Reforms, Investment, and Poverty in Rural China*

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I. Introduction

China is one of the few countries in the developing world that has made progress in reducing its total number of poor over the past 25 years.[1] Chinese official documents indicate that the number of poor in China fell dramatically, from 250 million in 1978 to 30 million in 2000.[2] A reduction in poverty on this scale and within such a short time is unprecedented in history and is considered by many to be one of the greatest achievements in human development in the twentieth century. Contributing to this success were policy and institutional reforms, promotion of equal access to social services and production assets, and public investments in rural areas.

The literature on Chinese agricultural growth and rural poverty reduction is extensive. Few researchers, however, have attempted to link these topics to public investment.[3] We argue that, even with the economic reforms that began in the late 1970s, it would have been impossible to achieve rapid economic growth and poverty reduction in China had there not been several prior decades of government investment. Before the reforms began, the effects of government investment were inhibited by policy and institutional barriers. The reforms reduced these barriers, enabling investments to generate tremendous economic growth and poverty reduction. Similarly, public investment may have played a large role in reducing regional inequality, an issue of increasing concern to policy makers. The primary purpose of this study is to develop an analytical framework for examining the specific role of different

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types of government expenditure on growth and poverty reduction in rural China by controlling for other factors such as institutional and policy changes.

Using provincial-level data for the past several decades, we construct an econometric model that permits the calculation of economic returns, the number of poor people raised above the poverty line, and the impact on regional inequality for additional units of expenditure on different items. The model enables us to identify the different channels through which government investments affect growth, inequality, and poverty. For instance, increased government investment in roads and education may reduce rural poverty not only by stimulating agricultural production but also by creating improved employment opportunities in the nonfarm sector. Understanding these different effects provides useful policy insights to improve the effectiveness of government poverty-alleviation strategies. Moreover, the model enables us to calculate growth, inequality, and poverty-reduction effects from the regional dimension. Specific regional information helps the government to better target its limited resources and achieve a more equitable regional development, a key objective that is debated in both academic and policy-making venues in China.

The remainder of the article is organized as follows. Section II details the evolution of reforms, growth, and poverty in rural China over the past several decades. Section III describes trends of government spending in technology, education, and infrastructure, as these have long-term effects on growth and poverty reduction. Section IV develops the conceptual framework to track multiple poverty effects of these expenditures, and Section V describes the data and estimation strategy and presents the estimation results. Section VI concludes the report with policy implications. Data description is provided in appendix A.

II. Reform, Growth, and Poverty

Per capita income in rural China was extremely low prior to the reforms. In 1978, the average income per rural resident was only about 220 yuan per year or about US$150 (table 1).[4] During the 29 years from 1949 to 1978, per capita income increased by only 95% or by 2.3% per annum. China was one of the poorest countries in the world. Most rural people struggled to survive from day to day. In 1978, 250 million residents in rural China, or 33% of the total rural population, lived below the poverty line; that is, they were without access to sufficient food or income to maintain a healthy and productive life.

This changed dramatically directly after the initiation of rural reforms in 1978. Per capita income increased to 522 yuan in 1984 from 220 yuan in 1978, a growth rate of 15% per annum (table 1). This rapid growth in agricultural income came from both productivity improvement and higher agricultural prices.[5] Income gains were shared widely enough to cut the number of poor and hence the rate of poverty by more than half. By 1984, only 11% of the rural population was below the poverty line. Because of the equitable

TABLE 1

PER CAPITA INCOME AND INCIDENCE OF POVERTY IN RURAL CHINA

	PER CAPITA INCOME		POVERTY INCIDENCE		
YEAR	Yuan per Person (1990 Prices)	% of Urban Residents	Official (%)	World Bank ($1 per day) (%)	GINI COEFFICIENT
1978	220	42	32.9		.21
1980	306	44	27.1		.23
1981	349	49	24.3		.24
1982	414	55	17.5		.23
1983	467	59	15.2		.25
1984	522	58	11.1		.26
1985	593	58	11.9		.26
1986	612	51	12.0		.29
1987	644	51	11.1		.29
1988	685	49	10.4		.30
1989	674	44	12.4		.30
1990	686	49	11.5	31.3	.31
1991	700	42	11.1	31.7	.31
1992	741	39	10.6	30.1	.31
1993	765	39	9.4	29.1	.32
1994	803	38	8.2	25.9	.33
1995	846	41	7.6	21.8	.34
1996	922	44	6.7	15.0	N.A.
1997	964	40	5.8	13.5	N.A.
1998	1,122	40	4.8	11.5	N.A.
1999	1,147	38	3.9		N.A.
2000	1,169	36	3.7		N.A.

SOURCES.—State Statistical Bureau, *China Statistical Yearbook* (Beijing: China Statistical Publishing House, various years); Ministry of Agriculture, *China Agricultural Development Report* (Beijing: Ministry of Agriculture, various years); World Bank, *China: Overcoming Rural Poverty* (Washington, D.C.: World Bank, 2000).

NOTE.—N.A. = not available.

distribution of land to families, income inequality, as measured by the Gini coefficient, increased only slightly.

During the second stage of reforms (1985–89), rural income continued to increase but at the much slower pace of 3% per annum (table 1). This was due mainly to the stagnation of agricultural production after the reforms. The effects of fast agricultural growth on rural poverty were largely exhausted by the end of 1984. Over this same period, the rural income distribution became less egalitarian, and the Gini index rose from 0.264 to 0.301.[6] The changes in income distribution probably resulted from the changed nature of income gains and the growing differential in rural nonfarm opportunities among regions.[7]

With real crop prices stagnating, rural income gains had to come from increased efficiency in agricultural production and marketing or from employment outside of agriculture.[8] Although the poor had increased access to modern inputs, their generally adverse production conditions kept gains low. With nonfarm income an increasingly large proportion of rural income, re-

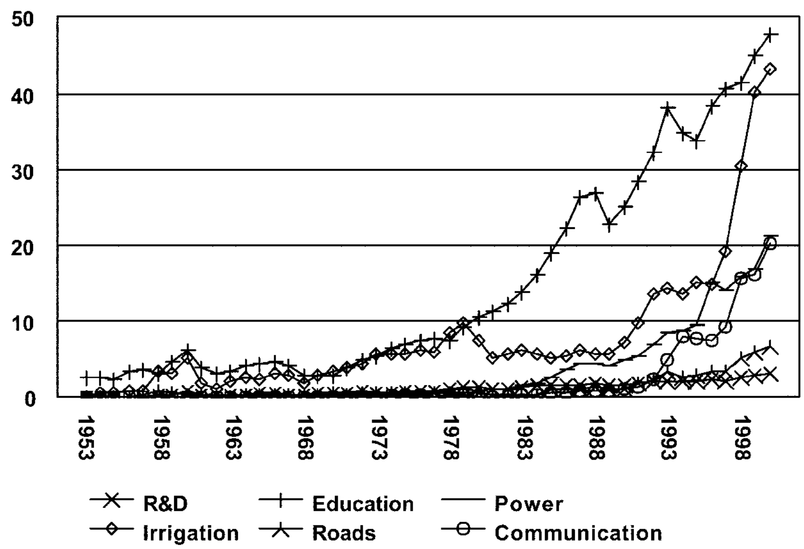

FIG. 1.—Public investment in rural China, 1990 billion yuan

gional variations in nonfarm income played a growing role in worsening income distributions. Development of the nonfarm sector was concentrated mostly in the coastal areas, where per capita income was already high and poverty incidence much lower than elsewhere. The large areas in the western and border provinces, home to most of the rural poor, lagged far behind. As a result, the number of poor increased from 89 million in 1984 to 103 million in 1989, a net gain of 14 million in 5 years (table 1).

Only in 1990 did rural poverty begin to decline once again. The number of rural poor dropped 9% per annum, from 103 million in 1989 to 30 million in 2000. Even using a higher poverty line of 1 dollar per day, the number of poor declined from 280 million in 1990 to 106 million in 1998, or a reduction of poverty rate from 31.3% to 11.5%.[9]

Rural residents earned less than half of what their urban cohorts earned in 1978; rural income was 42% of that in urban areas (table 1). Due to the success of rural reforms, that percentage increased to 59% in 1984. However, it declined again to 36% in 2000, mainly owing to fast growth in urban areas and relatively sluggish increases in rural earnings. Poverty in China is therefore still mainly a rural phenomenon. The urban poor have been relatively few in number in China, although income distribution in the cities has become less egalitarian in recent years. Nevertheless, the size and severity of urban poverty remain on a much lesser scale than in the rural areas.

III. Government Spending

This section of the article describes the trend and composition of government spending over the past several decades in rural China. As shown in figure 1, rural education spending accounted for 33% of total expenditures in rural areas in 2000. Irrigation is the next largest portion of expenditure, accounting for 30%. The irrigation spending considered in this study was only that directly related to irrigation and does not include urban water supply, navigation, and hydropower generation. Investment in rural infrastructure took about 33% of total government spending in rural areas, with 15% for rural power, 5% for rural roads, and 14% for rural telecommunications. Agricultural research, at 2.2%, accounted for only a small fraction of total government investment in rural areas.

A. Research and Development (R&D)

China's agricultural research system has expanded rapidly during the past 4 decades and is now one of the largest public systems in the world. However, the Chinese agricultural research system has experienced many ups and downs. Right after the founding of the People's Republic of China in 1949, China's investment in agricultural research was minimal, but it has grown rapidly since 1960 (fig. 1). The growth in the 1960s was relatively small due to the 3-year natural disaster (1959–61) and the Cultural Revolution (1966–76). Investment increased steadily during the 1970s, but this growth slowed down during the 1980s and grew only by 23% during the entire 10-year period. In the 1990s, agricultural research expenditures began to rise again, largely due to government efforts to boost grain production through science and technology.

B. Irrigation

The government assigned top priority to irrigation immediately after 1949. In 1953 the government spent 177 million yuan in irrigation investment, which was 10 times more than for research investment in agriculture (fig. 1). Investment in irrigation continued to increase until 1966. Under the commune system, it was rather easy for the government to mobilize a large number of rural laborers to take part in large irrigation projects. As a result of this increased investment, more than 10 million hectares of land were brought under irrigation. However, irrigation investment increased very little from 1976 to 1995. In fact, it declined from 1976 to 1989. In 1989, irrigation investment was only 44% of that of 1976. During this period, there was no increase in irrigated areas in Chinese agriculture production. In response to the grain shortfall and to heavy imports in 1995, the government increased investment in irrigation sharply subsequently in the period 1997–99. However, further expansion will be difficult to achieve because of the competing industrial and residential uses of water. As a result, the returns to investment in irrigation may decline in the future.

C. Education

The education level of the general population of China was one of the lowest in the world 4 decades ago. In 1956, it was still the case that less than one-half of the primary and secondary age children were in school. The periods of the Great Leap Forward (1958–61) and the Cultural Revolution (1966–76) were very disruptive times for Chinese society in general and for Chinese education in particular. The educational infrastructure was decimated as a result of the revolutionary struggles, and students suffered because of a vastly watered-down or nonexistent curriculum.

Since 1978, China has promoted the education policy of its "9-year compulsory schooling system," which requires all children to attend school for at least 9 years to finish both the primary and junior-school or middle-school programs. However, the policy was never seriously implemented, particularly in rural areas. In 1986, an education law requiring 9 years of compulsory education was formally issued. By 2000, the enrollment ratio of school-age children had risen to over 98%, and the percentage of primary school graduates who entered junior high school was at 85% in rural China.[10]

Consequently, labor quality has improved substantially, with a decline of the illiteracy rate of agricultural labor from 28% in 1985 to 10% in 1997. This improved human capital in rural areas provided great opportunity for farmers to use modern farming technology and to engage in nonfarm activities in both rural township enterprises and urban industrial centers.

Despite these successes, government investment in education is still not sufficient. In terms of expenditures, the government has spent roughly 2.6% of the total national GDP on education, a lower percentage than that spent on education by most developing countries, notable exceptions being Bangladesh, Indonesia, and Myanmar. In particular, many of the poor have not been reached by the government's efforts. Official provincial-level data reveal astonishing differences among provinces in the illiteracy rates of their rural laborers.[11] Not only has the illiteracy rate been higher in the western region but also its rate of decline has been the lowest of all of the provinces. The disparity can be even greater within a single province or county. According to official statistics, in the poorer half of the townships of 35 counties supported by a World Bank project in Yunnan, Guizhou, and Guangxi, the average school enrollment rate was at least 10 percentage points lower than the national average for the same age group.[12] Special household surveys document even greater disparities at the village level. The State Statistical Bureau's (SSB) 1994 survey of 600 households in the poorest townships of these 35 counties showed that the average school enrollment rate for children ages 6–12 was only 55%. It is therefore unsurprising that official statistics in these counties indicate an average literacy rate for the total population of only 35%.

D. Infrastructure

The mountainous topography in many parts of China has hindered the development of roads. In 1953, the total length of roads was only about 137 thousand kilometers, and the road density was about 14 kilometers per thousand square kilometers, much lower density than that of India at the time. Moreover, government investment in road construction increased very little from 1953 to 1976 (fig. 1). Nevertheless, the total length of roads has increased gradually. Since 1985, the government has geared up its investment in roads, particularly high-quality roads such as highways connecting major industrial centers in coastal areas.

For the past several decades, China has given a higher priority in its investment portfolio to electricity development than to road development (fig. 1). Investment in power was 90 times greater in 2000 than it was in 1953. Electricity consumption in rural areas increased from almost zero in 1953 to 242 billion kilowatts in 2000. A rapid growth in electricity use occurred in the 1970s and 1980s. By 1998, 98% of Chinese villages had access to electricity in 1998, and more than 97% of the households of these villages had connection to electricity. These percentages are much higher than the comparable percentages for India in the same year.

During most of the pre-1980 period, the growth in government investment in telecommunications was very slow (fig. 1). Such investment increased from 166 million yuan in 1953 to only 738 million yuan in 1980. However, large-scale development has occurred in the past several years; the number of rural telephone sets increased from 3.4 million in 1992 to 51.7 million in 2000. This growth was in large part a result of both public and private investment in the sector. Public investment for telecommunications was 20 times higher in 2000 than it was in 1989.

IV. Conceptual Framework and Model

This study develops a simultaneous equations model to estimate the various effects of government expenditure on production and poverty through different channels. There are at least two advantages to this method. First, many poverty determinants, such as income, production or productivity growth, prices, wages, and nonfarm employment, are generated from the same economic process as inequality and poverty. In other words, these variables are also endogenous variables. Ignoring this characteristic leads to biased estimates of the poverty and inequality effects. Second, certain economic variables affect poverty through multiple channels. For example, improved rural infrastructure reduces rural poverty not only through improved growth in agricultural production but also through improved wages and opportunities for nonfarm employment. It is very difficult to capture these different effects using a single-equation approach.

Equations (1)–(11) give the formal structure of the system. Table 2 presents definitions of the variables. Equation (1) models the determinants of rural poverty (P).[13] Determinants include agricultural GDP per agricultural laborer (AGDPPC), the rural nonfarm daily wage (WAGE), nonagricultural employment (NAGEMPLY), the domestic terms of trade for agriculture (TT), the percentage of urban population in the total population (URBANP), and a 3-year lagged moving average of per capita government spending on poverty alleviation loans (PLOAN). Agricultural GDP per worker is included as a variable in the poverty

TABLE 2

Definition of Exogenous and Endogenous Variables

Variable	Definition
Exogenous variable:	
LANDPC	Land area per worker
AKPC	Agricultural capital per worker
NAKPC	Capital per worker in rural nonagricultural sector
URBANP	Percentage of urban population in total population
UGDPPC	Per capita GDP produced by the urban sector
IRE	Government expenditure on irrigation, both from revenue and capital accounts
RDE	Government spending (both revenue and capital) on agricultural R&D
ROADE	Government investment and spending on rural roads
EDE	Government spending on rural education
RTRE	Government spending on rural telecommunications
PWRE	Government spending on rural power
PLOAN	Government expenditures for poverty alleviation per capita, measured as last 3 years moving average
Endogenous variable:	
P	Percentage of rural population below poverty line
SCHY	Average years of schooling of rural population 15 years and older
ROADS	Road density in rural areas
IR	Percentage of total cropped area that is irrigated
ELECT	Electricity consumption
RTR	Rural telephone
WAGE	Wage rate of nonagricultural labor in rural areas
NAGEMPLY	Percentage of nonagricultural employment in total rural employment
AGDPPC	Agricultural GDP per laborer
AGDPPCn	Agricultural productivity growth at the national level
NAGDPPC	Nonagricultural GDP per worker in rural area
TT	Terms of trade, measured as agricultural prices divided by a relevant nonagricultural GNP deflator

equation because agricultural income still accounts for a substantial share of total income among rural households.

$$P = f(\text{AGDPPC, WAGE, NAGEMPLY, TT, URBABP, PLOAN}), \quad (1)$$

$$\text{AGDPPC} = f(\text{LANDPC, AKPC, RDE, RDE}_{-1}, \ldots, \text{RDE}_{-I}, \text{IR, SCHY, ROADS, ELECT, RTR, X}), \quad (2)$$

$$\text{NAGDPPC} = f(\text{NAKPC, SCHY, ROADS, ELECT, RTR}), \quad (3)$$

$$\text{WAGE} = f(\text{ROADS, SCHY, RTR, ELECT, AGDPPC}_{-1}, \text{UGDPPC}_{-1}) \quad (4)$$

$$\text{NAGEMPLY} = f(\text{ROADS, SCHY, ELECT, RTR, AGDPPC}_{-1}, \text{UGDPPC}_{-1}), \quad (5)$$

$$\mathrm{IR} = f(\mathrm{IRE}, \mathrm{IRE}_{-1}, \ldots, \mathrm{IRE}_{-J}), \tag{6}$$

$$\mathrm{ROADS} = f(\mathrm{ROADE}, \mathrm{ROADE}_{-1}, \ldots, \mathrm{ROADE}_{-K}), \tag{7}$$

$$\mathrm{SCHY} = f(\mathrm{EDE}, \mathrm{EDE}_{-1}, \ldots, \mathrm{EDE}_{-M}), \tag{8}$$

$$\mathrm{RTR} = f(\mathrm{RTRE}, \mathrm{RTRE}_{-1}, \ldots, \mathrm{RTRE}_{-L}), \tag{9}$$

$$\mathrm{ELECT} = f(\mathrm{PWRE}, \mathrm{PWRE}_{-1}, \ldots, \mathrm{PWRE}_{-N}), \tag{10}$$

$$\mathrm{TT} = f(\mathrm{AGDPPC}, \mathrm{AGDPPC}_{n}). \tag{11}$$

Nonfarm employment income is the second most important source of income after agricultural production for rural residents in China. The wage and number of nonfarm laborers are good proxies for nonfarm income. Moreover, we can distinguish the differential impacts of changes in wages and number of workers in the nonfarm sector on rural poverty reduction. These differential impacts may have important policy implications for further poverty reduction. If improvement in rural wages reduces rural poverty more than increased rural nonfarm employment does, then government resources should be targeted to improve rural wages. If the opposite is the case, then resources should be directed to increasing rural nonfarm employment.

The terms-of-trade variable measures the impact on rural poverty of changes in agricultural prices relative to nonagricultural prices. Pricing policy can have a large effect on the rural poor. We hypothesize that, in the short run, the poor may suffer from higher agricultural prices if they are usually net buyers of food grains, but they may gain from higher prices if they are net sellers of agricultural products. In the long run, however, increased agricultural prices may induce government and farmers to invest more in agricultural production, shifting the supply curve outward.

Public spending on rural poverty loans has been a major policy instrument for the government to reduce poverty. For example, in 1996 such loans accounted for 82% of total government spending on poverty alleviation. Since these funds often take time to affect rural poverty, we use a moving average of the past 3 years of spending in our regression.

For the agricultural productivity function (eq. [2]), labor productivity is the dependent variable while independent variables include land and capital per worker (LANDPC and AKPC) as conventional inputs. The following supply shifter variables capture the direct impact of technology, infrastructure, and education on agricultural labor productivity growth: current and lagged government spending on agricultural research and extension (RDE, RDE_{-1}, . . ., RD_{-I}), percentage of irrigated cropped area in total cropped area (IR), average years of schooling of rural population (SCHY), road density (ROADS), per capita agricultural electricity consumption (ELECT), and number of rural telephone sets per thousand rural residents (RTR). The variable X captures the impact of rural reforms on agricultural productivity. In this case, we use the year dummies to capture the year-specific policy reforms on growth in agricultural productivity.

For the nonagricultural productivity function (eq. [3]), the dependent variable is nonagricultural (township and village enterprise) GDP labor productivity (NAGDPPC). Independent variables are capital per worker (NAKPC), workers' years of schooling, and infrastructure.

Equations (4) and (5) are wages and employment determination functions in the rural nonfarm sector. These equations are reduced forms of labor supply and demand, where equilibrium wages clear the labor market. The derived labor and wages are a function of labor productivity. Labor productivity, in turn, is a function of the capital/labor ratio and of production shifters such as infrastructure and improvements in education. Therefore, the final labor and wage equations are functions of capital/labor ratios and production shifters. However, when we include the capital/labor ratio in our model, the coefficients are not statistically significant. We therefore drop them from the equations. This lack of significance may be because TVEs may have difficulty in raising capital to expand production due to lack of credit support or a well-developed capital market. Growth in the urban sector (UGDPPC_{-1}) is included to control for the effects of urban growth on rural wages and nonfarm employment.

Equations (6)–(10) model the relationships between physical infrastructure levels and past government expenditures for different items. Equation (6) defines the relationship between the share of cropped areas irrigated and current and past government spending on irrigation ($\text{IRE}, \text{IRE}_{-1}, \ldots, \text{IRE}_{-J}$); equation (7) defines the relationship between road density and current and past government spending on rural roads ($\text{ROADE}, \text{ROADE}_{-1}, \ldots, \text{ROADE}_{-K}$); equation (8) defines the relationship between average years of schooling of the rural population and current and past government expenditures on education ($\text{EDU}, \text{EDU}_{-1}, \ldots, \text{EDU}_{-M}$); equation (9) models the relationship between the number of rural telephones and government expenditures on telecommunications ($\text{RTRE}, \text{RTRE}_{-1}, \ldots, \text{RTRE}_{-L}$); and equation (10) models the relationship between the consumption of electricity (ELECT) and government spending on power ($\text{PWRE}, \text{PWRE}_{-1}, \ldots, \text{PWRE}_{-N}$).

Equation (11) determines the agricultural terms of trade. Growth in agricultural productivity at the province and national level (AGDPPCn) increases the supply of agricultural products and thus reduces agricultural prices. The inclusion of national productivity growth reduces any upward bias in the estimation of the poverty alleviation effects of government spending within each province, since production growth in other provinces will also contribute to lower food prices through the national market. Initially, we also included some demand-side variables in the equation, such as population and income growth, but they were not significant and so we dropped them.

Institutional changes and policy reforms made large contributions to the rapid growth in agricultural and nonagricultural production and to poverty reduction in China's rural areas. This study does not aim to quantify these effects, as previous studies have already done so.[14] However, in order to reduce or eliminate the estimation bias from omitting these effects in our model estimation, we add year dummies in all equations to capture the year-specific institutional and policy changes on growth in agricultural and nonagricultural production and on poverty reduction. Regional dummies are also included to control for region-specific fixed effects.

V. Estimation and Results

This section discusses the estimation technique and the estimation results. It further details the calculation and analysis of the marginal returns derived from additional units of expenditure on various types of public spending and in different regions.

A. Model Estimation

We use double-log functional forms for all equations in the system. More flexible functional forms such as Translog or quadratic impose fewer restrictions on estimated parameters, but many coefficients are not statistically significant due to multicollinearity problems among various interaction variables. For the system equations, we use the full information maximum likelihood estimation technique.

Since our provincial poverty data are only available for 7 years (1985–89, 1991, and 1996), a two-step procedure is used in estimating the full equations system. The first step involves estimating all the equations except for the poverty equation using the provincial-level data from 1970 to 1997. Then the values of AGDPPC, WAGE, and NAGEMPLY and TT at the provincial level are predicted using the estimated parameters. The second step estimates the poverty equation using the predicted values of the independent variables at the provincial level, based on the available poverty data for 1985–89, 1991, and 1996. The advantage of this procedure is to fully use the information available for all nonpoverty equations, therefore increasing the reliability of estimates and avoiding the endogeneity problem of the poverty equation.

Government investments in R&D, roads, education, power, telecommunications, and irrigation can have long lead times in affecting agricultural production and poverty reduction, and their effects can be long term once they kick in. Thus, one of the thornier problems to resolve when including government investment variables in a production or productivity function concerns the choice of the appropriate lag structure. Most past studies use stock variables, which are usually weighted averages of current and past government expenditures on certain investments such as R&D. But what weights and how many years of lag should be used in the aggregation are under debate. Since the shape and length of these investments are largely unknown, we use a free-form lag structure in our analysis; that is, we include current and past government expenditures on certain investment items such as R&D, irrigation, roads, power, and education in the respective productivity, technology, infrastructure, and education equations. Then we use statistical tools to test and determine the appropriate length of lag for each investment expenditure.

Various procedures have been suggested for determining the appropriate lag length. The adjusted R^2 and Akaike's Information Criteria (AIC) are often used by economists.[15] This report simply uses the adjusted R^2. Since R^2 estimated from the simultaneous system does not provide the correct information on the fitness of the estimation, we use the adjusted R^2 estimated from the single equation. The optimal length is determined when adjusted R^2 reaches a maximum. The ACI is similar in spirit to the adjusted R^2 in that it rewards good fit but penalizes the loss of degrees of freedom. The lags determined by the adjusted R^2 approach are 17, 14, 16, 12, and 17 years for, respectively, R&D, irrigation, education, power, and roads.

Another problem related to the estimation of a lag distribution is that the independent variables (e.g., RDE, RDE_{-1}, RDE_{-2}, . . ., and RDE_{-I} in the productivity function) are often highly correlated, making the estimated coefficients statistically insignificant. A number of ways to tackle this problem have been proposed. The most popular is to use what are called polynomial distributed lags (PDLs). In a polynomial distributed lag, the coefficients are all required to lie on a polynomial of some degree d. This analysis uses PDLs with degree 2. In this case, we only need to estimate three instead of $I + 1$ parameters for the lag distribution.[16] Once the lengths of lags are determined, we estimate the simultaneous equation system with the PDLs and appropriate lag length for each investment.

B. Estimation Results

Table 3 presents the results of the systems equation estimation. Most of the coefficients in the estimated system are statistically significant at the 10% confidence level (one-tail test). Since we use the double-log functional form, the estimated coefficients are elasticities in their respective equations.

The estimated poverty equation (eq. [1]) supports the findings of many previous studies. Improvements in agricultural productivity, higher agricultural wages, and increased nonagricultural employment opportunities have all contributed significantly to reducing poverty. The coefficient of the terms of trade variable is negative and statistically significant, meaning that higher agricultural prices are good for the poor. This is explained by the fact that most poor farmers in China are net sellers of agricultural products. When agricultural prices rise, the incomes of these farmers rise. Government spending on poverty alleviation loans helps to reduce rural poverty, but the coefficient of the variable is not statistically significant.

The estimated agricultural labor productivity function (eq. [2]) shows that agricultural research and extension, roads, irrigation, and education have contributed significantly to growth in agriculture. However, the coefficient for

TABLE 3

ESTIMATES OF THE SIMULTANEOUS EQUATION SYSTEM

Equation No./Variable		Estimated Equations						R^2
(1) ln*P*	=	−1.219 lnAGDPPC (−2.99)$^{+}$	−.37 lnWAGE (−1.22)	−.937 lnNAGEMPLY (−3.82)$^{+}$	−1.15 lnTT (−1.62)	−.051 lnPLOAN (−.81)	− .389 lnURBANP (−.87)	.655
(2) lnAGDPPC	=	.438 lnLANDPC (9.36)	+.113 lnAKPC (5.16)$^{+}$	.079 lnRDE (2.47)$^{+}$	.099 lnROAD (3.43)$^{+}$	.481 lnIR (12.51)$^{+}$	.301 lnSCHY (2.62)$^{+}$	.914
		.079 lnRTR (4.40)$^{+}$	.010 lnELECT (.32)					
(3) lnNAGDPPC	=	.576 lnNAKPC (17.83)$^{+}$	.173 lnROADS (4.26)$^{+}$	.581 lnSCHY (3.71)$^{+}$	.011 lnELECT (.21)	.079 lnRTR (1.78)$^{+}$		.810
(4) lnWAGE	=	.090 lnROADS (2.05)$^{+}$	.112 lnELECT (1.70)	.035 lnRTR (2.21)$^{+}$	.690 lnSCHY (2.40)$^{+}$	.587 lnAGDPPC$_{-1}$ (8.79)$^{+}$	−.148 lnUGDPPC (−1.49)	.541
(5) lnNAGEMPLY	=	.100 lnROADS (3.16)$^{+}$	.036 lnRTR (1.90)$^{+}$	.406 lnSCHY (3.04)$^{+}$	.112 lnELECT (2.04)$^{+}$	−.063 lnaGDPPC$_{-1}$ (−1.36)	.112 lnUGDPPC (2.19)$^{+}$	.995
(6) lnIR	=	.247 lnIRE (3.374)$^{+}$						.976
(7) lnROADS	=	.120 lnROADE (1.752)$^{+}$						.959
(8) lnSCHY	=	.409 lnEDE (1.768)$^{+}$						.975
(9) lnRTR	=	.270 lnRTRE (2.13)$^{+}$						.976
(10) lnELECT	=	.328 lnPWRE (5.56)$^{+}$						.976
(11) lnTT	=	−.142 lnAGDPPC (−2.15)$^{+}$	−.041 lnAGDPPCn (−1.87)$^{+}$					.932

NOTE.—Region and year dummies are not reported. The coefficients for the technology, education, and infrastructure variables are the sum of those for past government expenditures. The *t* values are in parentheses.

$^{+}$ Statistically significant at the 10% level.

the electricity variable is not statistically significant. The coefficient reported here for agricultural research and extension is the sum of the past 17 years' coefficients from the PDLs distribution. The significance test is the joint *t*-test of the three parameters of the PDLs.

Estimated equation (3) shows that improved roads, education, and rural telecommunications have all contributed to the development of the rural nonfarm sector. Similar to the equation (2) estimation in the agricultural productivity function, the access to electricity variable is not statistically significant, although the sign of its coefficient is positive.

The estimates for equation (4) show that rural nonfarm wages are determined mainly by government investments in roads, education, and telecommunications. An important finding in this equation is that agricultural labor productivity affects rural nonfarm wages significantly. However, urban growth has no statistically significant impact on rural wages.

The estimates for equation (5) show that improved rural roads, telecommunications, electrification, and education have contributed to growth in nonfarm employment. Growth in the urban sector has also contributed significantly to the development of rural nonfarm employment. In contrast to the wage equation, agricultural labor productivity had no significant impact on rural nonfarm employment.

The estimated results for equations (6)–(10) show that government investments in irrigation, roads, education, rural telecommunications, and power have contributed to the improvement of irrigation, to the development of roads, to rural education, to rural communication, and to the increased use of electricity. All of the coefficients are statistically significant.

Finally, the estimated terms of trade equation (eq. [11]) confirms that increases in agricultural productivity at the local and national levels exerted a downward pressure on agricultural prices, worsening the terms of trade for agriculture.

C. Effects of Institutional Reforms and Government Spending

Using equations (1)–(11) and the estimates in table 3, we can derive the sources of growth and poverty reduction and the marginal returns to different types of government expenditures in growth and reduction of rural poverty, as shown in appendix B.

Table 4 shows the sources of agricultural growth and poverty reduction. From 1978 to 1984, rural reforms accounted for more than 60% of total production growth in Chinese agriculture. This share confirms the findings of Shenggen Fan and Justin Yifu Lin that the implementation of the household responsibility system has led to rapid growth in Chinese agriculture.[17] More important is the tremendous contribution of rural reforms to rural poverty reduction. More than 51% of poverty reduction can be attributed to these reforms. Public investment also played a significant role in the growth of both agricultural production and poverty reduction, as it accounted for 12% of growth and 45% of poverty reduction during this reform period of 1978–84.

TABLE 4

SOURCES OF AGRICULTURAL GROWTH AND POVERTY REDUCTION

	1978–84 (%)	1985–2000 (%)
Agricultural production growth:		
Institutional reforms	60.08	−.84
Public investment	12.43	63.25
Others	27.49	37.59
Poverty reduction:		
Institutional reforms	51.25	−.43
Public investment	45.45	94.17
Others	3.30	6.26

NOTE.—The institutional reform affects reduction in rural poverty through increased agricultural productivity. The other channels, such as those through improved labor market, are not captured here.

From 1985 to 2000, the impact of institutional reforms on agricultural productivity growth was not significant. In fact, it was slightly negative. The contribution of public investment increased to 63%, which is more than five times its share during the period 1978–84. More important is the large contribution of public investment to poverty reduction, accounting for 94% of that reduction. As with agricultural productivity growth, the institutional reforms in the agricultural sector had no impact on poverty reduction during the postreform period.

We calculate the marginal returns by different types of investments in three regions.[18] Table 5 shows the marginal effects of government spending on agricultural and nonagricultural production and rural poverty for the three regions and for China as a whole. These effects are measured as the returns in yuan or the number of the poor brought out of poverty per unit of spending in the year 2000. For example, the returns to investments in irrigation are measured as yuan of additional production or the number of persons brought out of poverty per one additional unit spent on irrigation.[19] These measures provide useful information for comparing the relative benefits of additional units of expenditure on different items in different regions, particularly for setting future priorities for government expenditure to further increase production and reduce rural poverty. Since the official poverty data by region are not available after 1996, we use Zude Xian and Sheng Laiyun's estimates of rural poverty rates by province in calculating the returns to poverty reduction.[20] There are two advantages in using these data. First, the rates are for 1998, and therefore they are more relevant for the current policy debate. Second, the income poverty line used is 836 yuan per year per person, which is close to the one dollar per day commonly used by the World Bank.

An important feature of the results in table 5 is that all production-enhancing investments reduce poverty while at the same time increasing agricultural and nonagricultural GDP. However, there are sizable differences in production gains and poverty reductions among the various expenditure items and across regions. For the country as a whole, government expenditure on

TABLE 5

RETURNS OF PUBLIC INVESTMENT, 2000

	Coastal	Central	Western	Average
Returns to total rural GDP (yuan per yuan expenditure):				
R&D	5.54	6.63	10.19	6.75
Irrigation	1.62	1.11	2.13	1.45
Roads	8.34	6.90	3.39	6.57
Education	11.98	8.72	4.76	8.96
Electricity	3.78	2.82	1.63	2.89
Telephone	4.09	4.60	3.81	4.22
Returns to agricultural GDP (yuan per yuan expenditure):				
R&D	5.54	6.63	10.19	6.75
Irrigation	1.62	1.11	2.13	1.45
Roads	1.62	1.74	1.73	1.69
Education	2.18	2.06	2.33	2.17
Electricity	.81	.78	.88	.82
Telephone	1.25	1.75	2.49	1.63
Returns to nonfarm GDP (yuan per yuan expenditure):				
Roads	6.71	5.16	1.66	4.88
Education	9.80	6.66	2.43	6.79
Electricity	2.96	2.04	.75	2.07
Telephone	2.85	2.85	1.32	2.59
Returns to poverty reduction (no. of poor reduced per 10,000 yuan expenditure):				
R&D	3.72	12.96	24.03	10.74
Irrigation	1.08	2.16	5.02	2.31
Roads	2.68	8.38	10.03	6.63
Education	5.03	13.90	18.93	11.88
Electricity	2.04	5.71	7.78	4.85
Telephone	1.99	8.10	13.94	6.17
Poverty loan	3.70	3.57	2.40	3.03

NOTE.—We use the parameters from the productivity functions to calculate the returns to GDP (table 3). Under the assumption of constant returns to scale, coefficients for nonlabor parameters in the production function should be the same as those in the labor productivity function. The marginal returns can be easily derived and calculated by multiplying production elasticities by partial productivity of each spending item. Since only two coefficients (on electricity) are not statistically significant, the results are little different when we use the only statistically significant coefficients in the calculation. The number of poor used in the calculation is from Zude Xian and Sheng Laiyun, "PRC's Rural Residents with Consumption Less Than 860 Yuan: Targeting Group and Characteristics" (Beijing: National Statistical Bureau, Beijing, 2002, mimeographed). Most of the estimates are statistically significant at the 10% level. The only exceptions are returns in agricultural GDP, nonfarm GDP, and overall GDP to electricity investment.

education had the largest impact in reducing poverty. In addition, it had the largest return to nonfarm GDP and overall rural GDP as well as the second largest return to AgGDP. Therefore, investing more in education is the dominant "win-win" strategy. For every 10,000 yuan investment, some 12 people are brought out of poverty.

Investment in agricultural R&D had the second largest impact on poverty, and its impact on AgGDP ranks first. Agricultural R&D is thus another very favorable investment. Government expenditure on rural infrastructure also made large contributions to poverty reduction. These impacts were realized through growth in both agricultural and nonagricultural production. Among the three infrastructure variables considered, the impact of roads is particularly large. For every 10,000 yuan invested, 6.6 of the poor are lifted above the poverty line. Roads thus rank third in poverty-reduction impact, after education and R&D. In terms of the impact on growth, for every yuan invested in roads, 6.57 yuan in rural GDP is produced, which is only slightly less than the return to education investments. This stems from the high returns to nonagricultural GDP, which is the second largest return at 4.88 yuan for every yuan invested.[21]

Next consider rural telephony. As can be seen in table 5, investments in rural telephony had favorable returns to both agricultural and nonagricultural GDP, and the impact on rural poverty was similar to that of road investments.

Although electricity investment showed low returns to both agricultural and nonagricultural GDP, its poverty reduction impact is significant. For every 10,000 yuan investment, 4.9 people were brought out of poverty. This is because access to electricity is essential to the expansion of nonfarm employment (table 3).

For the nation as a whole, irrigation investment had relatively little impact on rural poverty reduction, although its economic returns were still positive. This is because irrigation affects poverty reduction solely through improved agricultural productivity.

One striking result from our study is the very small and statistically insignificant impact of government poverty alleviation loans. For every 10,000 yuan invested, only slightly more than three people were brought out of poverty.

Regional variation is large in the marginal returns to government spending in both GDP growth and poverty reduction. In terms of poverty reduction effects, all types of investment had high returns in the western region. For example, for every 10,000 yuan invested in agricultural R&D, education, roads, telecommunications, and electricity, the respective numbers of poor reduced were 24, 19, 10, 14, and 8. These effects are 6.4, 3.7, 3.7, 7.0, and 3.8 times higher than those of the coastal areas. Even for irrigation, every 10,000 yuan additional investment was sufficient to bring five people out of poverty, a magnitude four times higher than that of the coastal area.

With respect to returns to growth in agriculture, most of the investments had their largest returns in the western areas. On the other hand, most government expenditures had their largest impact on rural nonfarm GDP in the coastal areas.

VI. Conclusion

Using provincial-level data for 1953–2000, this study developed a simultaneous equations model to estimate the effects of different types of government expenditure on growth and rural poverty in China. The results show that government spending on production-enhancing investments, such as agricultural R&D and irrigation, rural education, and infrastructure (including roads, electricity, and telecommunications), all contributed to agricultural productivity growth and reduced rural poverty. However, variations in the marginal effects on productivity were large among the different types of spending as well as across regions. During the period 1978–84, institutional and policy reform was the dominant factor both in promoting growth and in reducing rural poverty. However, during the period 1985–2000, public investment became the largest source of production growth and poverty reduction.

Government expenditure on education had the largest impact on poverty reduction and very high returns to growth in agriculture and the nonfarm sector, as well as to the rural economy as a whole.

Government spending on agricultural research and extension improved agricultural production substantially. In fact, this type of expenditure had the largest returns to growth in agricultural production. Since China is a large country, growth in agriculture is still much needed to meet the increasing food needs of its richer and larger population. Agricultural growth also trickled down in large benefits for the rural poor. The impact of R&D on poverty ranked second only to education investments.

Government spending on rural telecommunications, electricity, and roads also had a substantial marginal impact on rural poverty reduction. These poverty-reduction effects came mainly from improved nonfarm employment and increased rural wages. Specifically, road investment had the second largest return to GDP growth in the nonfarm economy and the second largest return to the overall rural economy.

Irrigation investment had only a modest impact on growth in agricultural production and even less of an impact on rural poverty reduction, even after trickle-down benefits were allowed for. This is consistent with the results of Shenggen Fan, Peter Hazell, and S. Thorat for India.[22] Another striking result is that government spending on loans specifically targeted for poverty alleviation had the least impact on rural poverty reduction. This type of spending also did not have any obvious productivity effect. Again, this is consistent with the Indian findings of Fan, Hazell, and Thorat.

Additional investments in the western region contribute most to reducing poverty, because this is where most of the poor are now concentrated. The poverty reduction effect of spending in education, agricultural R&D, and infrastructure is especially high in the region.

The results of this study have important policy implications for future priorities in government expenditure. The study reveals large differential impacts of various types of government spending on growth and poverty reduction. The potential gains from reallocating government resources are enormous. Based on the results of our study, we offer the following policy suggestions:

1. The government should continue efforts to increase its overall investment in rural areas. Government spending in rural areas accounted for only 20% of total government expenditures in 2000, but rural residents account for 69% of China's total population. Moreover, almost 50% of the

national GDP was produced by the rural sector (agriculture and rural township and village enterprises) in 2000. The government's rural spending as a percentage of rural GDP is only about 5% as compared with 16.4% for the whole economy. China has implemented an urban- and industry-biased investment policy for the past several decades. As a result, the rural-urban income gap is gigantic and has increased over time. Any policies against the rural sector will aggravate the existing disparity and should be discontinued.

2. There is an urgent need to increase investment in agricultural R&D. Agricultural research expenditure as a percentage of AgGDP is only 0.3%. This is extremely low in comparison with the 2% spent in many developed countries; it is even lower than the percentages in most developing countries (0.5%–0.8%). Various evidence, including this study, shows that agricultural research investment not only has high economic returns but also has a large impact in reducing rural poverty and regional inequality. Moreover, new evidence has revealed that agricultural research contributes to a large drop in urban poverty through lowered food prices.[23] Without agricultural research, China would have many more urban poor today. Finally, increased agricultural research investment is one of the most efficient ways to solve China's long-term food security problem.[24] All this suggests that increased investment in agricultural research is a "win-win-win" (growth, poverty and equity, food security) national development strategy.

3. The government should gear up its investment in rural education, even though its current rural education spending is already the largest of all rural expenditures. Improved education helps farmers access and use new technologies generated by the research system, thereby promoting agricultural growth. More important, education helps farmers to gain and improve the skills they need for nonfarm jobs in rural enterprises and for migration to the urban sector. Our results show that rural education investment has the largest poverty reduction effect per unit of spending. Therefore, continued increases in rural education investment, particularly in the less-developed western region, are a very effective means of promoting growth in agriculture and rural nonfarm employment and reducing rural poverty and regional inequality.

4. Rural infrastructure should receive high priority in the government's investment portfolio. Like rural education, investments in infrastructure contribute to reducing rural poverty mainly by spurring nonfarm employment and growth in agricultural production. Among all rural infrastructures, roads should receive special attention, as they have the largest poverty reduction and growth impact (as compared with telecommunications and electricity).

5. China invested heavily in irrigation in the past. Large-scale irrigation facilities were built, and a high percentage of the country's arable land is now under irrigation. The marginal returns from further investment may therefore be small and declining, and future investments should be geared to improving the efficiency of existing public irrigation systems.

6. The low returns of rural poverty alleviation loans to poverty reduction indicate that these loans should be better targeted. Studies show that a large part of the funds have gone to nonpoor regions and to nonpoor households, and many rural poor do not benefit from them at all. The funds are also often used for purposes such as covering administrative costs of local governments instead of for poverty alleviation. Although the government has realized the seriousness of the problem, more efforts are needed to better target the funds to the poor or otherwise use the money to improve rural education and infrastructure, both of which promote long-term growth and thereby offer a long-term solution to poverty reduction.

7. That the highest returns to all kinds of investment in reducing both rural poverty and regional inequality are in the western region, as shown in our study, is consistent with the national strategy to develop the western region. In particular, investment in agricultural research, education, and rural infrastructure should be the government's top priority. Considering China's decentralized fiscal system and the western region's small tax base, fiscal transfers from the richer coastal region are called for to develop the vast west.

Appendix A

Data Sources and Explanations

Poverty. There are several estimates of rural poverty in China. Official statistics indicate that the number of poor declined to about 50 million by 1997.[25] World Bank estimates are similar to Chinese official statistics. A third set of estimates made by Martin Ravallion and Shaohua Chen, which is based on a much higher poverty line, shows a far greater proportion of the total population subject to poverty, with a poverty incidence of 60% in 1978 and 22% in 1995.[26] However, the declining trend of rural poverty in this last set of estimates is steeper than that in the official Chinese statistics. Azizur Rahman Khan, using samples of the household survey, obtained 35.1% for 1988 and 28.6% for 1995.[27] Although these poverty rates are higher than the official rates, the change over time differs little from the official statistics.

The present study uses provincial-level poverty data from official sources. Few scholars have reported their estimates by province. Khan estimated provincial poverty indicators (both head count ratio and poverty gap index) for 1988 and 1995, using the household survey data. To test the sensitivity of our estimated results, we first used both official statistics and Khan's estimates, obtaining similar results, largely because the two sets of poverty figures share similar trends. Our final results are based on the official data simply because poverty data are available by province for more years.

Agricultural and nonagricultural GDP. Both nominal GDP and real GDP growth indices for various sectors are available from State Statistical Bureau of China, *The Gross Domestic Product of China* (Beijing: China Statistical Publishing House, 1997). Data sources and the construction of national GDP estimates were also published by the State Statistical Bureau (SSB) in *Calculation and Methods of China's Annual GDP* (Beijing: China Statistical Publishing House, 1997). According to this publication, the SSB used the UN standard system of national accounts (SNA) definitions to estimate GDP for 29 provinces by three economic sectors (primary, secondary, and tertiary) in mainland China for the period 1952–95. Since 1995, the *China Statistical*

Yearbook has published GDP data every year for each province by the same three sectors. Both nominal and real growth rates are available from SSB publications.

The agricultural sector is equivalent to the primary sector used by the SSB. We use the following procedures to construct GDP for the nonagricultural sector in rural areas: until 1996, China published the value of annual gross production for rural industry and services. In 1996, it began to publish value-added figures. The definition of value-added is equivalent to the GDP data. The Ministry of Agriculture published data on both gross production value and value-added for rural industry (including construction) and services in *China's Agricultural Yearbook 1996* (Beijing: China Agricultural Publishing House, 1997). The data on nominal value added for rural industry and services prior to 1995 were estimated using the growth rate of gross production value and 1995 value-added figures, assuming no change in the ratio of value added to gross production value.

The GDP for rural industry was subtracted from the GDP for industry as a whole (or the secondary sector as classified by the SSB) to obtain the GDP for urban industry. Similarly, the GDP for rural services was subtracted from the aggregate service sector GDP (or the tertiary sector as classified by the SSB) to obtain the GDP for the urban service sector. The GDP for rural enterprise is the sum of the GDP for rural industry and the GDP for rural services.

The implicit GDP deflators by province for the three sectors are estimated by dividing nominal GDP by real GDP. These deflators are then used to deflate the nominal GDP for rural industry and services to obtain their GDP in real terms.

Labor. Agricultural labor is measured in stock terms as the number of persons engaged in agricultural production at the end of each year. The data prior to 1978 were available in the SSB's *Historical Statistical Materials for Provinces, Autonomous Regions and Municipalities (1949–1989).* The data after 1977 were taken from various issues of *China's Agricultural Yearbook*, *China's Statistical Yearbook*, and *China's Rural Statistical Yearbook*. The labor input for the nonfarm sector is calculated simply by subtracting agricultural labor from total rural labor.

Capital stock. The capital stocks for the agricultural and nonagricultural sectors in rural areas are calculated from data on gross capital formation and annual fixed asset investment. For the three sectors classified, the SSB published data on gross capital formation by province after 1978. Gross capital formation is defined as the value of fixed assets and inventory acquired minus the value of fixed assets and inventory disposed. To construct a capital stock series from data on capital formation, we use the following procedure: define the capital stock in time t as the stock in time $t-1$ plus investment minus depreciation,

$$K_t = I_t + (1 - \delta)K_{t-1}, \qquad \text{(A1)}$$

where K_t is the capital stock in year t, I_t is gross capital formation in year t, and δ is the depreciation rate. The SSB's *China Statistical Yearbook* for 1995 reports the depreciation rate of fixed assets of state-owned enterprises for industry, railways, communications, commerce, and grain for the period 1952–92. We use the rates for grain and commerce for agriculture and services, respectively. After 1992, the SSB ceased to report official depreciation rates. For the years after 1992 we used the 1992 depreciation rates.

To obtain initial values for the capital stock, we used a procedure similar to that used by Kohli.[28] That is, we assume that, prior to 1978, real investment grew at a steady rate (r), which is assumed to be the same as the rate of growth of real GDP from 1952 to 1977. Thus,

$$K_{1978} = \frac{I_{1978}}{(\delta + r)}. \tag{A2}$$

This approach ensures that the 1978 value of the capital stock is independent of the 1978–95 data used in our analysis. Moreover, given the relatively small capital stock in 1978 and the high levels of investment, the estimates for later years are not sensitive to the 1978 benchmark value of the capital stock.

Estimates of capital stocks for rural industry and services are constructed using the annual fixed asset investment by province from 1978 to 1995. These are from the annual *China Statistical Yearbook* and the SSB's annual *China Fixed Asset Investment Statistical Materials,* 1950–95. Initial values are calculated using equation (A2), but the growth rate of real investment prior to 1978 is assumed to be 4%. Again, the initial capital stock is low, so the estimated series is not sensitive to the benchmark starting value.

The capital stock for rural industry is subtracted from that of total industry (or secondary industry as classified by the SSB) to obtain the capital stock for the urban industrial sector. Similarly, the capital stock for rural services is subtracted from the aggregate service sector (or tertiary sector as classified by the SSB) to obtain the capital stock for the urban service sector. Finally, the capital stock for rural enterprise is the sum of the capital stocks for rural industry and services.

Prior to constructing capital stocks for each sector, annual data on capital formation and fixed asset investment was deflated by a capital investment deflator. The SSB began to publish provincial price indices for fixed asset investment in 1987. Prior to 1987, we use the national price index of construction materials to proxy the capital investment deflator.

R&D expenditures. Public investment in agricultural R&D is accounted for in the total national science and technology budget. The sources of agricultural R&D investment are different government agencies. Science and technology commissions at different levels of government allocate funds to national, provincial, and prefectural institutes, primarily as core support. These funds are mainly used by institutes to cover researchers' salaries, benefits, and administrative expenses. Project funds come primarily from other sources, including departments of agriculture, research foundations, and international donors. Recently, revenues generated from commercial activities (development income) became an important source of revenue for the research institutes. The research expenditures reported in this study include only those expenses used to directly support agricultural research. The data reported here are from Fan and Pardey and various publications from the Government Science and Technology Commission and the State Statistical Bureau.[29] Research expenditures and personnel numbers include those from research institutions at national, provincial, and prefectural levels, as well as agricultural universities (only the research part).

When calculating returns to R&D investment, expenditures on agricultural research as well as extension at the national and subnational levels are used as total R&D spending. This implicitly assumes that research conducted at the national level affects each province's production in proportion to the province's research expenditures, and the impact of extension conducted in each province is proportional to research impact.

Irrigation expenditures. Provincial irrigation expenditures refer to total government fiscal expenditures in construction of reservoirs, irrigation and drainage systems, and flood and lodging prevention, as well as maintenance of these systems. However, government reports of such data are available only after 1980 in Ministry of Water Conservancy, *China Water Conservancy Yearbook* (Beijing: Ministry of Water Conservancy, 1980–2001). Prior to 1979, the Ministry of Water Conservancy reported total expenditure (not by item) on reservoirs, irrigation and drainage systems, flood and lodging prevention, water supply, and hydropower (Ministry of Water Conservancy, *Thirty Years of Water Conservancy Statistical Materials* [Beijing: Water and Power Publishing House, 1980]). This spending item is much broader than irrigation, as it also includes urban water supply, flood control, and hydropower generation. To calculate the cost solely of irrigation prior to 1979, we use the percentage of irrigation spending in total expenditures on water conservancy in 1980.

Education expenditures. Provincial expenditures for primary and middle school education in rural areas after 1990 are reported in various issues of the Ministry of Education's *China Education Yearbook* (Beijing: Ministry of Education, 1990–2001) and the SSB's *China Education Expenditure Yearbook* (Beijing: China Statistical Publishing House, 1985–2001). Expenditures prior to 1990 are extrapolated using the percentage of rural students in total students. Since education expenditure per student in urban areas is higher than that in rural areas, we use the cost difference in 1990 to adjust down the total education expenditures in rural areas.

Road expenditures. Road expenditures are reported in the SSB's *China Fixed Asset Investment Statistical Materials, 1950–95* (Beijing: China Statistical Publishing House, 1996) and various issues of the Ministry of Transportation's *China Transportation Yearbook* (Beijing: Ministry of Transportation, 1984–2001). However, there is no breakdown between rural and urban road expenditures. We use the percentage of the length of rural roads in total length of roads to extrapolate the cost of rural roads by assuming that the unit cost of rural road construction is one-third that of urban roads.

Power expenditures. Provincial power expenditures are available in *China Fixed Asset Investment Statistical Materials, 1950–95* and various issues of the Ministry of Water Conservancy and Power's *China Power Yearbook* (Beijing: Ministry of Electric Power, 1990–2001). We use the unit cost of electricity per kilowatt to calculate power expenditures for rural areas.

Telecommunications expenditures. Telecommunications expenditures by province are available in *China Fixed Asset Investment Statistical Materials, 1950–95* and various issues of the *China Transportation Yearbook* (Beijing: Ministry of Transportation, 1984–2001). However, as with expenditures on roads and power, there is no breakdown between rural and urban expenditures. We use the number of telephones in rural and urban areas to extrapolate the cost of rural telecommunications.

Rural education. We use the percentage of rural labor with different education levels to calculate the average years of schooling as our education variable, assuming 0 years for a person who is illiterate or semi-illiterate, 5 years for primary school education, 8 years for a junior high school education, 12 years for a high school education, 13 years for a professional school education, and 16 years for college and above education. Education levels for rural labor was published by various issues of the SSB's *China Rural Statistical Yearbook*.

Roads. The road variable is measured as road density, road length in kilometers per thousand square kilometers of geographic area. The length of total roads by province is reported in various issues of the *China Statistical Yearbook* and the *China*

Transportation Yearbook, while the length of rural roads in the 1980s is reported in various issues of the *China Rural Statistical Yearbook.* In more recent years, the *China Rural Statistical Yearbook* stopped reporting rural roads. We therefore use the trend of total length of roads (except highways) to extrapolate the length of rural roads for the years in which data are not available.

Electricity. Total rural electricity consumption for both production and residential uses by province are available in various issues of the SSB's *China Rural Statistical Yearbook* and the Ministry of Agriculture's *China Agricultural Yearbook*. In more recent years, the Ministry of Agriculture, in *China Rural Energy Yearbook* (Beijing: China Agricultural Publishing House, 1995–2000), began publishing the use of electricity separately for residential and production purposes by province. We use this newly available information to backcast the different use by province for earlier years.

Rural telephony. The number of rural telephones is used as a proxy for the development of rural telecommunications. The number of rural telephones by province is published in various issues of the *China Rural Statistical Yearbook*, the *China Statistical Yearbook*, and the *China Transportation Yearbook*.

Appendix B

Marginal Impact on Growth and Poverty Reduction

By totally differentiating equations (1)–(11), we can derive the marginal impact and elasticities of different types of government expenditures on growth in agricultural and nonfarm productivity and on reductions in rural poverty.

As an example, the marginal impact on agricultural productivity growth of R&D investment in year $t - i$ on agricultural labor productivity in year t can be derived as

$$d\text{AGDPPC}/d\text{RDE}_{-i} = \partial\text{AGDPPC}/\partial\text{RDE}_{-i}. \qquad \text{(B1)}$$

Equation (B1) measures the direct impact of investment in research on agricultural productivity growth. By aggregating the total effects of all past government expenditures over the lag period, the sum of marginal effects is obtained for any particular year. The marginal impact of government spending on nonfarm labor productivity can be derived similarly.

As an example, the impact of government investment in rural roads in year $t - k$ on poverty in year t is derived as

$$\begin{aligned} dP/d\text{ROADE}_{-k} = {} & \\ & (\partial P/\partial\text{AGDPPC})(\partial\text{AGGDPC}/\partial\text{ROADS})(\partial\text{ROADS}/\partial\text{ROADE}_{-k}) \\ & + (\partial P/\partial\text{WAGE})(\partial\text{WAGE}/\partial\text{AGDPPC})(\partial\text{AGDPPC}/\partial\text{ROADS})(\partial\text{ROADS}/\partial\text{ROADE}_{-k}) \\ & + (\partial P/\partial\text{NAGEMPLY})(\partial\text{NAGEMPLY}/\partial\text{AGDPPC})(\partial\text{AGDPPC}/\partial\text{ROADS})(\partial\text{ROADS}/\partial\text{ROADE}_{-k}) \\ & + (\partial P/\partial\text{TT})(\partial\text{TT}/\partial\text{AGDPPC})(\partial\text{AGDPPC}/\partial\text{ROADE}_{-k}) \\ & + (\partial P/\partial\text{WAGE})(\partial\text{WAGE}/\partial\text{ROADS})(\partial\text{ROADS}/\partial\text{ROADE}_{-k}) \\ & + (\partial P/\partial\text{NAGEMPLY})(\partial\text{NAGEMPLY}/\text{ROADS})(\partial\text{ROADS}/\partial\text{ROADE}_{-k}). \end{aligned} \qquad \text{(B2)}$$

The first term on the right-hand side of equation (B2) measures the direct effects on poverty of improved productivity attributable to greater road density.[30] Terms 2, 3, and 4 are the indirect effects of improved productivity through changes in rural nonfarm wages, employment, and prices. Terms 5 and 6 capture the direct effects on poverty of higher nonfarm wages and greater nonagricultural employment opportunities arising from government investment in roads. We can similarly derive the impact on rural poverty of increased investment in telecommunications, electricity, and education.

Using these elasticities, we can also analyze the sources of growth and poverty reduction. We first assume that the total growth and poverty reduction is equal to 100% over a certain period of time. The relative contribution of one particular input (e.g., public investment or institutional reforms) is its elasticity multiplied by its annual average growth rate of the respective variable. For more details, refer to Shenggen Fan, "Effects of Technological Change and Institutional Reform on Production Growth in Chinese Agriculture," *American Journal of Agricultural Economics* 73 (1991): 266–75.

Notes

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1. World Bank, *China: Overcoming Rural Poverty* (Washington, D.C.: World Bank, 2000).

2. The number of rural poor for each year is reported in *China Agricultural Development Report* (Beijing: China Agricultural Publishing House, 1995–2002), a white paper of the Ministry of Education. The poverty line is defined as the level below which income (and food production in rural areas) is below subsistence levels for food intake, shelter, and clothing.

3. Some studies link public investment to food security and agricultural growth. Examples include Shenggen Fan and Philip Pardey, "Research, Productivity, and Output Growth in Chinese Agriculture," *Journal of Development Economics* 53 (1997): 115–37; Jikun Huang, Mark Rosegrant, and Scott Rozelle, "Public Investment, Technological Change, and Agricultural Growth in China," working paper (Stanford University, Food Research Institute, Stanford, Calif., 1999); Jikun Huang, Scott Rozelle, and Mark W. Rosegrant, "China's Food Economy to the Twenty-First Century: Supply, Demand, and Trade," *Economic Development and Cultural Change* 47 (1999): 737–66; Shenggen Fan, "Research Investment and the Economic Returns to Chinese Agricultural Research," *Journal of Productivity Analysis* 14 (2000): 163–80. However, very few of these studies link these investments to poverty reduction in a systematic way.

4. Total and per capita incomes are all measured in 1990 constant prices.

5. Agricultural output grew at 6.69% per year when using a more appropriate aggregation and adjusted output (Shenggen Fan and Xiaobo Zhang, "Production and Productivity Growth in Chinese Agriculture: New National and Regional Measures," *Economic Development and Cultural Change* 50, no. 4 [July 2002]: 819–38), while the official rate of growth is 7.73% (State Statistical Bureau, *China Statistical Yearbook* [Beijing: China Statistical Publishing House, 1980–2001]). The productivity growth was 3.16% per annum during the period. The rest of the growth (or 53%) is from increased input use induced by higher output prices.

6. State Statistical Bureau, *China Statistical Yearbook*.

7. Scott Rozelle, "Rural Industrialization and Increasing Inequality: Emerging Patterns in China's Reforming Economy," *Journal of Comparative Economics* 19 (1994): 362–91.

8. Agricultural procurement prices increased at only 1.5% per annum over the period 1984–89, as compared with 4.5% over the period 1978–84.

9. World Bank (n. 1 above).

10. State Statistical Bureau, *China Statistical Yearbook*, 2001.

11. State Statistical Bureau of China, *China Rural Statistical Yearbook* (Beijing: China Statistical Publishing House, 2001).

12. A. Piazza and E. Liang, "Reducing Absolute Poverty in China: Current Status and Issues," *Journal of International Affairs* 52 (1998): 253–73.

13. All variables without subscripts indicate observations in year t at the provincial level. For presentation purposes, we omit the subscript. The variables with subscript "$-1, \ldots, -j$" indicate observations in year $t-1, \ldots, t-j$.

14. Justin Yifu Lin, "Rural Reforms and Agricultural Growth in China," *American Economic Review* 82 (1992): 34–51.

15. W. H. Greene, *Econometric Analysis* (Hemel Hempstead: Prentice-Hall, 1993).

16. For more detailed information on this subject, refer to R. Davidson and J. MacKinnon, *Estimation and Inference in Econometrics* (New York: Oxford University Press, 1993).

17. Shenggen Fan, "Effects of Technological Change and Institutional Reform on Production Growth in Chinese Agriculture," *American Journal of Agricultural Economics* 73 (1991): 266–75; Lin (n. 14 above).

18. The coastal region includes the following provinces: Hebei, Liaoning, Shandong, Jiangsu, Zhejiang, Fujian, Guangdong, and Guangxi. The central region contains Shanxi, Inner Mongolia, Anhui, Jiangxi, Henan, Hubei, and Hunan. The remaining provinces are classified as the western region. Tibet is excluded due to the lack of data. Hainan is included in Guangdong Province. Beijing, Shanghai, and Tianjin are excluded because of their small share of rural areas and population.

19. To convert the cost-benefit ratios to the rates of returns, simply use the following formula: $CBR = IRR/R$, where CBR is the cost/benefit ratio, IRR is a rate of returns, and R is the real interest rate (or the social discount rate). For a developing country like China, the common practice is to use 10% as the social discount rate. In this case, a cost/benefit ratio of 6.75 means a rate of return of 67.5%. Or in other words, if one invests one yuan today, he will get 0.675 yuan in return every year after this year forever.

20. Zude Xian and Sheng Laiyun, "PRC's Rural Residents with Consumption Less Than 860 Yuan: Targeting Group and Characteristics" (National Statistical Bureau, Beijing, 2002, mimeographed).

21. The return to road investment may be overstated due to understated cost. A male laborer is required to contribute about 20 days for road construction without pay. However, we do not have any viable statistical data to adjust the cost. Nevertheless, even if we increase the road cost by 30%, the ranking of the road effect on poverty is still the same.

22. Shenggen Fan, Peter Hazell, and S. Thorat, "Government Spending, Agricultural Growth, and Poverty in Rural India," *American Journal of Agricultural Economics* 82, no. 4 (2000): 1038–51.

23. For the estimates of rates of return to Chinese agricultural research, see Fan, "Research Investment and the Economic Returns to Chinese Agricultural Research" (n. 3 above). For the impact of agricultural research on urban poverty in China, see Shenggen Fan, Cheng Fang, and Xiaobo Zhang, "How Agricultural Research Affects Urban Poverty in Developing Countries: The Case of China," *World Development* 31 (2003): 733–41.

24. Huang, Rozelle, and Rosegrant (n. 3 above).

25. *China Agricultural Development Report* (Beijing: Ministry of Agriculture, 1998).

26. Martin Ravallion and Shaohua Chen, "When Economic Reform Is Faster Than Statistical Reform: Measuring and Explaining Inequality in Rural China" (World Bank, Policy Research Department, Washington, D.C., 1997, mimeographed).

27. The poverty estimated by Khan is reported in A. Khan, "Poverty in China in the Period of Globalization" (University of California, Riverside, 1997, mimeographed). The data set included 10,258 rural households in 1998 and 7,998 in 1995.

28. Kohli Ulrich, "A Gross National Product Function and the Derived Demand for Imports and Supply of Exports," *Canadian Journal of Economics* 18 (1982): 369–86.

29. Agricultural research expenditures prior to 1993 were constructed by Fan and Pardey (see n. 3 above).

30. The terms are separated by "+".