local investment in agricultural research, and in the northeast and southwest, research contributed around 30% and 23%, respectively, to the growth in agricultural output. In the north, a region that has experienced the highest rate of growth in agricultural output since 1965 (table 5), research accounted for only 9% of this growth. Much of the gains in this instance came from the increased use of fertilizers and energy as well as the market reforms of the past decade or so. In fact the limited contributions of research to output growth in the north, northwestern, and central regions no doubt stem in part from the relatively low levels of investments in agricultural research throughout these regions.

Chapter 5

CONCLUDING REMARKS AND OBSERVATIONS

Over the past 41 years (1949 to 1990) China's population has grown by 1.8% per annum reaching 1.14 billion by 1990. Although this relatively modest rate of growth slowed even further to 1.5% per annum over the past decade, it will be difficult to achieve any more reductions over the next decade because the population base is large and the substantial numbers of 1960s cohorts will enter reproductive age. So the demand for food will continue to grow, even abstracting from income effects. As industrialization and off-farm migration continue, the demand for marketable surpluses of cash crops will also increase. For these reasons the continued growth in and the changing structure of agricultural output will be the basis of Chinese economic development for some years to come.

An immediate policy response to this situation is to increase the use of agricultural inputs such as land, labor, chemical fertilizer, machinery, and so on. However, the potential for expanding the use of land in agriculture is particularly limited. It is conservatively estimated that there remain just 13 million hectares of new land in the country that has the potential to be brought in to crop production. This land is generally of poorer quality and located in the more remote areas of Heilongjiang Province and the Xinjiang autonomous region. If all these lands were reclaimed, it is unlikely that more than 10 million hectares of additional cropped area would be forthcoming (Sun 1987). And there are about 1.2 million square kilometers of land in agriculture that is susceptible to erosion. Since the mid-1960s, three million hectares have also been lost to desertification, while 23% of the total grassland area has suffered varying degrees of degeneration. Coupled with the expansion of cities and industries, additional areas (especially of high quality) will be given over to nonagricultural uses. To summarize, the total land input in agriculture, especially in quality-adjusted terms, will most likely decrease rather than increase in the near future.

In the context of a declining land base, the increased use of labor will add little to total production, given the same level of technology and other conventional inputs. More intensive use of modern inputs, especially chemical fertilizers, offers one possibility for increasing output. Although the average rate of fertilizer application per unit of land in China is higher than in most developing countries, the potential output increase through the use of more fertilizer is still substantial in some regions. They include the northeast, northwest, north, and southwest. Without increased efforts from agricultural research, however, the impact of these modern inputs on production growth will be limited because their marginal returns will be lower than they otherwise would be. In addition, the competing demands from the nonfarm sector for the resources embodied in these modern inputs will place growing constraints on their use in agriculture.

Agricultural research, along with the increased use of conventional inputs and institutional reforms, has contributed to the rapid production growth over the past several decades. Research accounted for about 20% of

the growth in agricultural output from 1965 to 1989 and was the second largest source of production growth. But it is worrisome to observe that the rates of growth after 1985 declined to the levels witnessed prior to the institutional reforms that got underway in the late 1970s. This suggests that the productivity effects of this initial round of institutional reforms may well be largely exhausted. While further such reforms offer the promise of additional growth, the new technologies, techniques, and know-how coming from agricultural research are likely to account for an ever-larger share of the increments of agricultural output over the longer term.

Developing a coherent and productive research system that contributes effectively to sustaining growth in agricultural output is well served by clearly articulated research policies. But this policy formulation process is especially difficult for a country such as China where disparate policymakers and stakeholders operate across national, provincial, prefectural, and local levels of government. To make matters even more problematic, research is often seen as an instrument of social policy. In this role it is called upon to address a multiplicity of equity and security concerns in addition to more focussed growth or efficiency objectives. What is not generally appreciated is that diverting attention towards nonefficiency objectives necessarily involves some foregone growth or productivity gains. The nature and size of these opportunity costs are not well understood[1] and in the case of agricultural research may be particularly large in light of the other policy instruments (e.g., investing in education, improved sanitation, health care, and the like) that governments have at their disposal. Improved information and analysis in this regard would provide the basis for more informed research policy design, priority-setting and coordination across and within all levels of government.

Aside from the difficulties of building a meaningful consensus on the objectives of China's agricultural research program, there are a host of policy design and priority-setting concerns relating to the *means* by which research can address these stated *objectives*. For example, choices need to be made about the overall size of the public commitment to agricultural research (and the mechanisms used to finance this commitment); the commodity, site, problem, and technology focus of the research program; the appropriate division of labor and research emphasis between research agencies in the different ministries and levels of government, and so on. All of these decisions have a direct bearing on the degree to which research contributes to the growth of the agricultural sector as well as any distributional or security concerns that may be pertinent. A good number of these issues have been touched on at various points throughout this monograph. But in many instances the more in-depth data and supporting analysis required for specific policy recommendations to be made are presently not available.[2] So the policy perspectives reported here indicate broad areas of concern rather than particular points of action.

Certainly the overwhelming size and institutional disparity of the Chinese system raise an immediate set of policy concerns. Determining whether the level of public investment in agricultural research is in any sense optimal or appropriate is a central point of debate among policymakers. The Chinese agricultural research system dwarfs most other NARSs, whether viewed in research personnel or (real) expenditure terms. This belies the fact that in relative terms — particularly when compared with the value of agricultural output — agricultural research investments in China

[1] A recent study of the impact of high-yielding rice varieties in South India by Hazell and Ramasamy (1991) demonstrates how difficult it is to identify the distributional consequences of technical change.

[2] In this respect China has been under-studied when compared with systems such as the United States, New Zealand, Australia and even other less-developed country NARSs in the Asian region. See Evenson and Pray (1991), for example.

are only on par with those in other Asian NARSs; they are less than one-fifth those in mo -developed countries. Deciding whether an increase in the intensity of agricultural research investments in China is warranted will require the government to weigh up the competing demands for its scarce resources. Certainly China has a declining comparative advantage in agriculture. However, the evidence presented in section 4.2 implies that the social rate of return to agricultural research in China over the past several decades has been high. When extrapolating this experience to the next few decades, it should be remembered that for many crops, the country's yields are already high by international standards. But these high yields are a two-edged sword. On the one hand they would suggest that the research-induced yield gains for crops such as rice may not be as substantial in the future as they have been in the past. Offsetting this tendency is the likelihood that there are substantial benefits to be wrested from maintenance research that seeks to replace or replenish the (yield) gains from past research endeavors.

The large degree of spatial diversity in production systems, agroecological zones, and socioeconomic characteristics give rise to their own set of institutional design and resource deployment issues. The location-specific nature of much agricultural technology requires decentralization of agricultural research, whereas the opportunities for economies of scale and economies of scope that characterize the production of knowledge or information point to some centralization of research operations. Balancing these conflicting requirements is a critical problem in the design of an efficient organizational structure for China. In any event, there is a clear need to improve coordination and to harmonize research agendas across the various levels of government and give more serious attention to developing functional links between research and extension activities. While complete harmonization is neither possible nor even desirable (given the necessarily different objectives of the national, provincial, and prefectural governments), there may be substantial economies of scope and scale to be realized through improvements in this area. Certainly a much clearer understanding of the potential to transfer research results from one specific locale to another will aid decision making in this regard.

If the recent pace of change in agriculture and the Chinese economy as a whole continues over the ensuing decades, the derived demand for technological goods and services will radically change with it. As the value-added in agriculture increasingly moves off farm, it will open up the possibility of privatizing hitherto public aspects of the country's NARS, particularly those aspects concerned with post-harvest and purchased-input technologies. While this would certainly change the role of the publicly supported research agencies, the need for continued investment in upstream kinds of research at the national level and adaptive kinds of research at the more local levels — especially the crop, livestock, and resource management research so essential to sustaining growth in agriculture but of less commercial interest to private investors — will continue unabated. A good deal of analysis and on-going consultations between all groups of policymakers and stakeholders will be required if the system is to keep abreast of the rapidly changing environment in which it finds itself.

REFERENCES

General References

Ahmad, Syed. 1966. "On the Theory of Induced Innovation." *Economic Journal* Vol. 76, pp. 344-57.

Alston, Julian M. and Philip G. Pardey. 1991. "Technical Change, Constraints and Incentives: The Damaging Consequences of Getting Policies Wrong." Paper presented at the World Bank conference on "Agricultural Technology: Current Policy Issues for the International Community and the World Bank," Airlie House, 21-23 October 1991.

An, Xij. 1985. "On the Reform of Price System and Adjustments in Price Policy." *Problems of Agricultural Economics* No. 10, p. 23 (in Chinese).

Anderson, Kym. 1983 "Economic Growth, Comparative Advantage and Agricultural Trade of Pacific Rim Countries." *Review of Marketing and Agricultural Economics* Vol. 51, No. 3, pp. 231-248.

Anderson, Kym. 1990. *Changing Comparative Advantages in China; Effects on Food, Feed and Fibre Markets.* Paris: Organization for Economic Cooperation and Development.

Barker, Randolph, Radha Sinha and Beth Rose. 1982. *The Chinese Agricultural Economy.* Boulder: Westview Press, Inc.

BAU. 1989. *Beijing Agricultural University.* Beijing: Knowledge Publishing House (in Chinese).

Berner, Boel. 1979. "The Organization and Planning of Scientific Research in China Today." Discussion Paper Series 134. Sweden: Research Policy Institute, University of Lund.

Billgren, Boel and Jon Sigurdson. 1977. *An Estimate of Research and Development Expenditures in the People's Republic of China in 1973.* Industry and Technology Occasional Paper No. 16. Paris: OECD Development Center.

Binswanger, Hans P. and Vernon W. Ruttan. 1978. *Induced Innovation — Technology, Institutions and Development.* Baltimore: Johns Hopkins University Press.

Boyce, James K. and Robert E. Evenson. 1975. *National and International Agricultural Research and Extension Programs.* New York: Agricultural Development Council.

CAAS. 1984. *Regionalization of Crop Production in China.* Beijing: Agricultural Publishing House (in Chinese).

CAAS. 1986. "Research Report on Agricultural Research Funding." December. Beijing: Chinese Academy of Agricultural Sciences. Mimeo (in Chinese).

CAAS. 1987. *Thirty Years of the Chinese Academy of Agricultural Sciences, 1957-1987.* Beijing: Chinese Academy of Agricultural Sciences (in Chinese).

CAAS. 1989. *Chinese Academy of Agricultural Sciences.* Beijing: Scientech Documentation and Information Center, Chinese Academy of Agricultural Sciences (in Chinese).

CAF. 1990. *Chinese Academy of Forestry: An Introduction to CAF.* Beijing: Chinese Academy of Forestry (in Chinese).

CAFS. 1990. *Chinese Academy of Fishery Sciences: An Introduction to CAFS.* Beijing: Chinese Academy of Fishery Sciences (in Chinese).

CAS. 1980. *A General Treatise on Chinese Agricultural Geography.* Beijing: Agricultural Publishing House (in Chinese).

Chen, Dunyi and Jishan Hu. 1983. *Chinese Economic Geography.* Beijing: China Perspective Publishing House (in Chinese).

Conroy, Richard. 1987. "The Disintegration and Reconstruction of the Rural Science and Technology System: Evaluation and Implications." In *The Reemergence of the Chinese Peasantry*, edited by Ashwanti Saith. London: Croom Helm.

Craig, Barbara J. and Philip G. Pardey. 1990. "Patterns of Agricultural Development in the United States." Staff Paper Series P90-72. University of Minnesota, St Paul. December.

Craig, Barbara J., Philip G. Pardey and Johannes Roseboom. 1991. "Patterns of Agricultural Growth and Economic Development." In *Agricultural Research Policy: International Quantitative Perspectives*, edited by Philip G. Pardey, Johannes Roseboom and Jock R. Anderson. Cambridge: Cambridge University Press.

de Janvry, Alain and Jean-Jacques Deither. 1985. "The Political Economy of Rate and Bias of Technological Innovation in Agriculture." Working Paper No. 341. Department of Agricultural and Resource Economics, University of California, Berkley.

Previous Page Blank

Delman, Jørgen. 1988. *The Agricultural Extension System in China*. Network Paper 3. Agricultural Administration Unit, Overseas Development Institute, Agricultural Administration Network, London.

Delman, Jørgen. 1991. *Agricultural Extension in Renshou County, China —A Case Study of Bureaucratic Intervention for Agricultural Innovation and Change*. Aarhus, Denmark: Institute of East Asian Studies, University of Aarhus.

Division of Economic Geography, The Institute of Geography, Chinese Academy of Sciences. 1983. *The Distribution of Agricultural Production in China*. Beijing: Agricultural Publishing House (in Chinese).

Echeverría, Ruben G., ed. 1990. *Methods for Diagnosing Research System Constraints and Assessing the Impact of Agricultural Research*. Vol. II, *Assessing the Impact of Agricultural Research*. The Hague: International Service for National Agricultural Research.

Evenson, Robert E. and Yoav Kislev. 1975. *Agricultural Research and Productivity*. New Haven: Yale University Press.

Evenson, Robert E. and Carl E. Pray. 1991. *Research and Productivity in Asian Agriculture*. Ithaca: Cornell University Press.

Fan, Shenggen. 1990. *Regional Productivity Growth in China's Agriculture*. Boulder: Westview Press.

Fan, Shenggen. 1991. "Effects of Technological Change and Institutional Reform on Production Growth in Chinese Agriculture." *American Journal of Agricultural Economics* Vol. 73, No. 2, pp. 266-275.

Fan, Shenggen and Vernon Ruttan. 1992. "Technical Change in Centrally Planned Economies." *Agricultural Economics* Vol. 6, No. 4, pp. 301-314.

Fan, Shenggen and Philip G. Pardey. 1992. "Research, Productivity and Output Growth in Chinese Agriculture." International Service for National Agricultural Research, The Hague. Mimeo.

Fang, Zhou. 1987. "Organization and Structure of the National Agricultural Research System in China." Paper presented at the International Workshop on Agricultural Research Management, International Service for National Agricultural Research, The Hauge.

FAO AGROSTAT. 1991. Diskettes. Rome: Food and Agriculture Organization of the United Nations.

Garnant, Ross. 1988. "Asia's Giant." *Australian Economic Papers* Vol. 27, No. 51, pp. 173-186.

Graham-Tomasi, T. 1990a. "Valuation of Nontimber Services of Forests: Economic Concepts in a Policy Context." In *Valuing the Contributions of Forests to Human Welfare: Theory and Practice*, edited by H.M. Gregersen and A. L. Lundgren. St. Paul: Forestry for Sustainable Development Program, University of Minnesota.

Graham-Tomasi, T. 1990b. "Techniques for the Valuation of the Services of Natural Forests." In *Valuing the Contributions of Forests to Human Welfare: Theory and Practice*, edited by H.M. Gregersen and A. L. Lundgren. St. Paul: Forestry for Sustainab Development Program, University of Minnesota.

Gunasekera, H. Don B.H., et al. 1991. "Agricultur Policy Reform in China." Discussion Paper 91. Australian Bureau of Agricultural and Resource Eco nomics, Canberra.

Guo, Wentao and Longgong Cao. 1989. *The Mode History of Science and Technology in China*. Beijin Chinese Agricultural Science and Technology Pre (in Chinese).

Handbook of Economics for Technology (Agricultur Editing Committee. 1983. *Handbook of Economic for Technology (Agriculture)*. Beijing: Agricultur Publishing House (in Chinese).

Hayami, Yujiro. 1975. "Agricultural Research Organiz tion in Economic Development: A Review of th Japanese Experience." In *Agriculture in Develop ment Theory* edited by Lloyd G. Reynolds. Ne Haven: Yale University Press.

Hayami, Yujiro and Vernon W. Ruttan. 1970. "Facto Prices and Technical Change in Agricultural Deve opment: The United States and Japan, 1880-1960. *Journal of Political Economy*. Vol. 78, pp. 1115 1141.

Hayami, Yujiro and Vernon W. Ruttan. 1971. *Agricu tural Development: An International Perspective* Baltimore: Johns Hopkins University Press.

Hayami, Yujiro and Vernon W. Ruttan. 1985. *Agricu tural Development: An International Perspective* Baltimore: Johns Hopkins University Press.

Hazell, Peter B.R. and C. Ramasamy. 1991. *The Gree Revolution Reconsidered*. Baltimore: Johns Hopkin University Press.

Hsu, Robert C. 1982. *Food for One Billion — China' Agriculture Since 1949*. Boulder: Westview Press.

IRRI. 1978. *Rice Research and Production in China: A International Rice Research Institute Team's View* Los Baños, Philippines: International Rice Researc Institute.

JAAS. 1987. *Jiangsu Academy of Agricultural Sciences* Nanjing: Jiangsu Academy of Agricultural Science (in Chinese).

Jain, H. Krishan. 1989. "Organization and Structure i National Agricultural Research Systems." Workin Paper No. 21. International Services for Nationa Agricultural Research, The Hague.

Judd, Ann M., James K. Boyce and Robert E. Evenson 1983. "Investing in Agricultural Supply." Discussio Paper No. 442. New Haven: Economic Growth Cen ter, Yale University.

Kislev, Yoav and Willis L. Peterson. 1982 "Prices, Tech nology, and Farm Size." *Journal of Political Econ omy* Vol. 90, No. 3, pp. 578-595.

Kravis, Irving. 1980. "An Approximation of the Relativ Real Per Capita GDP of the People's Republic o China." In *Report of the CSCPRC Economic Delega tion to the People's Republic of China*. Washington DC: National Academy of Sciences, pp. 64-86.

Krueger, Anne O. 1977. *Growth, Distortions, and Patterns of Trade among Many Countries*. Princeton, NJ: Princeton Studies in International Finance Series.

Lardy, R. Nicholas. 1983. *Agriculture in China's Modern Economic Development*. Cambridge: Cambridge University Press.

Lardy, R. Nicholas. 1985. "Agricultural Reform in China." A background paper prepared for the World Bank's *World Development Report 1986*, Seattle: University of Washington.

Li, Guanglin. 1990. "The National Natural Science Foundation of China: Its Background, Present, and Guiding Principles." *Science and Public Policy* Vol. 7, No. 4, pp. 235-241.

Lin, Justin Yifu. 1988. "The Household Responsibility System in China's Agricultural Reform: A Theoretical and Empirical Study." *Economic Development and Cultural Change*. Vol. 36, No. 3, pp. 5199-5224.

Lin, Justin Yifu. 1990. "Farming Institutions, Food Policy, and Agricultural Development in China." In *Sharing Innovation: Global Perspectives on Food, Agriculture, and Rural Development*. edited by N.G. Kottle. Washington D.C.: Smithsonian Institute Press.

Lin, Justin Yifu. 1991a. "The Household Responsibility System Reform and the Adoption of Hybrid Rice in China." *Journal of Development Economics* Vol. 36, No. 3, pp. 353-372.

Lin, Justin Yifu. 1991b. "Education and Innovation Adoption in Agriculture: Evidence from Hybrid Rice in China." *American Journal of Agricultural Economics* Vol. 73, No. 3, pp. 713-723.

Lin, Justin Yifu. 1991c. "Public Research Resource Allocation in Chinese Agriculture: A Test of Induced Technological Innovation Hypotheses." *Economic Development and Cultural Change* Vol. 40, No. 1, pp. 55-73.

Lin, Justin Yifu. 1992. "Rural Reforms and Agricultural Growth in China." *American Economic Review* Vol. 82, No. 1, pp. 34-51.

Liu, Guoguang, Liang Wensen et al. 1987. *China's Economy in 2000*. Beijing: New World Press.

Lu, Liangshu. 1985. "Current Status and Policy of Agricultural Sciences and Technology Development in the People's Republic of China." A Consultancy Report prepared for FAO. Regional Office for Asia and the Pacific, Bangkok.

Maruyama, Nobuo. 1990. *Industrialization and Technical Development in China*. Tokyo: Institute of Developing Economies.

Major Events in Chinese Agriculture Editing Committee. 1981 and 1984. *Major Events in Chinese Agriculture*. Beijing: Agricultural Publishing House. (in Chinese)

MOA and SSB. 1989. *Forty Years of Chinese Agriculture*. Beijing: Agricultural Publishing House (in Chinese).

McMillan, John, John Whalley and Lijing Zhu. 1989. "The Impact of China's Economic Reforms on Agricultural Productivity Growth." *Journal of Political Economy* No. 97, pp. 781-807.

NEAC. 1989. *Northeast Agricultural College, 1948-1988*. Harbin: Northeast Agricultural College (in Chinese).

Pannel, W. Glifton and J.C.Lawrence Ma. 1983. *China: The Geography of Development and Modernization*. V. H. Winston and Sons.

Pardey, Philip G. and Barbara Craig. 1989. "Causal Relationships Between Public Sector Agricultural Research Expenditures and Output." *American Journal of Agricultural Economics* Vol. 71, No. 1, pp. 9-19.

Pardey, Philip G., M. Sandra Kang and Howard Elliott. 1989. "Structure of Public Support for National Agricultural Research Systems: A Political Economy Perspective." *Agricultural Economics* Vol. 3, No. 4 (December) pp. 261-278.

Pardey, Philip G. and Johannes Roseboom. 1989. *ISNAR Agricultural Research Indicator Series: A Global Data Base on National Agricultural Research Systems*. Cambridge: Cambridge University Press.

Pardey, Philip G., Johannes Roseboom and Jock R. Anderson, eds. 1991. *Agricultural Research Policy: International Quantitative Perspectives*. Cambridge: Cambridge University Press.

Pardey, Philip G. and Stanley Wood. 1991. "Targeting Research by Agricultural Environments." Paper presented at the World Bank conference on "Agricultural Technology: Current Policy Issues for the International Community and the World Bank." Airlie House, 21-33 October 1991.

Pardey, Philip G., Johannes Roseboom and Barbara J. Craig. 1992. "A Yardstick for International Comparisons: An Application to National Agricultural Research Expenditures." *Economic Development and Cultural Change* Vol. 40, No. 2, pp. 333-349.

Perkins, Dwight. 1969. *Agricultural Development in China 1368-1968*. Chicago: Aldine Publishing Company.

Perkins, Dwight. 1988. "Reforming China's Economic System." *Journal of Economic Literature* Vol. XXVI, pp. 601-645.

Perkins, Dwight and Shahid Yusuf. 1984. *Rural Development in China*. Baltimore: Johns Hopkins University Press.

Peterson, Willis and Yujiro Hayami. 1977. "Technical Change in Agriculture." In *A Survey of Agricultural Economics Literature*, Vol. 1, edited by Lee Martin. Minneapolis: University of Minnesota Press.

Roe, Terry L. and Philip G. Pardey. 1991. "Economic Policy and Investment in Rural Public Goods: A Political Economy Perspective." In *Agricultural Research Policy: An International Quantitative Perspective* edited by Philip G., Johannes Roseboom and Jock R. Anderson. Cambridge: Cambridge University Press.

Ruttan, Vernon W. 1985. Trip Report to China. Department of Agricultural and Applied Economics, University of Minnesota. Unpublished notes.

Ruttan, Vernon W. 1982. *Agricultural Research Policy*. Minneapolis: University of Minnesota Press.

Ruttan, Vernon W. 1978. "Induced Institutional Change." In *Induced Innovation: Technology, Institutions, and Development*, edited by Hans P. Binswanger and Vernon W. Ruttan. Baltimore and London: The Johns Hopkins University Press.

Schultz, Theodore W. 1964. *Transforming Traditional Agriculture*. Chicago: University of Chicago Press.

Schultz, Theodore W. 1981. *Investing in People*. Berkeley: University of California Press.

Shen, Jinpu. 1990. "Organization of Chinese Agricultural Research." Oral presentation at International Service for National Agricultural Research.

Sicular, Terry. 1988. "Plan and Market in China's Agricultural Commerce." *Journal of Political Economy* Vol 92, No. 2., pp. 283-307.

Solow, Robert. 1957. "Technical Change and the Aggregate Production Function." *Review of Economics and Statistics* Vol. 39 (August): pp. 321-322.

SSTC. 1986. *Statistical Data on Science and Technology of 1985*. Beijing: State Science and Technology Commission of PRC (in Chinese).

SSTC. 1987, 1988, 1989 and 1990. *Guide to China's Science and Technology Policy (various years)*. Beijing: State Science and Technology Commission of PRC (in Chinese).

Star, Spencer. 1974. "Accounting for the Growth of Output." *American Economic Review* Vol. 64, No. 1, pp. 123-35.

Stavis, Benedict. 1978. "Agricultural Research and Extension Services in China." *World Development* Vol. 6, pp. 631-645.

STCMA and STDMA, 1989. *Forty Years of Agricultural Science and Technology in China*. Beijing: Agricultural Publishing House (in Chinese).

Stone, Bruce. 1990a. "Evolution and Diffusion of Agricultural Technology in China." In *Sharing Innovation: Global Perspectives on Food, Agriculture, and Rural Development*, edited by N.G. Kottle. Washington DC: Smithsonian Institute Press.

Stone, Bruce. 1990b. "The Next Stage of Agricultural Development: Implications for Infrastructure, Technology and Institutional Priorities." IFPRI reprint No. 191. Washington, DC: International Food Policy Research Institute.

SSB. 1987. *1% Population Survey*. Beijing: China Statistical Press (in Chinese).

Summers, Robert and Alan Heston. 1991. "The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950-1988." *Quarterly Journal of Economics* Vol. CVI, pp. 327-68.

Sun, Han. 1937. "9.6 Million Square Kilometers of Territory." In *Feeding a Billion*, edited by Wittwer Stkvab. East Lansing: Michigan State University Press.

Suttmeier, Richard P. 1989. "China: The Search for Strategies". In *Learning by Doing: Science and Technology in the Developing World* edited by Aaron Segal. Boulder: Westview Press.

Tang, Anthony and Bruce Stone. 1980. *Food Production in PRC*. Washington DC: International Food Policy Research Institute.

Tang, Anthony. 1984. *An Analytical and Empirical Investigation of Agriculture in Mainland China: 1952-1980*. Taibei: Chung-Hua Institute for Economic Research.

Tang, Tong B. 1984. *Science and Technology in China*. London: Longman.

Thirtle, Colin G. and Vernon W. Ruttan. 1987. *The Role of Demand and Supply in the Generation and Diffusion of Technical Change*. New York: Harwood Academic Publishers.

UNESCO. 1985. *Science and Technology in Countries of Asia and the Pacific*. Science Policy Studies and Documents No. 52. Paris: UNESCO.

Wittwer, Sylvan, Youtai Yu, Han Sun and Lianzhang Wang. 1987. *Feeding a Billion*. East Lansing: Michigan State University Press.

Wen, Guanzhong J. 1989. "The Current Land Tenure System and Its Impact on Long Term Performance of the Farming Sector: The Case of Modern China." unpublished PhD dissertation. Chicago: University of Chicago.

Wong, Lung-Fai. 1986. *Agricultural Productivity in the Socialist Countries*. Boulder: Westview Press Inc.

Wong, Lung-Fai and Vernon W. Ruttan. 1988. "Sources of Differences in Agricultural Productivity Growth Among Socialist Countries." In *Application of Modern Production Theory: Efficiency and Productivity* edited by A. Dogramaci and R. Fare. Boston: Kluwer Academic Publishers.

World Bank. 1981a. *China: Socialist Economic Development* Vol. 1, The Economy, Statistical System and Basic Data Washington, DC: World Bank.

World Bank. 1981b. *China: Socialist Economic Development*. Annex C: Agricultural Development. Washington, DC: World Bank.

World Bank. 1982. *China: Agricultural Education and Research Project*. A Staff Appraisal Report. Washington, DC: World Bank.

World Bank. 1984. *China: Second Agricultural Research Project*. A Staff Appraisal Report. Washington, DC: World Bank.

World Bank. 1987. *China: The Livestock Sector*. A World Bank Country Study, Washington, DC: World Bank.

World Bank. 1991a. *World Development Report 1991*. Oxford: Oxford University Press.

World Bank. 1991b. *China: Options for Reform in the Grain Sectors*. A World Bank Country Study, Washington, DC: World Bank.

ZAAS. 1983. *Zhejiang Academy of Agricultural Sciences.* Hangzhou: Zhejiang Academy of Agricultural Sciences (in Chinese).

Published Data Sources

Berner, Boel. 1979. "The Organization and Planning of Scientific Research in China Today." Discussion Paper Series 134. Sweden: Research Policy Institute, University of Lund.

Billgren, Boel and Jon Sigurdson. 1977. *An Estimate of Research and Development Expenditures in the People's Republic of China in 1973.* Industry and Technology Occasional Paper No. 16. Paris: OECD Development Center.

Boyce, James K. and Robert E. Evenson. 1975. *National and International Agricultural Research and Extension Programs.* New York: Agricultural Development Council, Inc.

China Agricultural Yearbook Editing Committee. 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987 1988, 1989 and 1990. *China's Agricultural Yearbook (various years).* Beijing: Agricultural Publishing House (in Chinese).

China Forestry Yearbook Editing Committee. 1987. *China Forestry Yearbook, 1949-1986.* Beijing: China Forestry Press (in Chinese).

FAO AGROSTAT. 1991. Diskettes. Rome: Food and Agriculture Organization of the United Nations.

FAO. 1991 and various issues. *FAO Yearbook, Fishery Statistics.* Rome: Food and Agriculture Organization of the United Nations.

Judd, Ann M., James K. Boyce and Robert E. Evenson. 1983. "Investing in Agricultural Supply." Discussion Paper No. 442. New Haven: Economic Growth Center, Yale University.

Lu, Liangshu. 1985. "Current Status and Policy of Agricultural Sciences and Technology Development in the People's Republic of China." A Consultancy Report prepared for FAO. Regional Office for Asia and the Pacific, Bangkok.

Ministry of Agriculture. 1985, 1987, 1988, 1989 and 1990. *China's Agricultural Statistical Materials (various years).* Beijing: China Agricultural Publishing House (in Chinese).

Ministry of Agriculture. 1988, 1989 and 1990. *Statistical Materials on Agricultural Science and Technology (various years).* Beijing: Ministry of Agriculture (in Chinese).

Ministry of Agriculture. 1989. *China's Rural Economic Statistical Materials, 1949-1986.* Beijing: Agricultural Publishing House (in Chinese).

Ministry of Agriculture and State Statistical Bureau. 1989. *Forty Years of Chinese Agriculture.* Beijing: Agricultural Publishing House (in Chinese).

Pardey, Philip G. and Johannes Roseboom. 1989. *ISNAR Agricultural Research Indicator Series: A Global Data Base on National Agricultural Research Systems.* Cambridge: Cambridge University Press.

Pardey, Philip G., Wilhelmina Eveleens, Edi Abdurachman and Stanley Wood. 1992. "Public Investment in Indonesian Agricultural Research and Extension." ACIAR-ISNAR Project Paper. Canberra and The Hague: ACIAR/ISNAR (forthcoming).

Roe, Terry L. and Philip G. Pardey. 1991. "Economic Policy and Investment in Rural Public Goods: A Political Economy Perspective." In *Agricultural Research Policy: An International Quantitative Perspective,* edited by Pardey, Philip G., Johannes Roseboom and Jock R. Anderson. Cambridge: Cambridge University Press.

SSTC. 1986. *Statistical Data on Science and Technology of 1985.* Beijing: State Science and Technology Commission of PRC (in Chinese).

SSTC. 1987, 1988, 1989 and 1990. *Guide to China's Science and Technology Policy (various years).* Beijing: State Science and Technology Commission of PRC (in Chinese).

State Statistical Bureau. 1989. *China's Trade Materials, 1988.* Beijing: China Statistical Press.

State Statistical Bureau. 1980. *National Agricultural Statistics for 30 Years, 1949-1979.* Beijing: State Statistical Bureau (in Chinese).

State Statistical Bureau. 1987. *1% Population Survey.* Beijing: China Statistical Press (in Chinese).

State Statistical Bureau, Agricultural Statistics Division. 1985, 1986, 1987, 1988, 1989 and 1990. *China's Rural Statistical Yearbook (various issues).* Beijing: China Statistical Press. (in Chinese)

State Statistical Bureau, Editorial Office. 1985, 1986, 1987, 1988, 1989, 1990 and 1991. *Statistical Abstract (various years).* Beijing: China Statistical Press (in Chinese).

State Statistical Bureau, Editorial Office. 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990 and 1991. *China's Statistical Yearbook (various years).* Beijing: China Statistical Press (in Chinese).

State Statistical Bureau, National Economy Division. 1987. *National Income Statistics, 1949-1985.* Beijing: China Statistical Press (in Chinese).

State Statistical Bureau, Social Statistics Division. 1985, 1987, 1988, 1989 and 1990. *China's Social Statistical Materials (various years).* Beijing: China Statistical Press (in Chinese).

State Statistical Bureau, Social Statistics Division. 1987. *China's Labor and Wage Statistical Materials, 1949-1985.* Beijing: China Statistical Press (in Chinese).

Stavis, Benedict. 1978. "Agricultural Research and Extension Services in China." *World Development* Vol. 6, pp. 631-645.

STCMA and STDMA. 1989. *Forty Years of Agricultural Science and Technology in China.* Beijing: Agricultural Publishing House (in Chinese).

Summers, Robert and Alan Heston. 1991. "The Penn World Table (Mark 5): An Expanded Set of Interna-

tional Comparisons, 1950-1988." *Quarterly Journal of Economics* Vol. CVI, pp. 327-68.

Swanson, B.E., B.J. Farner and R. Bahal. 1991. *International Directory of Agricultural Extension Organizations.* Rome: Food and Agriculture Organization of the United Nations.

Wu, Yuan-li and Robert B. Sheeks. 1970. *The Organization and Support of Scientific Research and Development in Mainland China.* New York: Praeger Publishers, Inc.

Appendices

Time-series statistics on Chinese agriculture have undergone significant revision in recent years. While it is the case that these data have become more accessible, many series are still only published in Chinese or must be compiled from disparate and in some cases not readily available sources. For these reasons we include here some of the recently released data of more general interest that were used in constructing the graphs and tables throughout this report, as well as the new agricultural research and development statistics compiled for this study.

All of the agricultural output and input data reported here relate strictly to primary agricultural production and related sideline activities. These series explicitly exclude nonfarm rural industries and service-related activities. The constant priced aggregates reported here were derived by taking physical output data at the commodity level and weighting by 1980 average prices received by farmers (*China's Statistical Yearbook 1991*, 1991, pp. 73, 384).

Appendix 1: *Regional Labor Productivity, Constant 1980 Yuan per Agricultural Worker*

Year	Region							National
	Northeast	North	Northwest	Central	Southeast	Southwest	South	
1965	785	337	673	503	436	309	450	440
1970	776	357	590	503	439	325	444	433
1975	999	475	705	589	507	341	443	510
1976	889	444	653	558	515	321	482	491
1977	905	449	621	562	488	347	524	497
1978	1,170	551	713	650	617	439	627	609
1979	1,463	620	705	764	739	475	600	673
1980	1,600	623	762	683	678	495	576	659
1981	1,620	639	793	723	815	503	597	698
1982	1,666	686	862	793	824	545	672	747
1983	1,859	776	902	802	827	573	687	704
1984	2,010	885	996	872	960	627	740	884
1985	1,880	956	1,131	967	1,118	651	846	960
1986	1,991	945	1,161	1,011	1,187	667	883	988
1987	2,080	1,025	1,188	1,015	1,239	675	947	1,032
1988	2,169	1,047	1,265	989	1,274	679	985	1,052
1989	1,900	1,072	1,282	998	1,247	680	1,043	1,052
1990	2,286	1,101	1,408	1,025	1,260	698	1,094	1,102
Growth rate[a]								
	%	%	%	%	%	%	%	%
1965-80	4.9	4.2	0.8	2.1	3.0	1.8	1.7	2.7
1980-85	3.2	8.9	8.2	7.2	10.5	5.1	8.0	7.7
1985-90	4.0	2.9	4.4	1.2	2.4	1.4	5.3	3.3
1965-90	*4.4*	*4.8*	*3.0*	*2.9*	*4.3*	*2.4*	*3.6*	*3.7*

Source: Agricultural labor after 1979 is taken from *China's Rural Statistical Yearbook* (various years). Labor inputs before 1979 are estimated from agricultural population, where agricultural population is taken from *National Agricultural Statistics for 30 Years, 1949 to 1979* (1980).

Note: Labor productivity is measured as total agricultural production divided by total labor input measured in full-time equivalent years. Rural nonfarm industry is excluded from agricultural production.

[a] Compound annual growth rates.

Appendix 2: *Regional Land Productivity, Constant 1980 Yuan per Hectare of Agricultural Land*

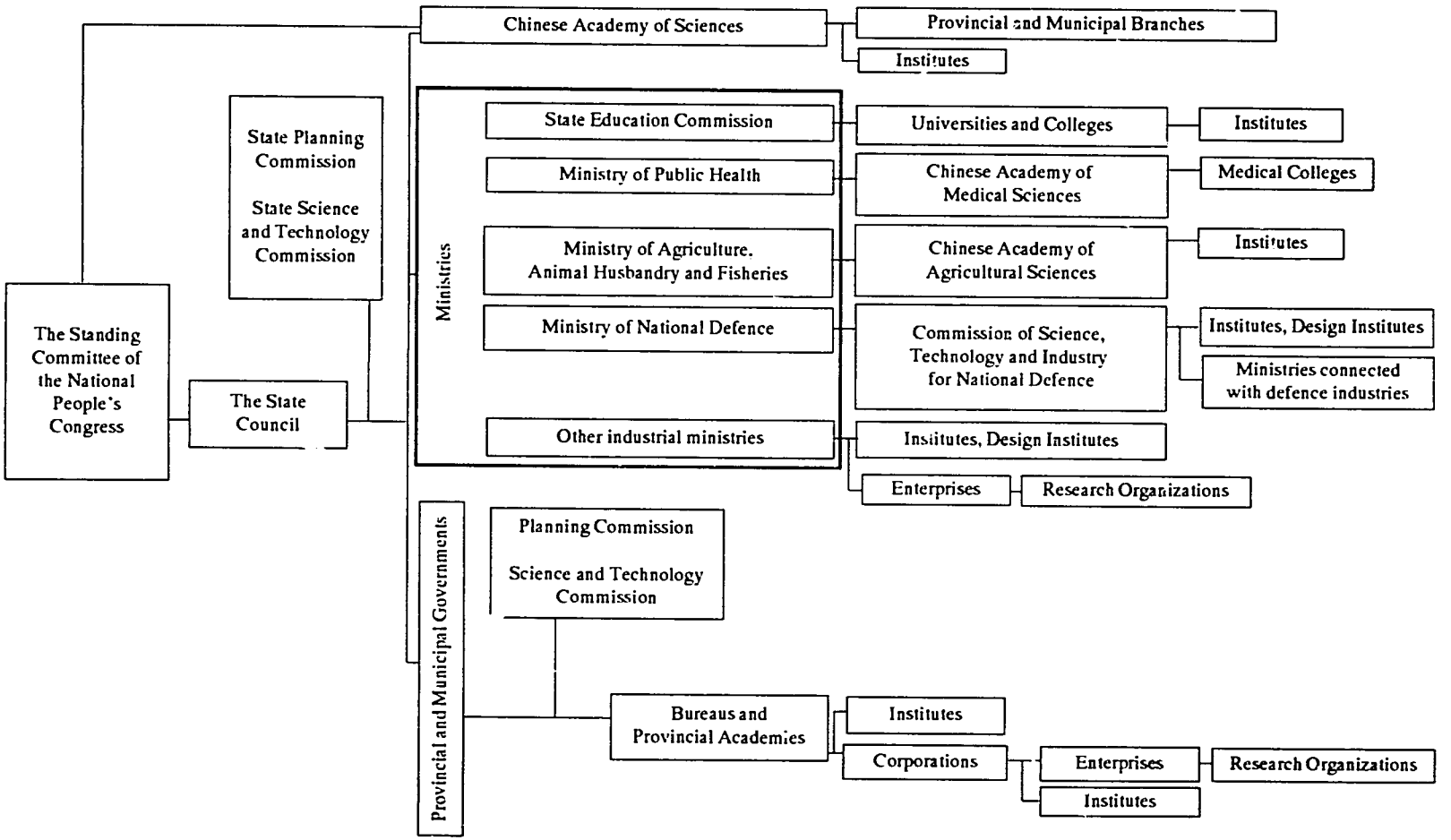
Year	Region							National
	Northeast	North	Northwest	Central	Southeast	Southwest	South	
1965	573	765	592	1,639	1,530	1,415	1,947	1,038
1970	734	993	720	2,054	1,883	1,489	2,320	1,268
1975	1,022	1,413	1,029	2,731	2,449	1,792	2,522	1,667
1976	912	1,336	967	2,593	2,489	1,701	2,745	1,614
1977	917	1,334	915	3,378	3,326	1,817	2,958	1,716
1978	1,028	1,443	955	3,464	2,637	2,031	3,143	1,792
1979	1,005	1,575	980	3,093	3,106	2,228	2,999	1,904
1980	1,234	1,720	826	2,953	3,101	2,532	2,950	1,973
1981	876	1,818	889	3,190	3,425	2,601	3,259	1,959
1982	1,354	2,000	988	3,642	3,879	2,912	3,769	2,358
1983	1,626	2,285	1,078	3,733	3,945	3,136	3,914	2,553
1984	1,748	2,564	1,201	4,177	4,533	3,422	4,274	2,841
1985	1,615	2,647	1,354	4,481	4,728	3,530	4,837	2,968
1986	1,774	2,591	1,394	4,633	5,015	3,643	5,007	3,058
1987	1,846	2,943	1,505	4,914	5,305	3,956	5,488	3,320
1988	1,979	3,070	1,636	4,919	5,512	4,090	5,799	3,458
1989	1,821	3,237	1,679	5,185	5,593	4,236	6,227	3,568
1990	2,267	3,451	1,888	5,455	5,797	4,457	6,650	3,838
Growth rate[a]								
	%	%	%	%	%	%	%	%
1965-80	5.2	5.6	2.2	4.0	4.8	4.0	2.8	4.4
1980-85	5.5	9.0	10.4	8.7	8.8	6.9	4.0	8.5
1985-90	7.0	5.4	6.9	4.0	4.2	4.8	6.5	5.3
1965-90	*5.6*	*6.2*	*4.7*	*4.9*	*5.5*	*4.7*	*5.0*	*5.4*

Source: *China's Statistical Yearbook* (various years) and *National Agricultural Statistics for 30 Years, 1949 to 1979* (1980).

Note: Agricultural land is measured in terms of sown area plus grassland sown-area-equivalent. One hectare of grassland was set equal to 0.0124 hectares of sown area in accordance with information obtained from *China's Statistical Yearbook 1985* (1986). Rural nonfarm industry is excluded from agricultural production.

[a] Compound annual growth rates.

Appendix 3: *R&D organization chart for China*



Source: Adapted from Maruyama (1990).

Appendix 4: *Organizational Affiliations of Chinese Agricultural Research Institutes at the National Level, 1990*

Institute	Research emphasis	Affiliation	Headquarters
Chinese Academy of Agricultural Sciences (CAAS)	Crops and animals	MOA	Beijing
Institute of Crop Breeding and Cultivation	Pland breeding and agronomy	CAAS, MOA	Beijing
Institute of Crop Germplasm Resources	Crop germplasm resources	CAAS, MOA	Beijing
Institute of Vegetable Crops and Flowers	Horticulture	CAAS, MOA	Beijing
Institute of Soils and Fertilizers	Soil and fertilizer	CAAS, MOA	Beijing
Institute of Plant Protection	Crop pests and diseases	CAAS, MOA	Beijing
Institute for Application of Atomic Energy	Application of atomic energy to agriculture	CAAS, MOA	Beijing
Institute of Animal Science	Livestock protection	CAAS, MOA	Beijing
Animal Feed Research Institute	Feed processing	CAAS, MOA	Beijing
Institute of Apiculture	Apiculture	CAAS, MOA	Beijing
Laboratory of Agrometeorology	Agricultural meteorology	CAAS, MOA	Beijing
Institute of Agricultural Economics	Agricultural economics, policy analysis, and development	CAAS, MOA	Beijing
Institute of Natural Agroresources Survey and Regionalization	Agricultural natural resources and agricultural zoning	CAAS, MOA	Beijing
Scientech Documentation and Information Center	Agricultural scientific and technological information	CAAS, MOA	Beijing
Farm Irrigation Research Institute	Irrigation and drainage	CAAS, MOA	Xinxiang Henan
China National Rice Research Institute	Rice	CAAS, MOA	Hangzhou Zhejiang
Institute of Cotton	Cotton	CAAS, MOA	Anyang Henan
Institute of Oil Crops	Oil crops	CAAS, MOA	Wuhan Hubei
Institute of Bast Fiber Crops	Bast fiber crops	CAAS, MOA	Yuanjiang Henan
Institute of Tobacco	Tobacco	CAAS, MOA	Yidu Shandong
Institute of Sugar Beet	Sugar beets	CAAS, MOA	Hulan Heilongjiang
Xingcheng Institute of Pomology	Pome fruit trees	CAAS, MOA	Xincheng Liaoning
Zhengzhou Institute of Pomology	Berry fruits, stone fruits, and melons	CAAS, MOA	Zhengzhou Henan
Institute of Citrus	Citrus	CAAS, MOA	Chongqing Sichuan
Institute of Tea	Tea	CAAS, MOA	Hangzhou Zhejiang
Institute of Sericulture	Silkworms and mulberries	CAAS, MOA	Zhenjiang Jiangsu
Harbin Institute of Veterinary Sciences	Veterinary problems	CAAS, MOA	Harbin Heilongjiang
Lanzhou Institute of Veterinary Sciences	Viruses, parasitoses, mycoses, infectious diseases in the North and Northwest	CAAS, MOA	Lanzhou Gansu

Appendix 4: *Organizational Affiliations of Chinese Agricultural Research Institutes at the National Level, 1990 (Contd.)*

Institute	Research emphasis	Affiliation	Headquarters
Institute of Traditional Chinese Veterinary Medicine	Traditional Chinese veterinary medicine	CAAS, MOA	Lanzhou Gansu
Lanzhou Institute of Animal Sciences	Forage production and animal raising	CAAS, MOA	Lanzhou Gansu
Shanghai Institute of Animal Parasitology	Animal parasitoses of South China	CAAS, MOA	Shanghai
Institute of Grasslands	Grass, grassland, and grass forage	CAAS, MOA	Huhehot Inner Mongolia
Institute of Special Wild Animals and Plants of Economic Importance	Wild animals and plants of economic importance	CAAS, MOA	Zuojia Jilin
Department of Agricultural History	Chinese agricultural history	CAAS, MOA	Nanjing Jiangsu
Biotechnology Research Center	Biotechnology R&D	CAAS, MOA	Beijing
Chinese Academy of Forestry (CAF)	Forestry industry	MOF	Beijing
Research Institute of Forestry	Forestry	CAF, MOF	Beijing
Research Institute of Wood Industry	Timber industry	CAF, MOF	Beijing
Research Institute of Chemical Processing Utilization of Forest Products	Utilization of forest products	CAF, MOF	Nanjing Jiangsu
Research Institute of Forestry Economics	Forestry economics	CAF, MOF	Beijing
Research Institute of Tropical Forestry	Tropical forestry	CAF, MOF	Hainan
Research Institute of Subtropical Forestry	Subtropical forestry	CAF, MOF	Fuyang Zhejiang
Research Institute of Scientific and Technical Information on Forestry	Information exchange	CAF, MOF	Beijing
Research Institute of Forestry Resources Information Techniques	Forestry resources	CAF, MOF	Beijing
Institute of Shellac	Shellac	CAF, MOF	Jindong Yunnan
Guangxi Daquingshan Experimental Bureau	Experiment	CAF, MOF	Penyiang Guangxi
Jiangxi Dagangshan Experimental Bureau	Experiment	CAF, MOF	Fenyi Jiangxi
Inner Mongolia Tongkou Experimental Bureau	Experiment	CAF, MOF	Tongkou Inner Mongolia
Beijing Forestry Mechanization Institute	Forestry mechanization	CAF, MOF	Beijing
Harbin Forestry Mechanization Institute	Forestry mechanization	CAF, MOF	Harbin Heilongjiang
Chinese Academy of Fishery Science (CAFS)	Fisheries	MOA	Beijing
Yellow Sea Fishery Research Institute	Marine fisheries	CAFS, MOA	Qingdao Shandong
East China Sea Fishery Research Institute	Marine fisheries	CAFS, MOA	Shanghai
South China Sea Fishery Research Institute	Marine fisheries	CAFS, MOA	Guangzhou Guangdong
Heilongjiang River Fishery Research Institute	Freshwater fisheries	CAFS, MOA	Harbin Heilongjiang
Yangtze River Fishery Research Institute	Freshwater fisheries	CAFS, MOA	Shashi Hubei

Appendix 4: *Organizational Affiliations of Chinese Agricultural Research Institutes at the National Level, 1990 (Contd.)*

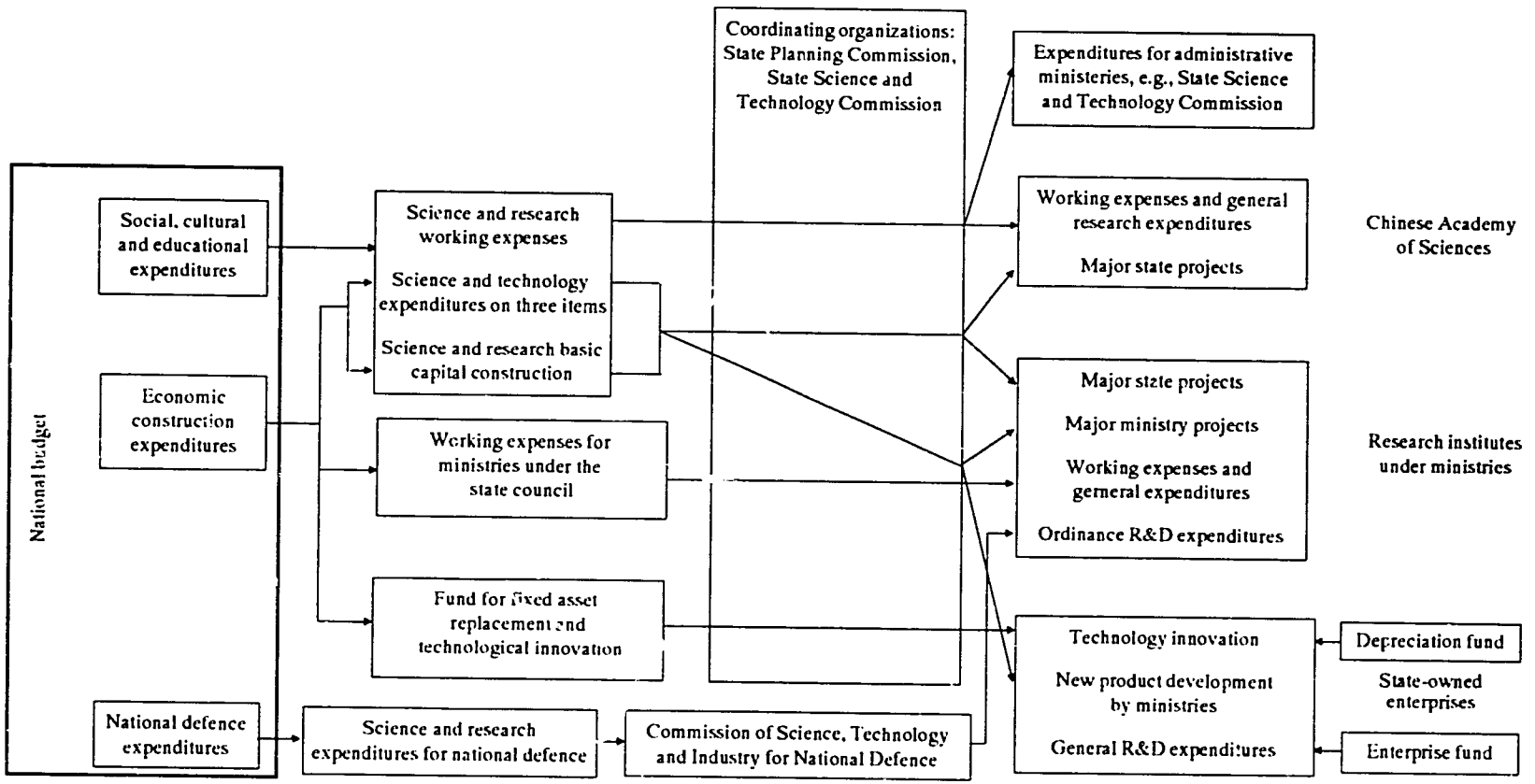
Institute	Research emphasis	Affiliation	Headquarters
Pearl River Fishery Research Institute	Freshwater fisheries	CAFS, MOA	Guangzhou Guangdong
Freshwater Fishery Research Center	Freshwater fisheries	CAFS, MOA	Wuxi Jiangsu
Fishery Engineering Research Institute	Fishery engineering	CAFS, MOA	Qingdao Shangdong
Fishery Machinery and Instrument Research Institute	Fishery machinery and instruments	CAFS, MOA	Shanghai
Taihu Fishery Enhancement and Scientific Experimental Base	Experiment	CAFS, MOA	Wuxi Jiangsu
Bohai Sea Fishery Enhancement and Scientific Experimental Base	Experiment	CAFS, MOA	
Fish Disease Research Division	Fish diseases	CAFS, MOA	Beijing
Fishery Planning and Designing Institute	Fishery planning	CAFS, MOA	Beijing
Fishery Scientific Information Research Institute	Information exchange	CAFS, MOA	Beijing
Fishery Economics Research Institute	Fishery economics	CAFS, MOA	Beijing
Fishery Environment Protection Research Division	Fishery environment	CAFS, MOA	Beijing
Fishery Vessel Designing and Research Division	Fishery vessels	CAFS, MOA	Beijing
Institute of Agricultural Engineering and Design	Agricultural engineering	MOA	Beijing
Agricultural Environment Protection Institute	Environmental protection	MOA	Beijing
Biogas Institute	Biogas application	MOA	Chengdu
South China Academy of Tropical Crops (SCATC)	Tropical crops	MOA	Danxiang Hainan
Institute of Rubber Cultivation	Rubber	SCATC, MOA	Danxiang Hainan
Institute of Tropical Crops	Tropical crops	SCATC, MOA	Danxiang Hainan
Hainan Institute of Plant Protection	Tropical crop protection	SCATC, MOA	Danxiang Hainan
Institute of Information	Information exchange	SCATC, MOA	Danxiang Hainan
Institute of Processing and Designing of Tropical Products	Crop processing	SCATC, MOA	Zhanjiang Guangdong
Institute of Tropical Mechanization	Mechanization	SCATC, MOA	Zhanjiang Guangdong
Yuexi Experimental Station	Experiment	SCATC, MOA	Zhanjiang Guangdong
Xinlong Experimental Station	Experiment	SCATC, MOA	Wanlin Guangdong
Wencheng Coconut Experimental Station	Experiment	SCATC, MOA	Wencheng Guangdong

Appendix 4: *Organizational Affiliations of Chinese Agricultural Research Institutes at the National Level, 1990 (Contd.)*

Institute	Research emphasis	Affiliation	Headquarters
Chinese Academy of Agricultural Mechanization (CAAM)	Agricultural mechanization	MOMB, MOA	Beijing
Luyan Tractor Institute	Tractor research	CAAM, MOMB	Luyan Henan
Shanghai Engine Institute	Agricultural engines	CAAM, MOMB	Shanghai
Huhehot Livestock Machinery Institute	Livestock mechanization	CAAM, MOMB	Huhehot Inner Mongolia
Nanjing Agricultural Mechanization Institute	Agricultural mechanization	CAAM, MOMB	Nanjing Jiangsu
Beijing Agricultural Mechanization Institute	Agricultural mechanization	CAAM, MOMB	Beijing
Institute of Water Construction	Water management	MOWCP	Beijing
Chinese Academy of Sciences (CAS)	Basic research and integrated experimentation		Beijing
Changsha Institute of Agricultural Modernization	Agricultural modernization research	CAS	Changsha Hunan
Shijazuang Institute of Agricultural Modernization	Agricultural modernization research	CAS	Shijazhung Hebei
Heilongjiang Institute of Agricultural Modernization	Agricultural modernization research	CAS	Heilongjiang
Other institutes affiliated with CAS	Basic agricultural research	CAS	
Academy of Water and Electricity	Water projects	MOWCP	Beijing
Academy of Meteorological Sciences	Meteorology	NMB	Beijing

Source: Compiled by the authors from various Chinese documents.

Appendix 5: *Sources and Flows of R&D Funds in China*



Source: Adapted from Maruyama (1990).

Note: This chart refers explicitly to the sources and flow of R&D funds across national-level units. Nevertheless, the flow-of-funds chart at the subnational (i.e., provincial or prefectural) level parallels this national-level schema in most respects except that the "science and technology expenditure on three items" component comes directly from national rather than provincial or prefectural budgets.

Appendix 6: *Agricultural Research Personnel in China, 1949 to 1988*

Year	Research institutes			Universities			Total		
	Scientists & engineers	Technical support staff	Total	Scientists & engineers	Technical support staff	Total	Scientists & engineers	Technical support staff	Total
1949	-	-	470	-	-	-	-	-	-
1952	-	-	1,000	130	-	-	-	-	1,130
1953	-	-	-	151	20	171	-	-	-
1954	-	-	-	172	23	195	-	-	-
1955	-	-	4,450	193	25	218	-	-	-
1956	-	-	-	214	28	242	-	-	-
1957	-	-	-	237	31	268	-	-	-
1958	-	-	-	300	39	339	-	-	-
1959	-	-	-	363	48	411	-	-	-
1960	5,940	3,960	9,900	426	56	482	6,366	4,016	10,382
1961	5,597	3,731	9,328	489	64	553	6,086	3,795	9,881
1962	6,204	4,136	10,340	552	72	624	6,756	4,208	10,964
1963	7,524	5,016	12,540	522	68	590	8,046	5,084	13,130
1964	6,593	4,396	10,989	492	65	557	7,085	4,461	11,546
1965	8,910	5,940	14,850	464	61	525	9,374	6,001	15,375
1966	9,834	6,556	16,390	451	59	510	10,285	6,615	16,900
1967	9,966	6,644	16,610	438	57	495	10,404	6,701	17,150
1968	10,032	6,680	16,712	425	56	481	10,457	6,736	17,193
1969	9,900	6,600	16,500	412	54	466	10,312	6,654	16,966
1970	9,768	6,512	16,280	399	52	451	10,167	6,564	16,731
1971	8,184	5,456	13,640	440	58	498	8,624	5,514	14,138
1972	9,636	6,424	16,060	481	63	544	10,117	6,487	16,604
1973	10,296	6,864	17,160	522	68	590	10,818	6,932	17,750
1974	12,804	8,536	21,340	562	74	636	13,366	8,610	21,976
1975	15,378	10,252	25,630	602	78	680	15,980	10,330	26,310
1976	16,500	11,000	27,500	804	106	910	17,304	11,106	28,410
1977	17,820	11,880	29,700	1,118	147	1265	18,938	12,027	30,965
1978	20,460	13,640	34,100	1,411	185	1596	21,871	13,825	35,696
1979	20,485	15,657	36,142	2,016	265	2281	22,501	15,922	38,423
1980	24,974	16,649	41,623	2,358	309	2667	27,332	16,958	44,290
1981	26,825	17,883	44,708	2,592	340	2932	29,417	18,223	47,640
1982	30,475	20,317	50,792	3,424	449	3873	33,899	20,766	54,665
1983	31,575	21,077	52,652	4,117	540	4657	35,692	21,617	57,309
1984	34,447	22,964	57,411	4,770	626	5396	39,217	23,590	62,807
1985	37,799	21,219	59,018	5,649	741	6390	43,448	21,960	65,408

Appendix 6: *Agricultural Research Personnel in China, 1949 to 1988 (Contd.)*

	Research institutes			Universities			Total		
	Scientists & engineers	Technical support staff	Total	Scientists & engineers	Technical support staff	Total	Scientists & engineers	Technical support staff	Total
1986	40,378	29,194	69,572	5,804	949	6753	46,182	30,143	76,325
1987	43,237	30,892	74,129	7,651	936	8587	50,888	31,828	82,716
1988	46,649	28,895	75,544	8,597	927	9524	55,246	29,822	85,068

Note: The nonuniversity sector includes personnel from the agricultural research institutes at the national, provincial, and prefectural levels. Here agriculture is interpreted in its broader sense to include primary crops and livestock plus forestry and fisheries.

Total research personnel comprises both scientists and engineers as well as technical support staff. Scientists and engineers (S&E) include science and technology personnel who hold a university or higher level educational degree or are conferred with senior or intermediate academic titles. Technical support staff includes personnel directly engaged in supporting the design and implementation of research. It explicitly excludes other support staff such as secretaries, drivers, farm laborers, etc., who are not directly involved in research activities. Generally, personnel with a PhD, MSc, or equivalent level of education directly enter the research institutes with an academic title that affords them S&E status. Those with a BSc or equivalent usually enter as technical support staff and after one or two years of work experience can be promoted to S&E levels. Personnel with post-secondary technical training may also be promoted to S&E levels but are usually first required to work as technical support staff for some years. The more recent data for which direct estimates are available were compiled in accordance with UNESCO standard definitions and concepts (*Statistical Data on Science and Technology of 1985*, 1986).

Research Institutes:

Total:

1985-88: Taken from *Guide to China's Science and Technology Policy, various years* (1987, 1988, 1989, 1990) and *Statistical Data on Science and Technology 1985* (1986).

1960-84: Derived from research personnel data reported in *China's Labor and Wage Statistical Materials, 1949-85* (1987). For the years 1952 and 1979-85, for which disaggregated data are available, agricultural research personnel as a share of total research personnel averaged a relatively constant 11%. For the years 1960-78 agricultural research personnel were estimated at 11% of total research personnel. These estimates were endorsed by Chinese colleagues at CAAS.

1949, 1952, and 1955: Taken from Lu (1985) and STCMA and STDMA (1989).

Scientists and Engineers:

1985-88: Taken from *Guide to China's Science and Technology Policy, various years* (1987, 1988, 1989, 1990) and *Statistical Data on Science and Technology, 1985* (1986).

1960-84: Disaggregated data from *Guide to China's Science and Technology Policy, various years* (1987, 1988, 1989, 1990) indicate that an average of 60% of all research personnel are scientists and engineers. The 1960-84 data were derived as a 60% share of total agricultural research personnel.

Technical Support Staff:

1960-88: Total agricultural research personnel minus scientists and engineers.

Universities:

The general approach taken here was to obtain estimates of the total number of scientific and technical staff working at the agricultural universities and then derive estimates of full-time equivalents. *China's Social Statistical Materials* (1987) reports total scientific and technical agricultural university staff for 1952, 1975, 1962, 1965, 1970, 1975-80, and 1987. *Guide to Science and Technology Policy, various issues* (1988 and 1989) report the 1987 total while the 1986 version of the same publication reports a corresponding total for the agricultural sciences rather than for agricultural universities per se. Intervening years were obtained by linear interpretation.

Appendix 6 Agricultural Research Personnel in China, 1949 to 1988 (Contd.)

Total:

1987-88: Taken from *Guide to China's Science and Technology Policy, various years* (1988 and 1989).

1986: Taken from *Guide to Science and Technology Policy* (1987) where data refer to agricultural sciences rather than agricultural universities per se.

1960-85: Data for 1986 and 1987 indicate that 21.7% of total university scientific and technical staff are full-time-equivalent "R&D" staff. Thus, an interpolated rate from 10% in 1979 (see following) to 20% in 1985 was used to prorate total scientific and technical staff numbers into corresponding full-time equivalents for the 1980-85 period.

1971-79: Berner (1979) indicated that 10-20% of the teaching staff at universities and colleages were full-time-equivalent "researchers". We used the lower bound of this range for agricultural universities and colleges since the level of research activity in these particular institutions is somewhat less than it is in other universities and colleges. Thus an interpolated rate from 3.3% in 1970 (see following) to 10% in 1979 was used to prorate total staff numbers into corresponding full-time equivalents for the 1970-71 period.

1952-70: Wu and Sheeks (1970) estimated that 2,000 faculty members in the higher-education institutions were participating in research in 1956, rising to 2,300 in 1957 and 47,000 in 1965. This is approximately one-third of the total staff in the higher-education institutions. Their informal survey of these institutions suggested that a conversion factor of 10% was appropriate when converting the R&D total into full-time equivalents and that is the conversion factor used here. Consequently 3.3% of total faculty members were prorated into full-time-equivalent researchers.

Scientists and Engineers:

1986-88: Taken from *Guide to China's Science and Technology Policy, various years* (1987, 1988, 1989).

1960-85: Data from *Guide to China's Science and Technology Policy, various years* (1987, 1988, 1989) indicates that an average of 88.4% of total, full-time-equivalent research staff (i.e., including scientists and engineers plus technical support staff) at the universities during 1986-88 were full-time-equivalent scientists and engineers. This percentage was applied to the total research staff data to derive scientist and engineer estimates for the 1960-85 period.

Technical Support Staff:

1986-88: Taken from *Guide to China's Science and Technology Policy, various years* (1987, 1988, 1989).

1960-85: Total research personnel minus scientists and engineers.

Appendix 7: *Agricultural Research Expenditures in China, 1953 to 1988*

	Research institutes				Universities				Total			
	Yuan		Dollars		Yuan		Dollars		Yuan		Dollars	
	Current	Constant 1980	Atlas	PPP	Current	Constant 1980	Atlas	PPP	Current	Constant 1980	Atlas	PPP
						(*millions*)						
1953	5.6	7.1	4.7	15.8	1.4	1.7	1.2	3.8	6.0	8.8	5.9	19.6
1954	12.2	15.2	10.1	33.7	1.5	1.9	1.3	4.2	13.7	17.1	11.4	37.9
1955	21.3	26.2	17.4	58.2	1.7	2.1	1.4	4.6	23.0	28.3	18.8	62.8
1956	52.3	64.3	42.8	142.8	1.9	2.3	1.5	5.1	54.2	66.6	44.4	148.0
1957	52.3	63.3	42.2	140.7	2.1	2.5	1.7	5.5	54.4	65.8	43.9	146.2
1958	112.4	135.8	90.5	301.7	2.7	3.2	2.2	7.2	115.1	139.0	92.6	308.9
1959	191.5	229.3	152.7	509.4	3.3	4.0	2.6	8.8	194.8	233.2	155.4	518.2
1960	338.1	392.6	261.6	872.3	3.8	4.4	2.9	9.8	341.9	397.0	264.5	882.1
1961	194.9	194.8	129.8	432.7	4.4	4.4	2.9	9.8	199.3	199.2	132.7	442.5
1962	137.3	132.2	88.1	293.7	5.0	4.9	3.2	10.8	142.3	137.0	91.3	304.4
1963	186.1	190.9	126.8	423.0	4.7	4.8	3.2	10.7	190.8	195.2	130.1	433.7
1964	242.7	257.8	171.8	572.7	4.6	4.9	3.2	10.8	247.3	262.6	175.0	583.5
1965	271.7	296.5	197.6	658.8	4.3	4.6	3.1	10.3	276.0	301.2	200.6	669.1
1966	250.6	274.3	182.8	609.5	4.1	4.5	3.0	10.0	254.7	278.8	185.7	619.4
1967	153.5	169.3	112.8	376.1	3.9	4.3	2.9	9.6	157.4	173.6	115.7	385.8
1968	148.0	163.1	108.7	362.4	3.9	4.3	2.9	9.6	151.9	167.4	111.6	372.0
1969	241.5	269.2	179.3	598.0	3.8	4.2	2.8	9.4	245.3	273.4	182.1	607.4
1970	299.6	334.7	223.0	743.6	3.6	4.0	2.7	9.0	303.2	338.7	225.7	752.6
1971	276.8	311.6	207.6	692.7	3.9	4.4	3.0	9.8	280.7	316.0	210.5	702.1
1972	361.0	407.3	271.4	904.9	4.4	5.0	3.3	11.1	365.4	412.3	274.7	916.0
1973	345.9	387.9	258.4	861.8	4.7	5.3	3.5	11.8	350.6	393.2	261.9	873.5
1974	346.5	386.5	257.5	858.7	5.2	5.8	3.9	12.9	351.7	392.3	261.4	871.6
1975	403.1	448.9	299.1	997.4	5.5	6.1	4.1	13.6	408.6	455.1	303.2	1,011.1
1976	392.5	435.8	290.4	968.3	7.4	8.2	5.5	18.3	399.9	444.0	295.8	986.5
1977	414.8	451.4	300.7	1,002.8	10.2	11.1	7.4	24.7	425.0	462.5	308.1	1,027.5
1978	533.3	576.5	384.1	1,280.8	12.9	14.0	9.3	31.0	546.2	590.4	393.4	1,311.8
1979	622.9	660.2	439.8	1,466.8	18.4	19.5	13.0	43.4	641.3	679.7	452.9	1,510.2
1980	645.9	645.9	430.3	1,435.0	21.6	21.6	14.4	47.9	667.5	667.5	444.7	1,482.9
1981	615.8	601.5	400.7	1,336.3	23.6	23.1	15.4	51.2	639.4	624.5	416.1	1,387.5
1982	625.9	599.8	399.6	1,332.5	31.2	29.9	19.9	66.4	657.1	629.6	419.5	1,398.9
1983	790.3	746.1	497.1	1,657.7	37.6	35.5	23.7	78.9	827.9	781.6	520.7	1,736.6
1984	947.2	869.7	579.4	1,932.1	43.4	39.9	26.6	88.6	990.6	909.5	606.0	2,020.7
1985	1,025.9	865.6	576.7	1,923.2	51.5	43.4	28.9	96.5	1,077.4	908.1	605.6	2,019.7
1986	1,084.5	863.5	575.3	1,918.4	61.5	49.0	32.7	108.9	1,146.0	912.5	607.9	2,027.3
1987	1,072.5	795.7	530.1	1,767.8	70.0	52.0	34.6	115.5	1,142.5	847.7	564.7	1,883.3
1988	1,419.4	888.8	592.1	1,974.7	89.7	56.2	37.4	124.8	1,509.1	945.0	629.6	2,099.5

Appendix 7: Agricultural Research Expenditures in China, 1953 to 1988 (Contd.)

Note: The institutional coverage of the data reported here correspond to that used in compiling the research personnel data given in appendix 6. Similarly, agriculture is interpreted here in its broader sense to include primary crops and livestock plus forestry and fisheries.

Research Institutes:

Current Yuan

1985-88: Taken from *Guide to China's Science and Technology Policy, various years* (1986, 1987, 1988, 1989) and *Statistical Data on Science and Technology of 1985* (1986).

1953-84: Calculated as 10% of the national research budget as reported in *China's Statistical Yearbook* (1986). Averaging the 1986-88 data reported above indicates that around 10% of the nation's research budget for this period was allocated to agriculture. Chinese colleagues confirmed that in the apparent absence of any direct estimates of agricultural research expenditures for earlier years the procedure used here yields a tolerable first approximation.

Constant Yuan

Research expenditures measured in current yuan were deflated to constant 1980 yuan using the national retail price index taken from *China's Statistical Yearbook* (1991).

Constant Dollars

Two dollar measures are reported. The first converts constant 1980 yuan to purchasing power parity (PPP) dollars using the 1980 PPP over GDP conversion factor reported in Summers and Heston (1991). The second reports 1980 Atlas dollars using the 1980 World Bank Atlas convertor (which is a simple average of the official market exchange rate for the current year and two predicted exchange rates for the current year that are based on observed exchange rates and relative inflation rates of the previous two years, see World Bank [1991a, pp. 273-4] for details) as reported in Pardey and Roseboom (1989). Further details on various currency translation procedures, and the rationale for choosing among them, are given in Pardey, Roseboom and Craig (1992).

Universities:

Current Yuan

Guide to China's Science and Technology Policy, various years (1986, 1988, 1989) report only research expenditures by agricultural universities (or in the case of 1986 for the agricultural sciences) from locally sourced and donor-sourced project-based funds. These expenditures explicitly exclude nonoperational costs related to these projects, such as faculty salaries appropriable to research and certain capital costs related to buildings, land, etc. Using the State Science and Technology Commission's data on research institutes for this period, it was possible to estimate the ratio of nonoperational to total research expenditures, z. Taking this institute ratio as roughly representative of the situation in the universities as well, we recalibrated the reported university-related agricultural research expenditures by $[z/(1-z) = 1.574]$ to implicitly factor in the nonoperational components of university research to the project-based funds that are reported.

1953-85: Recalibrated 1987 expenditures per full-time-equivalent university researchers (i.e., 9123.8 yuan) were used in conjunction with the university researcher data from appendix 6 to calculate a total university agricultural research expenditure series for this period.

Constant Yuan and Dollars

See research institute notes above for details.

Appendix 8: *Yields of Principal Crops, 1949 to 1990*

Year	Grain crops							Cash crops					
	Rice[a]	Wheat	Corn	Soybeans	Potatoes[b]	Millet	Sorghum	Cotton	Rapeseed	Peanuts	Tobacco	Sugar beet[c]	Sugarcane[c]
	(*kg per hectare*)												
1949	1,890	645	1,185	615	1,410	–	–	165	495	1,020	705	11,970	24,420
1950	2,107	635	1.238	780	1,620	–	–	180	480	1,305	930	11,745	27,878
1951	2,248	747	1,293	810	1,695	–	–	188	495	1,260	1,020	15,352	32,715
1952	2,415	735	1,350	825	1,890	1,170	1,185	240	510	1,290	1,200	13,642	38,955
1953	2,517	713	1,275	810	1,845	1,050	1,170	225	525	1,200	1,110	10,380	37,485
1954	2,467	865	1,305	720	1,740	1,035	1,050	195	525	1,320	1,065	13,545	39,277
1955	2,675	859	1,395	795	1,890	1,125	1,275	263	420	1,290	1,029	13,898	39,713
1956	2,476	909	1,301	855	1,995	990	1,080	233	435	1,290	1,035	11,018	39,150
1957	2,700	855	1,440	795	2,100	1,020	1,155	285	390	1,320	720	9,420	38,985
1958	2,533	876	1,358	915	2,160	972	1,112	353	435	1,260	1,140	10,635	41,130
1959	2,389	941	1.281	885	1,950	923	1,080	307	465	1,140	1,110	10,013	28,605
1960	2,017	812	1,209	690	1,500	882	1,050	203	315	600	675	4,598	26,670
1961	2,041	557	1,140	660	1,980	840	1,025	210	255	885	660	3,848	22,620
1962	2,340	690	1,485	690	1,935	825	960	225	360	855	735	4,065	22,395
1963	2,662	777	1,335	720	1,800	855	1,020	270	360	975	990	6,683	42,413
1964	2,803	820	1,485	795	1,785	1,020	1,065	338	525	975	1,155	10,470	39,728
1965	2,940	1,020	1,515	720	1,785	945	1,155	420	600	1,050	1,155	11,610	38,220
1966	3,125	1,056	1,619	990	1,935	1,022	1,251	473	525	1,215	1,515	13,560	33,030
1967	3,078	1,126	1.731	975	2,100	1,104	1,356	465	615	1,140	1,395	14,070	36,608
1968	3,162	1,113	1,851	960	2,160	1,194	1,469	473	645	1,110	1,350	12,698	32,235
1969	3,124	1,084	1,978	915	2,310	1,290	1,592	428	615	1,065	1,380	12,863	32,010
1970	3,399	1,146	2,115	1,110	2,490	1,395	1,725	458	675	1,260	1,365	10,575	34,725
1971	3,299	1,271	2,145	1,110	2,415	1,215	1,770	428	765	1,245	1,440	9,682	30,855
1972	3,226	1.368	1,920	855	2,265	1,035	1,500	398	720	1,110	1,530	8,730	34,418
1973	3,469	1,332	2,340	1,140	2,040	1,380	2,040	518	645	1,215	1,695	9,390	33,608
1974	3,489	1,510	2,475	1,035	2,550	1,335	2,175	495	675	1,050	1,530	8,588	33,360
1975	3,514	1,638	2,550	1,035	2,610	1,455	2,310	480	660	1,215	1,530	8,190	31,830
1976	3,473	1,773	2,505	990	2,580	1,245	2,010	420	585	1,020	1,710	8,228	30,742
1977	3,619	1,463	2,520	1,065	2,640	1,380	2,055	420	525	1,170	1,710	6,983	35,025
1978	3,975	1,845	2,805	1,065	2,700	1,545	2,340	450	720	1,350	1,725	8,175	38,535
1979	4,245	2,145	2,985	1,035	2,595	1,470	2,400	495	870	1,365	1,590	9,555	42,030
1980	4,140	1,890	3,075	1,095	2,835	1,410	2,520	555	840	1,545	1,815	14,250	47,565
1981	4,320	2,115	3,045	1,170	2,700	1,485	2,550	570	1,080	1,545	2,190	14,595	53,820
1982	4,890	2,445	3,270	1,080	2,895	1,635	2,505	615	1,380	1,620	2,085	14,520	56,460
1983	5,100	2,805	3,630	1,290	3,120	1,845	3,090	765	1,170	1,800	2,010	16,890	47,610
1984	5,370	2,970	3,960	1,335	3,165	1,860	3,150	915	1,230	1,800	2,160	16,500	54,285
1985	5,250	2,940	3,600	1,365	3,030	1,800	2,895	810	1,245	2,010	1,920	15,915	53,430
1986	5,340	3,045	3,705	1,395	2,910	1,530	2,865	825	1,200	1,815	1,530	15,960	52,860
1987	5,415	2,985	3,915	1,470	3,180	1,621	2,910	870	1,260	2,040	1,785	16,350	55,140

Appendix 8: *Yields of Principal Crops, 1949 to 1990 (Contd.)*

	Grain crops							Cash crops					
	Rice[a]	Wheat	Corn	Soybeans	Potatoes[b]	Millet	Sorghum	Cotton	Rapeseed	Peanuts	Tobacco	Sugar beet	Sugarcane[c]
1988	5,280	2,970	3,930	1,440	2,985	1,756	3,135	750	1,020	1,905	1,800	17,190	53,115
1989	5,505	3,045	3,885	1,290	3,000	1,566	2,715	735	1,095	1,815	1,605	16,245	50,850
1990	5,730	3,195	4,530	1,455	3,015	2,008	3,673	810	1,260	2,190	1,680	21,660	57,120
Annual growth rates													
	%	%	%	%	%	%	%	%	%	%	%	%	%
1949-57	5.2	3.8	3.4	2.5	3.3	-	-	7.0	-2.9	3.3	0.3	-2.9	6.0
1958-61	-6.9	-14.0	-5.7	-10.3	-2.9	-4.7	-2.4	-15.9	-16.3	-11.1	-16.6	-28.7	-18.1
1962-65	7.9	13.9	0.7	1.4	-2.6	4.6	6.4	23.1	18.6	7.1	16.3	41.8	19.5
1966-78	2.0	4.8	4.7	0.6	2.8	3.5	5.3	-0.4	2.7	0.9	1.1	-4.1	1.3
1979-90	2.8	3.7	3.9	3.1	1.4	2.9	3.9	4.6	3.4	4.4	0.5	7.7	2.8
1949-90	*2.7*	*4.0*	*3.3*	*2.1*	*1.9*	*1.4*[d]	*3.0*[d]	*4.0*	*2.3*	*1.9*	*2.1*	*1.5*	*2.1*

Source: *China's Statistical Yearbook* (1991) and *China's Rural Economic Statistical Materials, 1949-1986* (1989).

Note: Corn yields for 1950-51, 1958-60, and 1966-69 were derived by geometric interpolation, as were millet and sorghum yields for 1958-60 and 1966-69. All yields are expressed in terms of output per unit of area sown as detailed in appendix 9, not simply area under crops. Consequently, multiple-cropped areas are counted more than once.

[a] In Chinese statistics, grain production data are reported in paddy-rice terms. To convert these data to the more standard milled-rice equivalent would require multiplying by the milling rate conversion factor of 0.7.

[b] In keeping with common Chinese practice, potatoes are classified as a grain crop and reported in "grain-equivalent" terms where one unit of fresh tubers equals 0.2 units of grain. This figure includes both sweet potatoes and irish potatoes.

[c] Measured in fresh-weight terms.

[d] 1952-90.

Appendix 9: *Area Sown to Principal Crops, 1949 to 1990*

Year	Grain crops							
	Rice	Wheat	Corn	Soybeans	Potatoes	Millet	Sorghum	Total grain crops[a]
	('000 hectares)							
1949	25,709	21,515	–	8,325	7,011	–	–	109,959
1950	26,163	22,800	–	9,620	7,696	–	–	114,406
1951	26,933	23,055	–	10,801	8,285	–	–	117,769
1952	28,382	24,780	12,566	11,679	8,688	9,835	9,386	123,979
1953	28,321	25,636	13,134	12,362	9,016	9,866	9,558	126,637
1954	28,722	26,967	13,171	12,654	9,781	9,003	8,646	128,995
1955	29,173	26,739	14,639	11,442	10,054	8,929	8,060	129,839
1956	33,312	27,272	17,663	12,047	10,992	8,618	6,067	136,339
1957	32,241	27,542	14,943	12,748	10,495	8,377	6,634	133,633
1958	31,915	25,775	16,211	9,551	15,382	7,798	6,349	127,613
1959	29,034	23,575	13,002	9,863	12,289	7,260	6,077	116,023
1960	29,607	27,294	14,090	9,348	13,531	6,759	5,816	122,429
1961	26,276	25,572	13,602	9,957	12,026	6,293	5,567	121,443
1962	26,935	24,075	12,817	9,504	12,171	6,429	6,327	121,621
1963	27,715	23,771	15,376	9,633	11,899	7,042	6,716	120,741
1964	29,607	25,408	15,363	10,009	11,257	6,711	6,252	122,103
1965	29,825	24,709	15,671	8,593	11,175	6,562	6,150	119,627
1966	30,529	23,919	15,443	8,425	11,647	6,514	5,842	120,988
1967	30,436	25,839	15,218	8,503	10,716	6,468	5,549	119,230
1968	29,894	24,658	14,996	8,363	10,307	6,421	5,270	116,157
1969	30,432	25,162	14,777	8,329	10,447	6,375	5,006	117,604
1970	32,358	25,458	14,562	8,356	10,257	6,329	4,755	119,267
1971	34,918	25,639	16,726	7,791	10,405	6,302	4,988	120,846
1972	35,141	26,302	16,703	7,583	10,841	5,759	5,357	121,209
1973	35,090	26,438	16,571	7,408	11,306	5,909	5,227	121,156
1974	35,512	27,061	17,410	7,261	11,069	5,287	5,254	120,976
1975	35,729	27,661	18,598	6,999	10,969	6,251	4,670	121,062
1976	36,217	28,417	19,230	6,691	10,366	4,501	4,329	120,743
1977	35,526	28,065	19,657	6,845	11,229	4,477	3,759	120,440
1978	34,421	29,183	19,961	7,144	11,796	4,271	3,457	120,587
1979	33,873	29,357	20,133	7,247	10,952	4,173	3,173	119,262
1980	33,879	29,228	20,353	7,226	10,153	3,872	2,693	117,235
1981	33,295	28,307	19,425	8,023	9,620	3,889	2,610	114,958
1982	33,071	27,995	18,543	8,419	9,370	4,039	2,784	113,463
1983	33,137	29,050	18,824	7,567	9,402	4,087	2,707	114,047
1984	33,179	29,577	18,537	7,286	8,988	3,797	2,451	112,284
1985	32,070	29,218	17,694	7,718	8,572	3,318	1,936	108,845
1986	32,266	29,616	19,124	8,295	8,685	2,980	1,875	110,933
1987	32,193	28,798	20,212	8,445	8,867	2,688	1,864	111,268

Appendix 9: *Area Sown to Principal Crops, 1949 to 1990 (Contd.)*

Year	Grain crops							
	Rice	Wheat	Corn	Soybeans	Potatoes	Millet	Sorghum	Total grain crops[a]
				('000 hectares)				
1988	31,987	28,785	19,692	8,072	9,054	2,513	1,784	110,123
1989	32,701	29,841	20,353	8,057	9,097	2,396	1,629	112,205
1990	33,065	30,753	21,401	7,559	9,121	2,278	1,545	113,466
Annual growth rate								
	%	%	%	%	%	%	%	%
1949-57	2.9	3.1	–	5.5	2.9	–	–	2.5
1958-61	– 6.3	– 0.3	– 6.0	1.4	– 6.7	– 6.9	– 4.3	1.7
1962-65	3.4	0.9	6.9	– 0.3	3.4	– 0.9	– 0.9	– 0.5
1966-78	1.0	1.7	2.2	– 1.4	1.0	– 3.4	– 4.3	– 0.03
1979-90	– 0.2	0.4	0.6	0.4	– 0.3	– 5.4	– 6.3	0.5
1949-90	*0.6*	*0.9*	*1.4*[c]	*– 0.2*	*0.6*	*– 3.8*[c]	*– 4.6*[c]	*0.08*

Appendix 9: *Area Sown to Principal Crops, 1949 to 1990 (Contd.)*

Year	Cash crops							Total crops
	Cotton	Peanuts	Rapeseed	Sugarcane	Sugar beet	Tobacco	Total cash crops[b]	
	('000 hectares)							
1949	2,770	1,255	1,515	108	16	61	–	–
1950	3,785	1,343	1,423	113	21	61	–	–
1951	5,485	1,666	1,567	141	23	239	–	–
1952	5,576	1,804	1,863	183	35	186	12,494	141,256
1953	5,180	1,775	1,667	193	49	191	11,659	144,035
1954	5,462	2,097	1,706	219	73	218	12,422	147,926
1955	5,773	2,269	2,338	204	115	252	13,986	151,081
1956	6,255	2,582	2,165	221	149	385	14,699	159,173
1957	5,775	2,541	2,308	267	159	355	8,460	157,244
1958	5,556	2,271	2,288	305	289	342	13,765	151,995
1959	5,512	1,931	2,043	314	317	298	13,549	142,405
1960	5,225	1,345	2,415	310	347	295	12,914	150,575
1961	3,870	1,199	1,467	122	207	147	9,320	143,214
1962	3,497	1,301	1,361	154	83	176	8,763	140,229
1963	4,409	1,459	1,443	184	78	236	10,194	140,218
1964	4,935	1,802	1,789	306	131	281	11,991	143,531
1965	5,003	1,845	1,822	350	171	325	12,210	143,291
1966	4,925	1,917	1,748	345	194	380	12,242	146,829
1967	5,098	1,932	1,665	345	185	407	12,203	144,943
1968	4,986	1,741	738	321	170	327	11,353	139,827
1969	4,829	1,735	1,427	328	185	325	11,426	140,944
1970	4,997	1,709	1,453	387	199	291	11,713	143,487
1971	4,923	1,787	1,616	426	219	319	11,933	145,584
1972	4,896	1,878	1,966	477	266	344	12,534	147,919
1973	4,942	1,761	2,096	505	285	362	12,795	148,547
1974	5,013	1,827	2,063	492	266	384	12,888	148,635
1975	4,955	1,877	2,313	523	303	460	13,399	149,545
1976	4,929	1,841	2,347	541	357	543	13,723	149,723
1977	4,845	1,687	2,217	507	352	569	13,532	149,333
1978	4,867	1,769	2,599	548	331	613	14,440	150,104
1979	4,512	2,075	2,761	511	325	509	14,767	148,477
1980	4,920	2,339	2,844	479	443	397	15,921	146,380
1981	5,185	2,472	3,801	551	436	586	17,561	145,157
1982	5,829	2,416	4,122	593	462	888	18,793	144,755
1983	6,077	2,201	3,669	654	544	572	17,761	143,993
1984	6,923	2,421	3,413	728	502	715	19,288	144,221
1985	5,140	3,318	4,494	965	561	1,077	22,378	143,626
1986	4,306	3,253	4,916	950	521	895	20,285	144,204
1987	4,844	3,022	5,267	859	498	913	20,725	144,957
1988	5,535	2,977	4,937	924	745	1,304	21,496	144,869

Appendix 9: *Area Sown to Principal Crops, 1949 to 1990 (Contd.)*

Year	Cash crops							Total crops
	Cotton	Peanuts	Rapeseed	Sugarcane	Sugar beet	Tobacco	Total cash crops[b]	
				('000 hectares)				
1989	5,203	2,946	4,993	959	569	1,503	20,989	146,554
1990	5,588	2,907	5,503	1,009	671	1,342	21,417	148,362
Annual growth rate								
	%	%	%	%	%	%	%	%
1949-57	9.6	9.2	5.4	12.0	33.3	24.7	–	–
1958-61	– 11.4	– 19.2	– 13.8	– 26.3	– 10.5	– 24.5	– 12.2	– 2.0
1962-65	12.6	12.3	10.2	31.5	27	22.7	11.7	0.7
1966-78	– 0.1	– 0.7	3.4	3.9	4.5	4.1	1.4	0.2
1979-90	2.0	3.1	6.5	6.4	6.8	9.2	3.4	– 0.7
1949-90	*1.7*	*2.1*	*3.2*	*5.6*	9.5	*7.8*	*1.4*[c]	*0.1*[c]

Source: *China's Statistical Yearbook, 1990* (1991) and *China's Rural Economic Statistical Materials, 1949-1986* (1989).

Note: Sown areas to corn, millet, and sorghum for 1958-60 and 1966-69 were derived by geometric interpolation.

[a] Besides the crops listed here this figure includes coarse grains in addition to sorghum and millet.

[b] In addition to the crops listed here, this figure also includes oil-bearing crops (other than rapeseed), flax, silkworm cocoon, tea, and fruits.

[c] 1952-90.