DSGD DISCUSSION PAPER NO. 12

ROAD DEVELOPMENT, ECONOMIC GROWTH, AND POVERTY REDUCTION IN CHINA

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ABSTRACT

Since 1978, China has adopted a series of economic reforms leading to rapid economic growth and poverty reduction. National Gross Domestic Product (GDP) grew at about 9 percent per annum from 1978 to 2002, while per capita income increased by 8 percent per annum. The post-reform period was also characterized by an unprecedented decline in poverty. However, income inequality has worsened between coastal and interior provinces as well as between rural and urban areas. A number of factors contributed to this widening disparity in regional development in China, including differences in natural resources endowments, and infrastructure and human capital development.

When the policy reforms began in 1978, China was poorly endowed with transportation infrastructure. With rapid economic growth, the demand for road transport soared and consequently transportation shortages and congestion problems surfaced. Since 1985, the government has given high priority to road development, particularly development of high-quality roads such as highways connecting major industrial centers in coastal areas. In the 1990s, investment in infrastructure became a national priority and various policies were implemented to promote the rapid construction of highways. The development of expressways has been particularly remarkable, increasing from 147 kilometers in 1988 to 25,130 kilometers in 2002, equivalent to an average annual growth rate of 44%. In contrast, the length of low quality, mostly rural roads increased very little, by only 3% per year over the same period.

The objective of this study is to assess the impact of public infrastructure on growth and poverty reduction in China, paying a particular attention to the contribution of roads. The beneficial impacts of roads on production and productivity, as well as on poverty alleviation, are well recognized in the literature but some important gaps remain. First, the impact of roads of different quality has received little attention. While the total length or density of roads is a useful indicator of the road infrastructure available in a country, it is important to account for quality differences because different types of roads

(e.g. rural vs. urban) can have very different economic returns and poverty impacts. Second, most studies have only focused on rural poverty in China as urban poverty has only recently emerged as an important and growing problem. To address these limitations, this study disaggregates road infrastructure into different classes of roads to account for quality. The study also estimates the impact of road investments on overall economic growth, urban growth, and urban poverty reduction, in addition to agricultural growth and rural poverty. To achieve these goals, an econometric model that captures the different channels through which road investments impact on growth and poverty is developed and estimated using provincial-level data for 1982-1999.

The most significant finding of this study is that low quality (mostly rural) roads have benefit/cost ratios for national GDP that are about four times larger than the benefit/cost ratios for high quality roads. Even in terms of urban GDP, the benefit/cost ratios for low quality roads are much greater than those for high quality roads. As far as agricultural GDP is concerned, high quality roads do not have a statistically significant impact while low quality roads are not only significant but generate 1.57 yuan of agricultural GDP for every yuan invested. Investment in low quality roads also generates high returns in rural nonfarm GDP. Every yuan invested in low quality roads yields more than 5 yuan of rural nonfarm GDP.

In terms of poverty reduction, low quality roads raise far more rural and urban poor above the poverty line per yuan invested than do high quality roads.

Another significant finding of the study is the trade-off between growth and poverty reduction when investing in different parts of China. Road investments yield their highest economic returns in the eastern and central regions of China while their contributions to poverty reduction are greatest in western China (especially the southwest region). This implies different regional priorities depending on whether economic growth or poverty reductions are the most important goals for the country.

The results of this study have important implications for future road project investments. China has invested heavily in the past in building expressways and inter-city highways. These investments were a major force in China's economic transformation during the 1980s and 1990s. However, as more and more investments are being poured into these projects, the marginal returns are beginning to decline, although they are still positive and economically sound. At the same time, low quality roads or rural roads have received less attention than high quality roads and as a result their marginal returns are much larger today than the returns to high quality roads. Low quality roads also raise more poor people out of poverty per yuan invested than high quality roads, making them a win-win strategy for growth and poverty alleviation. The government should now consider giving greater priority to low quality and rural roads in its future investment strategy.

ROAD DEVELOPMENT, ECONOMIC GROWTH AND POVERTY REDUCTION IN CHINA

Shenggen Fan and Connie Chan-Kang *

I. INTRODUCTION

Since the mid-1980s, China has invested massively in road infrastructure. The resulting expansion of the road network, in addition to policy reforms and improvements in human capital, has been identified as one of the major engines of China's economic growth over the past decade (Fan, Zhang, and Zhang, 2002). From 1985 to 2002, national GDP grew by more than 9% per year, making China's economy one of the most dynamic in the world.[1] While the Asian financial crisis unexpectedly hit the star performing economies of South Korea, Hong Kong, Singapore, Thailand, and Indonesia, the Chinese economy continued its growth momentum with an annual GDP growth rate of 7-9% from 1998 to 2002.

Accompanying the rapid growth of the national economy was an astounding reduction of absolute poverty in rural China. Based on the official poverty line of $0.66 per day (constant 1985 purchasing power parity dollars), the incidence of poverty in rural China declined from 250 million in 1978 to 29 million in 2001.[2] A reduction in poverty

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[1] The data on GDP, income, and income distribution used in this report, if not otherwise specified, are from the latest issues of *China Statistical Yearbooks* published by the National Statistical Bureau (Beijing: China Statistical Press).

[2] The number of rural poor for each year is reported in the *China Agricultural Development Report*, a white paper of the Ministry of Agriculture. The poverty line is defined as the level below which income (and food production in rural areas) are below subsistence levels for food intake, shelter, and clothing. Using this criterion, the rural poverty line in 1985 is 206 yuan in nominal price per person while it increased to 625 yuan per person in 2000. The 206 per year poverty line is equivalent to $0.66 dollar per day measured in 1985 purchasing parity (World Bank, 2001). China has never officially published the urban poverty rate although scattered reports on some cities are available using the ad hoc poverty lines.

of this scale and within such a short time is unprecedented in history and is seen by many to be one of the greatest achievements in human development in the twentieth century.

However, China still faces many challenges today. One challenge is that many people still live close to the official poverty line. For example, if, instead of using the official poverty line, poverty is measured using the international poverty line of one-dollar per day (constant 1985 purchasing power parity dollars), then China still had more than 100 million rural poor and 20 million urban poor in 1998 (World Bank, 2001). Another challenge is to implement policies that distribute economic gains more equally among the general population. Over the last three decades, the Gini coefficient index increased from 0.21 in 1978 to 0.46 in 2000, making China one of the more unequal societies in the world. Another feature of the Chinese economy is the unequal development among regions. China has long pursued a biased development policy with the largest portion of public investment being concentrated in the coastal regions and in urban areas. It is not surprising therefore that the difference in economic growth rates between the coastal and inland regions was as high as 3 percentage points during the past two decades, and that regional inequality for China as a whole increased significantly. Moreover, as a result of the government's urban-biased policy, the income and productivity gaps between rural and urban areas have increased over time. In 2002, rural per capita income was only one third of the urban per capita income. Thus, the majority of the poor people in China still reside in rural areas.

There is a large body of literature on economic growth and poverty reduction in China. However, few studies have attempted to link these issues to public investment and infrastructure development. It is widely recognized that improvements in human and physical capital are fundamental for economic growth and poverty reduction. Fan, Zhang, and Zhang (2002) were the first to link investments in infrastructure to rural poverty reduction in China. The authors used roads, electricity consumption, and the number of rural telephones as proxy variables for rural infrastructure in an econometrically estimated equations system. However their analysis of road infrastructure was quite crude with the road variable expressed in terms of the total length of all types of roads and failing to discriminate between different quality roads.

This study builds on the earlier work of Fan, Zhang, and Zhang and uses a similar econometric model fitted to time series data at the provincial level. However, the model used here provides a more disaggregated analysis of the impact of road investments on economic growth and poverty alleviation in China. Roads are disaggregated into different classes to account for differences in their quality, and poverty impacts are measured separately for the rural and urban populations.

The paper is organized as follows: Section II reviews the trends in economic growth and poverty in China. The third section reviews the development of China's road infrastructure, encompassing a review of government's policies about roads, trends in road investment and construction, and the means by which they were financed. The fourth section provides a literature survey of the impact of road investments on growth and poverty reduction. The fifth section then presents the conceptual framework and model used, followed by a description of the available data and the model results in Section VI. We conclude with a summary of the key findings and a discussion of their policy implications in Section VII.

II. ECONOMIC GROWTH, REGIONAL DEVELOPMENT, AND POVERTY REDUCTION

This section provides an overview of China's economic growth, regional development and poverty trends in recent decades. It also highlights the institutional and policy environment in which these changes took place. The analysis draws on Chinese official documents including various issues of *China Development Report* (National Statistical Bureau), *China Agricultural Development Report (*Ministry of Agriculture*)*, *China Rural Poverty Monitoring Report (*National Statistical Bureau*)*, and *An Overview of the Development-oriented Poverty Reduction Program for Rural China* (State Council Leading Group Office of Poverty Alleviation and Development).

Economic Growth

China's economy has experienced major structural changes and economic transformations since the establishment of the Communist Party in 1949. The history of China's economic development is typically divided into two broad periods: the central planning period from 1949-1978, and the market-oriented reforms period from 1978 to the present.

The Central Planning Period, 1949-1978

Following the establishment of the People's Republic of China in 1949, the Communist Party became the ruling party, leading the country's political life and socio-economic activities. The leaders' goals were to transform China into a modern, powerful, and socialist nation. The party initially adopted the Soviet economic model of communism, with its emphasis on a heavy industrial base, state ownership of the means of production, large collective units in agriculture, and centralized economic planning. At first, industrial GDP grew at a remarkable 16.1% per annum between 1952 and 1957, whereas total GDP grew by 9% per annum and the agricultural sector by 5% per annum. The government gradually took over control of the industrial and agricultural sectors of the economy and by the end of the 1950s privately owned firms were practically nonexistent. In the agricultural sector, land was confiscated by the state and merged into large and socialized production cooperatives, which evolved into communes in 1958. The commune was based on the collective ownership of all land and major inputs by its members, who produced mainly to meet state planning targets.

In the late 1950s, the authorities decided that China should make a great leap forward and modernize. The goal was to depart from the Soviet model and catch up with the United Kingdom in 15 years. All the country's resources were mobilized to reach this goal. This unrealistic campaign resulted in a severe economic crisis and GDP declined precipitously by a negative rate of 8.7% per annum between 1958 and 1962. Agricultural GDP also fell by 3.1% per annum and industrial GDP by 14.3% per annum. Between 1962 and 1965, the Chinese economy entered a period of readjustment and recovery, driven by a series of corrective measures. Particularly noteworthy was the decentralization of decision-making within the commune structure. The production brigades and teams became accountable for all decisions concerning production and the distribution of income among their members. In the industrial sector, production decisions were based on rational and efficient planning rather than on ideology. These changes were beneficial to the Chinese economy and GDP in all sectors grew to their levels prior to the Great Leap Forward.

These developments were suppressed again with the Cultural Revolution (1966-76) when China was run under a strict Maoist vision. The government restored most of the controls that had been relaxed during the three-year adjustment period 1962-1965 and all foreign ties were cut off, isolating China from the rest of the world. During this period, the pace of growth in all sectors of the economy slowed down.

In sum, by the end of the Cultural Revolution, China was a centrally planned economy. The central government not only owed nearly all means of production, but also dictated and controlled the economy through a variety of regulatory mechanisms. The government set production goals, controlled prices, and allocated resources. As self-reliance was emphasized, foreign investment was discouraged and trade was negligible.

Table 1: Gross Domestic Product by Sector

	GDP Total	Agriculture	Urban industry	Urban service
	(100 million yuan, 2002 constant prices)			
1952	2,591	1,309	541	742
1957	4,029	1,622	1,196	1,211
1962	3,639	1,434	1,137	1,067
1965	5,550	2,106	1,947	1,497
1970	7,755	2,731	3,140	1,884
1975	10,334	3,348	4,725	2,261
1978	12,222	3,434	5,886	2,902
1979	13,151	4,100	6,232	2,820
1980	14,177	4,266	6,878	3,033
1981	14,914	4,741	6,918	3,255
1982	16,271	5,414	7,323	3,534
1983	18,044	5,962	8,046	4,036
1984	20,787	6,654	9,003	5,130
1985	23,593	6,689	10,177	6,728
1986	25,670	6,954	11,304	7,411
1987	28,647	7,674	12,576	8,397
1988	31,885	8,182	14,069	9,633
1989	33,192	8,299	14,286	10,606
1990	34,453	9,319	14,335	10,799
1991	37,623	9,204	15,841	12,578
1992	42,965	9,355	18,870	14,740
1993	48,766	9,690	23,131	15,944
1994	54,910	11,106	26,272	17,532
1995	60,676	12,444	29,610	18,622
1996	66,500	13,562	32,928	20,011
1997	72,352	13,808	36,168	22,376
1998	78,003	14,489	38,451	25,064
1999	83,573	14,737	41,302	27,534
2000	90,259	14,757	45,332	30,169
2001	97,028	15,366	48,606	33,055
2002	104,791	16,117	53,541	35,133
Annual Growth Rates				
1952-2002	7.62	5.68	8.94	7.90
1978-2002	9.76	6.33	10.25	11.93
1952-1977	5.43	4.24	8.08	4.01
1978-1983	7.83	11.14	6.04	7.09
1984-1991	8.59	5.53	8.02	12.45
1992-2002	9.02	5.43	10.16	9.41

Source: Authors' calculations based on China's National Bureau of Statistics, Statistical Yearbook of China, 2001, 2003.
Notes: Since there is no official GDP deflator, we calculated the real GDP by multiplying the real GDP index listed in the Statistical Yearbook of China by the 1952 base year value. To calculate the GDP by sector, we multiplied the real GDP by the respective shares of each sector in total nominal GDP.

Despite these constraints, during China's communist regime all sectors of the economy expanded at a respectable rate. Between 1952 and 1977, real GDP in the agricultural sector grew by 4.2% per annum, whereas the corresponding rates in the industrial and service sectors were 8.1% per annum and 4.0% per annum, respectively (Table 1).

The Reform Period, 1978-Present

In December 1978, China's party leaders decided to embark on a program of gradual but fundamental reform of the economic system. Underlying the reform was a principle of incrementalism or gradualism: new measures were first to be implemented locally, and if they were proved successful, popularized and disseminated nationally.

The first stage of the economic reform program (1978-1984) focused mainly on the rural sector. The government aimed at expanding agricultural production, diversifying the rural economy, improving the rural standard of living, and promoting new technologies. One of the most important and successful reform policies was the implementation of the household responsibility system, which allowed farmers to have use rights over land. Collectively owned and operated land was distributed to farmers based on family size and the number of family workers. Farmers had the right to choose their own crop mix and input levels as long as they fulfilled government quotas for certain grain and cash crops. Any surplus output could be sold in the free markets. This system motivated farmers to reduce production costs and to increase productivity since their efforts were closely linked to their income. Accompanying increases in procurement prices and government encouragement of the establishment of free farmers' markets stimulated agricultural production further.[3]

In the industrial sector, policies were introduced to increase the autonomy of enterprise managers, to reduce the prominence of planned quotas, and to allow

[3] The forced procurement policy for grains and certain cash crops was implemented from 1950s to 1978. Under this policy, production teams had to sell certain amount of their outputs to the governments (the so-called quota). The procurement (or quota) prices were usually much lower than the international prices and free market prices. In 1978, the government decided to increase the quota price by 20 % and the price for over-quota grain by additional 50 % (*China Agricultural Development Report*, 1997).

enterprises to produce and sell goods in the market. Township and Village Enterprises (TVE), which are industries owned by townships and villages, were established and individual enterprise was allowed after having virtually disappeared during the Cultural Revolution. Moreover, China introduced an open door policy permitting international trade and foreign direct investment.

These initiatives improved the standard of living for most Chinese. Income as well as the availability of food, housing, and other consumer goods increased substantially. Between 1978 and 1983, real GDP grew on average by 7.8% per annum, and agricultural and industrial output grew at 11.1% and 6.0%, respectively (Table 1).

The second phase of the reform program (1984-1991) was aimed at broadening the reforms to include industrial enterprises in urban areas, creating market institutions, and dismantling the central planning system. Two particularly important policies were introduced: the dual track pricing system for industrial goods and the enterprise contract responsibility system. Under the dual-track pricing, some goods and services were allocated at state controlled prices, while others were allocated at market prices. Prices were gradually deregulated while allowing markets to play an increasing role in setting prices. The enterprise contract responsibility system granted greater autonomy to production and employment decisions within enterprises. Another key element of the reforms was to allow private as well as foreign enterprises to compete with State Owned Enterprises (SOEs). The development of the non-state sector in China provided employment opportunities and contributed to the country's economic growth. Other important measures included: the dissolvement of China's monobank system under which the People's Bank of China served as both the central bank and the sole commercial bank; the introduction of an enterprise tax system; and an expansion of the number of special economic zones. These policy changes proved beneficial to the industrial and services sectors, which grew rapidly between 1984 and 1991 by 8.0% and 12.5% per annum, respectively (Table 1).

The third phase of reform program (1992 to the present) aimed at establishing a socialist market economic system, under which the economy continues to remain primarily under public ownership but market forces are allowed to play a fundamental role in resource allocation and distribution decisions. To achieve this goal, several measures have been taken to reform the financial and fiscal sectors. In the financial sector a key focus of the strategy was to create a banking system engaged in commercial transactions and responsive to market forces, shifting away from the banks' traditional role of supporting state-owned enterprises. In the fiscal sector, measures were directed to improve tax administration and set up stable and transparent tax rates. Since the mid-1990s, Chinese authorities have been focusing on improving the efficiency and profitability of the state-owned enterprises and in developing the social security system.

China's accession to the WTO in late 2001 is an important step in the country's transformation into a market driven economy. In accordance with its membership in the WTO, China will have to further open and liberalize its economy in the coming years. Trade barriers will have to be lowered, financial markets and institutions further developed, and the private sector further deregulated. China will also have to continue improving the performance of state-owned firms.

Over the past fifty years, the economic structure of China has undergone tremendous changes. In 1952, China's economy was essentially based on agriculture. The agricultural sector accounted for half of national GDP, whereas the industrial and service sectors contributed 21% and 29%, respectively (Table 2). By 2002, China had emerged as an industrial economy with 51% of GDP derived from industry, 34% from services and only 15% from agriculture. Nevertheless, the agricultural sector remains an important component of China's economy, and still employed 50% of the labor force in 2002.

In sum, since the initiation of economic reforms, China's economy has grown at an impressive rate of 9.8% per annum. Most Chinese have benefited from rising income levels and living standards, and China is now classified as a lower middle-income country. However, a number of challenges remain. In the financial sector, for example, inefficient state owned banks still dominate the sector and continue to fund the SOEs. Although the viability of SOEs has been challenged with increasing competition from

Table 2: GDP and Employment Shares by Sector

	Share of GDP by sector			Share of employment by sector		
	Agriculture	Urban industry	Urban service	Agriculture	Urban industry	Urban service
			(Percent)			
1952	50.5	20.9	28.6	83.5	7.4	9.1
1957	40.3	29.7	30.1	81.2	9.0	9.8
1962	39.4	31.3	29.3	82.1	7.9	9.9
1965	37.9	35.1	27.0	81.6	8.4	10.0
1970	35.2	40.5	24.3	80.8	10.2	9.0
1975	32.4	45.7	21.9	77.2	13.5	9.3
1978	28.1	48.2	23.7	70.5	17.3	12.2
1979	31.2	47.4	21.4	69.8	17.6	12.6
1980	30.1	48.5	21.4	68.7	18.2	13.1
1981	31.8	46.4	21.8	68.1	18.3	13.6
1982	33.3	45.0	21.7	68.1	18.4	13.4
1983	33.0	44.6	22.4	67.1	18.7	14.2
1984	32.0	43.3	24.7	64.0	19.9	16.1
1985	28.4	43.1	28.5	62.4	20.8	16.8
1986	27.1	44.0	28.9	60.9	21.9	17.2
1987	26.8	43.9	29.3	60.0	22.2	17.8
1988	25.7	44.1	30.2	59.4	22.4	18.3
1989	25.0	43.0	32.0	60.0	21.6	18.3
1990	27.0	41.6	31.3	60.1	21.4	18.5
1991	24.5	42.1	33.4	59.7	21.4	18.9
1992	21.8	43.9	34.3	58.5	21.7	19.8
1993	19.9	47.4	32.7	56.4	22.4	21.2
1994	20.2	47.8	31.9	54.3	22.7	23.0
1995	20.5	48.8	30.7	52.2	23.0	24.8
1996	20.4	49.5	30.1	50.5	23.5	26.0
1997	19.1	50.0	30.9	49.9	23.7	26.4
1998	18.6	49.3	32.1	49.8	23.5	26.7
1999	17.6	49.4	32.9	50.1	23.0	26.9
2000	16.4	50.2	33.4	50.0	22.5	27.5
2001	15.8	50.1	34.1	50.0	22.3	27.7
2002	15.4	51.1	33.5	50.0	21.4	28.6

Source: Authors' calculation based on data reported by China's National Bureau of Statistics, *Statistical Yearbook of China, 2001, 2003*

domestic and foreign firms, they continue to monopolize some sectors such as heavy industry and utilities. Moreover, the social security system is not yet functioning well. Problems include insufficient funding and limited and insufficient coverage of beneficiaries. In the agricultural sector, additional reforms are needed as most farms remain very small and use low levels of technology. Moreover, most farmers still do not have secure title to their land.

Regional Development

For a country as large and as geographically diverse as China, uneven regional development is far from being unexpected. The coastal area, endowed with favorable geographical and natural conditions, has historically developed faster than the interior regions. Over the years, China's development policies have exacerbated this unequal development pattern. During the central planning period, the government pursued a strategy of regional economic self-sufficiency, which significantly shaped regional economic outcomes. Each region was expected to be self-sufficient in terms of both food production and industrial goods. This policy severely distorted the allocation of resources, which in turn impacted on production efficiency and aggravated the unevenness in regional economic development. The introduction of economic reforms further shifted China's focus away from developing the interior provinces. To attract foreign direct investment and to promote foreign trade, the government established special economic zones along the coast. The resulting rapid economic growth in the coastal provinces continued to widen the gap between the coastal and the interior regions.

Differences in economic development among regions can be gauged by their GDP per capita, agriculture's share in regional GDP, and rural income per capita (Table 3). In 2002, per capita GDP in the northwest and southwest averaged 5,000-6,000 yuan, or only about half the income level in the east, the northeast, and the northern regions. The rural income per capita in the northwest (1,744 yuan) and southwest China (1,894 yuan) was also considerably lower than the national average (2,476 yuan) and the east (3,203 yuan). Moreover, the shares of agriculture in total GDP are higher in the northwest and southwest (18 and 21 percent) than in the east and north regions (12 to 10 percent), indicating that farming is still a major source of rural income in western China.

Table 3: Major Economic Indicators by Region, 2002

	Population	Per capita GDP	AgGDP/GDP	Per capita income	
				Urban	Rural
	(10000)	*(yuan)*	*(percent)*		*(yuan)*
North	12,459	10,758	10	8,296	2,703
Northeast	10,715	10,813	13	6,315	2,509
East	36,761	12,266	12	8,823	3,203
Central	30,892	9,018	15	8,505	2,641
Southwest	25,039	5,144	21	6,872	1,894
Northwest	11,652	6,180	18	6,304	1,744
China	127,518	9,255	14	7,703	2,476

Source: Authors' calculations based on data reported China's National Bureau of Statistics, Statistical Yearbook of China, 2003.
Note: Rural and urban per capita income are weighted average figures which are obtained by multiplying the average per capita income by province reported in the 2003 yearbook by the region population shares for 2000.

A combination of economic, social, geographical, and others factors, have restricted labor mobility in China's less developed regions and this been a major contributor to the widening regional disparities (Kanbur and Zhang, 1999). Differences in the shares of the rural labor force employed by the rural nonfarm sector are also seen as important (Rozelle, 1994). For the nation as a whole, about 29 percent of the rural labor force was engaged in nonagricultural activities in 1997, and the non-farm sector contributed more than one-third of rural income. But in the east, the non-farm sector employed 40% of the rural labor force compared with less than 20% in northwest and southwest China.

Given that such an overwhelmingly large share of the rural labor force is employed in agricultural activity in China's western region, labor productivity is inevitably low. In fact, labor productivity in the southwest was half the national level in 1997. Poor natural resource endowments, weak infrastructure, low literacy rates and insufficient investment and personnel in regionally focused science and technology research all constrain the development and adoption of new technologies and associated improvements in agricultural productivity. Moreover, difficulties in accessing national and international markets constrains the choice of cropping mix and the development of high value agricultural products in western China (Fan, et al, 2001).

The growing inequality and increasing concentration of poverty in the western region led the central government in 1999 to launch an official plan aimed at developing western China. Among the specific objectives included in the proposed plan are the improvement of infrastructure, the intensification of environmental protection, and the development of science, technology and education.

Poverty

China has achieved tremendous success in reducing poverty since the introduction of economic reforms in the late 1970s. Based on China's official poverty line of $0.66 per day (in constant 1985 purchasing power parity dollars), the number of rural poor decreased dramatically from 250 million in 1978 to 29.3 million in 2001, implying that over 200 million people escaped from poverty in the past twenty-three years (Table 4). The reduction in rural poverty was particularly rapid during the first phase of the reform period when increases in agricultural production, productivity, and prices stimulated the rural economy. By the end of 1984, the year marking the end of first phase of the reforms, the number of rural poor (128 million) was half the level of 1978 (250 million). Likewise, the rural poverty rate fell dramatically during this period from 33.1% in 1978 to 15.1% in 1984 (Table 4).

During the second stage of the reform, the government introduced the first important poverty reduction program. The government allocated funds for public works with the goal of boosting income in poor counties and stimulating local economic growth. Rural poverty continued to decline rapidly during this period. By the end of the second phase of the reform period in 1992, rural poverty had declined to 80.1 million and the incidence of rural poverty had fallen to 8.8% (Table 4).

Table 4. Rural Poverty in China: 1978-2001

Year	Number of Poor	Poverty Incidence (%)
	(million)	*(percent)*
1978	250	33.1
1984	128	15.1
1985	125	14.8
1992	80.1	8.8
1993	75	8.2
1994	70	7.6
1995	65	7.1
1996	58	6.3
1997	49.6	5.4
1998	42.1	4.6
1999	34.1	3.7
2000	32.1	3.4
2001	29.3	3.2

Source: China Statistics Press, *China Rural Poverty Monitoring Report* (various issues)

In the mid-1990s, China launched an ambitious poverty alleviation plan aimed at eradicating poverty by the end of the 20th century. Some key features of the program included subsidized loans, food-for-work infrastructure schemes, and various grants, which were targeted to 592 nationally designed poor counties[4]. The government directly supported agriculture by providing low interest loans. Poverty declined rapidly during this period, from 70 million in 1994 to 29 million in 2001, while the incidence of rural poverty fell from 7.6% to a mere 3.2% (Table 4).

However, estimates of the extent of poverty reduction are sensitive to the choice of the poverty line. If poverty is measured using the World Bank's international poverty standard of $1.00 a day (in 1985 purchasing power parity dollars) instead of the official Chinese poverty line, then while poverty is still found to have declined rapidly since the beginning of the reform period, a much larger number of poor remain today (106 million rural poor in 1998, equivalent to a poverty rate of 11.5% (World Bank, 2001)). Clearly, this much higher poverty figure demonstrates that a large number of rural people live just

[4] The detailed proposed poverty reduction programs were described in the book "*An Overview of the Development-oriented Poverty Reduction Program for Rural China* (State Council Leading Group Office of Poverty Alleviation and Development, 2003).

above the official poverty line, and thus pose an important and remaining challenge for the Chinese government.

When characterizing poverty in terms of nutrition, evidence shows that there was a remarkable improvement in child nutrition in rural China in the 1990s. Between 1990 and 1998, the incidence of underweight children under five declined from 22% to 12.6% in rural China, while the incidence of stunting fell from 41.4% to 22%. These achievements were partly driven by the rapid socio-economic developments of the 1990s including the various poverty alleviation and other special programs that were put in place.

Rural poverty is not evenly distributed in China as shown in Table 5. Regardless of the sources of data, it is clear that the incidence of rural poverty is significantly higher in western China, a region characterized by poor agricultural land and weak infrastructure. Based on the World Bank's estimates, the poverty rate averaged 19% and 11% in the northwest and southwest regions, respectively, in 1996, while the comparable figure for the whole country was 6%. In contrast, for that same year, only 1.2% and 2.6% of the rural population was living under the poverty line in the eastern and central regions, respectively. Moreover, the reduction in the incidence of rural poverty was not as dramatic in western China as it was in the other regions. Consequently, rural poverty is increasingly concentrated in the western provinces. The southwest and northwest regions together accounted for about 70% of the total rural poor in China in 1996, a 40 percentage point increase over 1988 (Table 5).

Although urban poverty has recently emerged as an important policy issue, its relatively low level in previous years was due to various urban-biased policies of the Chinese authorities since the 1950s. First, as part of the country's industrial development strategy, various implicit and explicit transfer programs favoring the urban sector were implemented (Lin, Cai, and Li 1996; Hussain, A. 2003).[5] The urban sector benefited

[5] This bias still exists even today, but in different forms (for example, the government spends more in urban than rural areas, universities have higher admission scores for rural students, and there are still visible and invisible restrictions on rural-urban migration).

Table 5: Regional Distribution of Rural Poor

	Xian and Sheng (2001)	World Bank (2001)			
	Poverty incidence	Poverty incidence		Share of national total	
	1998	1988	1996	1988	1996
North		**15.2**	**4.6**	**9.8**	**7.6**
Beijing	2.37	0.5	0.8	0	0.1
Tianjin	16.16	1.8	0.3	0.1	0
Hebei	39.11	14	3.9	5.8	4.1
Shanxi	44	22.1	7.5	3.9	3.4
Northeast		**10.2**	**4.7**	**4.6**	**5.1**
Liaoning	13.04	8	2.9	1.5	1.3
Jilin	18.18	8.8	4.7	1.1	1.3
Heilongjian	22.84	13.6	6.7	2.1	2.5
East		**7**	**1.2**	**14.9**	**6.4**
Shanghai	0.45	0.3	0.1	0	0
Jiangsu	12.37	4.5	0.1	2	0.1
Zhejiang	2.5	2.8	0.1	0.8	0.1
Anhui	27.64	10.3	2.7	3.9	2.7
Fujian	2.73	3.9	0.5	0.8	0.3
Jiangxi	9	8.5	0.7	2.1	0.5
Shandong	15.58	9.4	1.9	5.3	2.7
Central		**13.6**	**2.6**	**23.1**	**11.3**
Henan	31.75	25	4.3	14.6	6.6
Hubei	16.33	11	2.7	3.6	2.1
Hunan	5.08	7.9	1.5	3.4	1.6
Guangdong	2.46	2.7	0.2	1.1	0.2
Hainan		12.1	8.2	0.4	0.8
Southwest		**20.5**	**10.5**	**31.9**	**41.2**
Chongqing			6.6		3.2
Sichuan	21.49	16.7	7	12.8	9.7
Guizhou	42	23	12.8	5.3	7.6
Yunnan	36.45	23.8	22.9	6.2	15.3
Tibet	57.33	32.3	10.1	0.5	0.4
Guangxi	20.08	24.1	6.4	7.2	5
Northwest		**26.2**	**18.6**	**15.7**	**28.4**
Inner Mongolia	19.78	17.3	9.3	2	2.6
Shaanxi	38.06	24.9	17.5	5.3	9.6
Gansu	49.7	38.4	22.7	5.7	8.9
Qinghai	35.52	22.4	17.7	0.5	1.2
Ningxia	28.39	24.7	18.5	0.7	1.4
Xinjiang	45.64	22.3	27.4	1.4	4.8
China	**22.25**	**13.9**	**6.3**	**100**	**100**

from the industrialization led economic growth at the expense of the countryside. Moreover, the rationing system introduced in the 1950s enabled urban residents to have equal access to food and other necessities at much lower prices than rural people. Almost all urban residents of working age also had guaranteed jobs in the state- or collective-owned sectors. Because these jobs were permanent ("iron rice bowl"), urban unemployment was virtually nonexistent. These jobs also provided urban residents with many benefits such as free or subsidized housing, and healthcare. Not surprisingly, poverty alleviation in urban areas was not on the policy agenda until recently, and China's anti-poverty program, first initiated in 1986, mainly focused on rural areas.

China's recent economic reforms have been beneficial to urban dwellers in general but have also contributed to worsening poverty and inequality for some. One key feature of the reforms was the reduction of workers' lifetime ties to their employers, thereby providing them with a higher degree of freedom to change jobs and achieve higher incomes. The reforms also allowed market forces to determine wages and better match wages with workers' skills. The efficiency gains from the urban reform are evidenced by a dramatic increase in the average per capita urban income, which grew at about 6% per year in the 1990s. On the other hand, urban reforms and increased competition have resulted in soaring financial losses for many state- and collective-owned enterprises, and an increasing number of urban workers have been laid off.[6] Many of these workers are not adequately compensated by the existing social safety net programs. Also, the liberalization of the welfare system may have made some disadvantaged groups more vulnerable to sudden shocks such as catastrophic illness. Nowadays, the urban poor in China can be grouped into the following three categories: (i) urban people with no working ability, no income, or no providers; (ii) unemployed workers; and (iii) low income or temporarily laid-off workers. To mitigate the surge of urban unemployment and poverty, the government introduced some safety net programs in urban areas, and promoted the development of small and medium enterprises for job creation.

[6] The number of layoff workers is reported to be 11.57 million in 1997 (China Development Report, 1998).

Table 5 reports poverty estimates for urban China.[7] Three poverty measures are used: (i) the headcount index (P_0) which measures the spread of urban poverty; (ii) the poverty-gap ratio (P_1), which measures the depth of poverty and is sensitive to changes in the average income of the poor; and (iii) the square-poverty gap (P_2), which measures the severity of poverty and is sensitive to changes in the inequality of income distribution of the poor.[8]

The incidence of urban poverty declined from 1992 to 1995 and increased thereafter following the implementation of major urban reforms (Table 6). The level of poverty is sensitive to the choice of the poverty line. Based on the $1.0 per day poverty line, the proportion of urban poor vary between 1.65% and 2.73% over the 1992-1998 period. Given that real expenditure per capita grew on average by 6 percent per annum between 1992 and 1998, the rate of reduction of the number of people living under $1.0 a day is astonishingly low, suggesting that the rapid economic growth has not trickled down to the poor. On the other hand, estimates based on a $1.5 per day poverty line show not only a higher proportion of urban poor in China, but also a sharp decline in the poverty rate over the period of study. The incidence of urban poverty declined from 14% in 1992 to about 9% in 1998. The high sensitivity of the poverty estimates to small changes in the poverty line implies that a large share of the urban non-poor is concentrated just above the $1 per day poverty line. Thus, these households are extremely vulnerable to external shocks and to a fall into poverty.

No matter which poverty line is used, the depth (P_1) and severity of urban poverty (P_2) declined sharply between 1992 and 1996, increased between 1996 and 1997, and declined afterwards. For the period as a whole, the depth and severity of urban poverty declined substantially, indicating that the average income as well as the distribution of income has improved.

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[7] For more details about urban poverty measures, refer to the section on data.

[8] These poverty measures are members of the Foster-Greer-Throbecke class of poverty measures, known as $P(\alpha)$, α=0, 1, 2.

Table 6: Urban Poverty Measures

Year	\$ 1.0 per day			\$1.5 per day			Official poverty line			World Bank
	P_0	P_1	P_2	P_0	P_1	P_2	P_0	P_1	P_2	P_0
					(percent)					
1992	2.09	0.45	0.17	13.74	2.6	0.82	2.48	0.51	0.18	0.83
1994	2.73	0.47	0.16	13.18	2.77	0.91	2.9	0.53	0.17	0.86
1995	1.65	0.36	0.12	10.27	1.98	0.64	1.68	0.29	0.08	0.61
1996	1.69	0.27	0.07	8.41	1.67	0.53	1.76	0.27	0.07	0.46
1997	2	0.42	0.14	9.21	2.06	0.71	2.44	0.45	0.14	0.53
1998	2.06	0.3	0.08	8.86	1.88	0.6	2.13	0.32	0.08	0.98
Annual Growth Rate (%)										
1992-95	-7.58	-7.17	-10.96	-9.25	-8.68	-7.93	-12.17	-17.15	-23.69	-9.76
1996-98	10.41	5.41	6.9	2.64	6.1	6.4	10.01	8.87	6.9	45.96
1992-98	-0.24	-6.53	-11.81	-7.05	-5.26	-5.07	-2.5	-7.47	-12.8	2.81

Source: Except for the last column, all figures are calculated by Fang, Zhang, and Fan (2002). No official national urban poverty line is available in China with different cities publishing different figures. The city-specific official poverty lines are taken from China Development Report (1998). The poverty line of the World Bank measure is \$32.74 per month. The figures are available from http://www.worldbank.org/research/povmonitor/countrydetails/China.htm.
Notes: P_0 refers to the headcount index, which measures the spread of poverty; P_1 is the poverty gap ratio, which measures the depth of poverty; and $P_{,3}$ is the square poverty gap ratio, which measures the severity of poverty.

There are marked regional variations in the incidence of urban poverty in China. Table 7 presents the proportion of urban poor for China's coastal, central, and western regions. Three features are particularly noteworthy. First, the fraction of the urban population living under the poverty line was higher in the western region than in central and eastern China over the period of study. Using the \$1.5 per day poverty line, about 20% of the urban populations of western cities were poor during the sample period compared to less than 8% in the coastal cities. This finding is not surprising given that the western region is home to many of the country's worst performing state-owned heavy industries. Factory closures and layoffs resulting from the reforms have exacerbated the incidence of urban poverty in the region. Second, the incidence of poverty is highly sensitive to the choice of poverty line, particularly in the western and central regions. For example, the \$1.5 per day poverty line shows a poverty rate of about 12% in the central region in 1998 compared with only 2.5% when the \$1 per day poverty line is used. This indicates that a large number of households is clustered just above the 1\$ per day poverty line. Third, the drop in urban poverty was more pronounced in the coastal region than in the central and western regions. While the incidence of poverty fell by 51% in eastern China between 1992 and 1998, it declined by 39% in central China, and by only 13% in the western region. Moreover, under both the $1.0 per day and the official poverty lines, the incidence of urban poverty increased in the central region and stagnated in the western region between 1992 and 1998. These results suggest that the government should adopt more proactive measures to target the urban poor in the central and western regions if it wants to eliminate poverty more effectively.

Table 7: Urban Poverty by Regions: Headcount Index

	$ 1.0 per day	**$1.5 per day**	**Official poverty line**
		(percent)	
Coastal region			
1992	2.20	7.15	1.61
1994	4.95	7.89	1.50
1995	1.75	5.54	0.77
1996	4.14	4.42	0.65
1997	2.22	3.04	0.63
1998	1.07	3.48	0.70
Central region			
1992	2.22	19.36	1.89
1994	3.49	16.04	3.00
1995	1.53	13.89	1.48
1996	1.73	8.53	2.13
1997	2.10	12.27	3.02
1998	2.49	11.69	2.79
Western region			
1992	6.71	20.46	5.91
1994	7.38	22.23	6.50
1995	5.86	16.39	4.52
1996	5.07	18.98	4.10
1997	6.63	20.21	6.27
1998	6.32	17.70	4.65

Source: Calculated by Fang, Zhang, and Fan (2002)

III. DEVELOPMENT OF ROAD INFRASTRUCTURE

This section reviews the development of road infrastructure in China and draws on various issues of *China Transportation Yearbooks*, *1984-2002*.

Government Policies

The development of China's transportation infrastructure has been shaped by the various policy and institutional reforms that took place in the country over the past fifty years. Under the centrally planned system prior to the economic reforms, the Chinese government exercised its authority in all sectors of the economy, including all decisions pertaining to infrastructure development. The inward-looking development strategy oriented towards heavy industrialization and self-sufficiency, promoted the expansion of the transportation network in northern China where heavy industries were located. These policies also promoted railways, which were viewed as a cost-effective mean for transporting material from resources-rich provinces to industrialized provinces (Démurger, 2001). However, despite these improvements, development of the transportation infrastructure remained relatively unimportant in China's national development strategy during the pre-reform period (World Bank, 1999). Consequently, China was poorly endowed with transportation infrastructure when the reforms began in 1978. There were only 97 kilometers of roads per thousand square kilometer of land in China in 1980, compared with 230 kilometer of roads per thousand square kilometer of land in India.[9] Despite the priorities given to develop China's transportation infrastructure in the early years of the reform period, investments were low compared to those in the industrial sector (Démurger, 1999). The fiscal policies aimed at controlling inflation appeared to be a limiting factor to infrastructure development. During the 1980s, the government curbed overheated demands for consumption and infrastructure investments

[9] Road density estimates for India are based on road length data reported by the Indiastat database and refers to the length of paved roads. For China, road length data are reported in the Chinese Statistical Yearbook (2001) and refers to the length of highways. For both countries, land area data are taken from the *World Bank 2003 Development Indicator* database.

by controlling rigidly the money supply and by implementing a tight credit policy (Démurger, 1999).

Thus China's infrastructure development did not kept pace with a soaring demand in the early 1980s. The growth in interregional trade following the reforms combined with the relatively low level of investments in infrastructure created transportation shortages and urban congestion (Démurger 2001). Since 1985, the government has geared up its investment in roads, particularly high-quality roads like highways connecting major industrial centers in the coastal areas.

In the 1990's, investments in infrastructure became a national priority. The Chinese government invested massively in road construction to speed up the expansion of the road network in counties and towns, to improve the quality of roads, and to increase the mileage of expressways. Although more resources were initially devoted to the coastal regions, the Chinese government has more recently shifted its focus to the western region. Road projects are now an important part of China's strategy to develop the western region. In 2003 for example, over 200 projects were launched to improve transportation in Western China. These projects aimed at connecting all counties with highways and expanding the length of the road network.

Roads Development

Table 8 shows the development of the length and density of the road network in China from 1952 to 2002. The mountainous topography in many parts of China has historically hindered the development of roads. In 1952, China's transportation infrastructure included only 126.7 thousands kilometers of roads, corresponding to a road density of 13.6 kilometers per thousand square kilometer of land. In that year, the road network handled about 132 million tons of goods and 45 million passengers, representing 41 and 19 % of the total volume of goods and passengers carried by Chinese transportation system, respectively. By 2002, the length of roads had increased to 176.5 thousands kilometers, carrying some 14.7 billion passengers and 11.1 billion tons of goods. This implied a road density of 189 kilometers per square kilometer of land, a

Table 8: Characteristics of Roads in China

	Length of highway	Road density	Passengers	Freight Traffic
	10,000 km	*Km/1000 sq km*	*million persons*	*million tons*
1952	12.7	13.6	45.6	131.6
1957	25.5	27.3	237.7	375.1
1962	46.4	49.7	307.4	327.9
1965	51.5	55.2	436.9	489.9
1970	63.7	68.3	618.1	567.8
1975	78.4	84.0	1,013.5	725.0
1978	89.0	95.4	1,492.3	851.8
1979	87.6	93.9	1,786.2	3,710.4
1980	88.3	94.7	2,228.0	3,820.5
1981	89.8	96.2	2,615.6	3,636.6
1982	90.7	97.2	3,006.1	3,792.1
1983	91.5	98.1	3,369.7	4,014.1
1984	92.7	99.4	3,903.4	5,333.8
1985	94.2	101.0	4,764.9	5,380.6
1986	96.3	103.2	5,442.6	6,201.1
1987	98.2	105.3	5,936.8	7,114.2
1988	100.0	107.2	6,504.7	7,323.2
1989	101.4	108.7	6,445.1	7,337.8
1990	102.8	110.2	6,480.9	7,240.4
1991	104.1	111.6	6,826.8	7,339.1
1992	105.7	113.3	7,317.7	7,809.4
1993	108.4	116.2	8,607.2	8,402.6
1994	111.8	119.8	9,539.4	8,949.1
1995	115.7	124.0	10,408.1	9,403.9
1996	118.6	127.1	11,221.1	9,838.6
1997	122.6	131.5	12,045.8	9,765.4
1998	127.9	137.1	12,573.3	9,760.0
1999	135.2	144.9	12,690.0	9,904.4
2000	140.3	150.4	13,473.9	10,388.1
2001	169.8	182.0	14,028.0	10,563.1
2002	176.5	189.2	14,752.6	11,163.2

Source: China's National Bureau of Statistics, *Statistical Yearbook of China, 2001, 2003*

fourteen-fold increase over 1952. In the mid-1980s, the government emphasized the construction of high quality roads. The construction of expressways has expanded substantially in China since the country completed its first expressway project in 1988. The length of expressways increased from 147 kilometers in 1988 to 25,130 kilometers in 2002, representing a more than 100 fold increase over 14 years (Table 9). Likewise, the length of class 1 highways increased rapidly, from 196 kilometers in 1980 to 27,468 kilometers in 2002, or an annual growth rate of 28.5%. Class 2 highways also expanded rapidly with an average annual growth rate of over 14% between 1980 and 2002. In contrast, the length of lower quality roads expanded at much slower rate. The length of class 3 and class 4 roads increased by only 5.4% and 3.5% per annum from 1980 to 2002, whereas the length of substandard roads declined by 1.3% over the same period.

Table 9: Lengths of Roads by Class

	Expressway	Class 1	Class 2	Class 3	Class 4	Substandard	Total
				Kilometers			
1980		196	12,587	108,291	400,060	367,116	888,250
1981							
1982		231	15,665	115,249	419,149	356,669	906,963
1983		255	17,167	119,203	426,190	352,264	915,079
1984		328	18,693	124,011	437,329	346,365	926,726
1985		422	21,194	128,541	456,286	335,952	942,395
1986		748	23,762	136,790	476,410	325,059	962,769
1987		1,341	27,999	147,838	491,212	313,853	966,178
1988	147	1,673	32,949	159,376	503,126	302,282	999,553
1989	271	2,101	38,101	164,345	511,105	283,866	999,789
1990	522	2,617	43,376	169,756	524,833	287,244	1,028,348
1991	574	2,897	47,729	178,024	535,444	276,468	1,041,136
1992	652	3,575	54,776	184,990	542,942	269,772	1,056,707
1993	1,145	4,633	63,316	193,567	559,472	261,343	1,083,476
1994	1,603	6,334	72,389	200,738	580,336	256,421	1,117,821
1995	2,141	9,580	84,910	207,282	606,841	246,255	1,157,009
1996	3,422	11,779	96,990	216,619	619,258	237,721	1,185,789
1997	4,771	14,637	111,564	230,787	635,737	228,909	1,226,405
1998	8,733	15,277	125,245	257,947	662,041	209,231	1,278,474
1999	11,605	17,716	139,957	269,078	718,380	194,955	1,351,691
2000	16,285	25,219	177,787	305,435	791,202	363,919	1,679,847
2001	19,437	25,214	182,102	308,626	800,665	361,968	1,698,012
2002	25,130	27,468	197,143	384,756	998,170	382,296	1,765,222
Growth rates (%)							
1980-02	44.4	28.5	14.0	5.4	3.5	-1.3	2.9

Source: China's National Bureau of Statistics, Statistical Yearbook of China, (various issues)
Notes: Growth rate for expressway is from 1988 to 2002.

The expansion of the highway network contributed greatly to China's economic development. The State Planning and Development Committee estimated that highway construction has increased economic growth by up to 0.4 percentage points and has absorbed 4 to 5 million workers in the construction industry.

There are significant changes in the shares of different classes of roads in China over time. In 1980, high quality roads (expressways, and class 1 and class 2 roads) accounted for only 1.5% of the total road length, while low quality roads accounted for more than 98.5%. In particular, class 4 and substandard roads constituted more than 85% of the total road length. By 2002 these shares had changed substantially with high quality roads accounting for 31.5% of the total length of roads and low quality roads for 68.5%.

Large regional variations exist in the density and quality of road infrastructure in China (Table 10). The western region is poorly served by roads compared to the central and western regions. In 2002, there were only 166 and 66 kilometers of roads for every thousand square kilometer of land in southwest and northwest China, respectively, compared to more than 460 kilometers per thousand square kilometer of land in the eastern and central regions. Among all provinces, Tibet and Qinghai are particularly poorly endowed with road infrastructure, with a road density of only 33 kilometers per thousand square kilometer of land. Road quality is also the worst in the western region. In southwest China, for example, high quality roads (expressways and class 1 and class 2 roads) account for less than 6% of the road network compared to 20% in the northern and the eastern regions.

Road development has also been uneven between rural and urban areas. There are currently about 184 towns and 54,000 villages that have no access to roads in rural China, most of which are located in the western region. Large-scale road projects have recently been launched to expand and improve the rural road network (Xinhua News Agency, 2003).

Table 10: Length and Density of Roads by Region, 2002

			Shares in total length of highways	
	Length of highways	Road density	Expressway, class 1 and 2	Below class 4
	(kilometer)	*(km per 1000 sq-km)*	*(percent)*	
North	**146,745**	**392.2**	**19.7**	**8.5**
Beijing	14,359	854.3	18.2	2.9
Tianjin	9,696	857.7	22.1	5.9
Hebei	63,079	332.0	21.4	14.4
Shanxi	59,611	382.1	17.9	4.0
Northeast	**152,192**	**193.3**	**17.7**	**5.3**
Liaoning	48,051	329.3	27.9	0.6
Jilin	41,095	219.3	16.0	6.5
Heilongjiang	63,046	138.9	11.0	8.2
East	**368,500**	**463.3**	**20.5**	**15.5**
Shanghai	6,286	991.4	30.0	4.2
Jiangsu	60,141	586.2	25.6	16.9
Zhejiang	45,646	448.4	20.1	6.3
Anhui	67,547	483.9	12.8	9.1
Fujian	54,155	446.1	11.9	23.9
Jiangxi	60,696	363.7	12.7	40.6
Shandong	74,029	472.4	35.4	0.2
Central	**372,061**	**478.4**	**16.6**	**24.3**
Henan	71,741	429.6	23.8	7.3
Hubei	86,098	463.1	14.9	21.8
Hunan	84,808	400.4	7.5	54.7
Guangdong	108,538	609.8	21.3	10.0
Hainan	20,876	596.5	10.1	43.6
Southwest	**391,790**	**166.2**	**5.6**	**38.1**
Chongqing	31,060	376.9	12.7	29.4
Sichuan	111,898	230.7	10.4	33.9
Guizhou	44,220	251.1	5.8	31.0
Yunnan	164,852	418.4	1.9	34.7
Tibet	39,760	32.6	1.5	79.0
Guangxi	56,297	237.8	10.7	25.1
Northwest	**277,637**	**65.7**	**10.5**	**18.2**
Inner Mongolia	72,673	61.6	9.2	13.3
Shaanxi	46,564	226.5	12.6	12.4
Gansu	40,223	88.4	11.5	23.4
Qinghai	24,003	33.3	12.8	23.0
Ningxia	11,245	170.4	21.4	1.5
Xinjiang	82,929	51.8	7.8	24.2
National Total	**1,765,222**	**184.7**	**14.1**	**21.7**

Source: *China's National Bureau of Statistics, Statistical Yearbook of China, 2003*

Sources of Funding

Prior to the reform period, road projects were predominantly funded from domestic sources in China. These sources included government appropriations, profits from state-owned enterprises and local government levies. The central government was accountable for the development of national roads, while the provincial and local governments were responsible for the provincial and local road networks (Yin, 2001; Demurger, 2001). Under the centrally planned system, provincial and local governments typically received funds for infrastructure construction from the central government.

Following the economic reforms, the sources of funds for roads have been increasingly diversified and include not only funds from central and local governments, but also loans from international organizations and banks, as well as foreign capital. Another important change has been the issuance of long-term public bonds to finance infrastructure projects. Between 1998 and 2002, the government issued over 660 billion yuan in bonds. These bonds were issued to state owned banks, such as the Industrial and Commercial Bank of China and the Agricultural Bank of China, and were assigned to projects aimed at:

a. Infrastructure investment in agriculture, forests, water conservancy, and the environment.
b. Construction of highways, railways, aerodrome, ports, and telecommunications.
c. Environment protection.
d. Upgrading rural and urban electric networks.

As local governments were granted more autonomy in the post-reform period, they became responsible for most of the infrastructure projects financed by bonds. Local governments applying for expressway construction projects are now required to raise 35% of the cost themselves from their own revenue (including tolls) and by selling bonds. The remaining 65% of the cost is funded through bank loans. In the past, banks were reluctant to provide loans for road projects. However investment in roads, especially in highways and expressways, has proved to be beneficial in recent years. Consequently, banks are now keener to fund road projects especially in the eastern region. In western China, the situation is quite different. Highway and expressway investments are less profitable. As fewer cars uses highways and expressways, local government cannot get enough revenue from tolls to pay for road maintenance and to repay principal and interest.

Table 11 shows the breakdown in highway investments by source of funds. Between 1998 and 2001, local governments contributed the most to highway investments (88%), followed by the central government (8.3%), and foreign capital (3.8%). Two categories of funds make up the lion's share of highway investment: domestic loans and self-raised funds by local governments which together accounted for more than 80% of the total investment in highways between 1998 and 2001.

Table 11: Highway Funding by Sources

	Central government			Local government				
Year	**Total**	**(1)**	**(2)**	**Total**	**(3)**	**(4)**	**(5)**	**Foreign capital**
					(percent)			
1998	7.1	6.6	0.5	87.8	36.0	5.3	46.5	5.1
1999	6.7	5.9	0.8	89.7	36.3	4.9	48.6	3.6
2000	7.3	6.6	0.7	88.8	36.0	4.4	48.5	3.9
2001	12.0	8.9	3.1	85.1	40.7	3.6	40.9	2.9
Average	***8.3***	***7.0***	***1.3***	***87.9***	***37.3***	***4.6***	***46.1***	***3.8***

Source: China highway transport statistics collection (1998-2000)
Notes: Numbers in the table represent the following variables: (1) ministry special funds; 2) central fiscal special funds; 3) domestic loans; 4) local fiscal funds; 5) self-raised funds and others.

The greater autonomy given to local governments also contributed to widening regional inequality as the capacity to raise funds to finance infrastructure projects depended on local government revenue (which in turn depended on the level of local economic activity) and the ability of local governments to negotiate higher contributions from the central government (Démurger 1999). The growing disparity in road provision across regions led the central government to launch major road construction projects in the central and western regions. As a result, the share of highway investment in eastern China declined from 54.8% in 1998 to 45.2% in 2001, whereas the corresponding shares in central and western China increased from 45.1% to 54.9 (Table 12).

Table 12: Regional Shares of Highway Investments

Year	East	Central	West
		(percent)	
1998	54.8	23.9	21.2
1999	52.1	25.2	22.6
2000	49.2	26.8	24.0
2001	45.2	30.6	24.3
Average	***50.0***	***26.8***	***23.1***

Source: *China highway transport statistics collection (1998-2000)*

IV. INFRASTRUCTURE AND POVERTY REDUCTION: A LITERATURE REVIEW

There is a large literature on the impact of road investments on economic growth and poverty reduction. We classify this literature into three broad groups: 1) studies that examine the relationship between road investments and economic growth; 2) studies that look at the relationship between road investments and poverty alleviation; and 3) studies that focus on China.

Economic Growth and Road Investments

To formally assess the contribution of road investments to production growth, a number of studies specify an aggregate production function that includes transportation infrastructure among the set of explanatory variables. Antle (1983), for example, estimated a Cobb Douglas production function for 47 developing countries and 19 developed countries. Infrastructure was specified as the gross national output from the transportation and communication industries per square kilometer of land area. Antle found a strong and positive relationship between the level of infrastructure and aggregate productivity. Ratner (1983), Aschauer (1989), Binswanger et al (1987), Binswanger et al (1989), Easterly and Rebelo (1993), and Baffes and Shah (1993) also found transportation infrastructure was as an effective factor of production.

There are several limitations to these studies. First, they to not take into account reverse causality. Reverse causality occurs if income growth increases the demand for infrastructure.[10] Ignoring reverse causality can lead to over estimation of the coefficients of the infrastructure variable in the production function. A second problem with these studies is the failure to take road quality into account. Road quality can vary greatly within a country and different quality roads can act in different ways. Failure to discriminate amongst types of roads can also lead to biased estimates. The studies

[10] For more information on reverse causality see Canning and Bennathan (2000), World Bank (1994), and Kessides (1993).

reviewed immediately below take these issues into consideration either jointly or in isolation.

Causality and Rates of Return to Roads

Fernald (1999) is the only study we found that explored the direction of the causal links between infrastructure and productivity. Using data from 29 U.S. manufacturing industries from 1953 to 1989, Fernald examined whether road investments lead to productivity growth or whether productivity growth entails greater road construction. His research findings suggest causation from roads to productivity implying that the productivity decline in U.S. manufacturing after 1973 may have been a result of lower public spending on road infrastructure. Fernald's study also suggests that the marginal returns to road investments are not as high as commonly thought, primarily because road construction offers only a one-time increase in the level of productivity rather than a continuous series of impacts.

Using cointegration methods to circumvent reverse causality, Canning and Bennathan (2000) estimated the rates of return to paved roads for a panel of 41 countries over the past 4 decades. Canning found that the highest rates of return to road infrastructure occurred in countries with infrastructure shortages. Canning also analyzed whether physical capital, human capital, labor, and other infrastructure variables are complements or substitutes to roads. He found that the length of paved roads is highly complementary with physical and human capital. However he observed that the marginal return to roads declines rapidly if the length of roads is increased in isolation from other inputs. Canning concluded that infrastructure investments are not sufficient by themselves to yield large changes in output. This finding is in line with Gannon and Zhi (1997) who also concluded that transport access is complementary to other services such as health and education.

Studies by Fan et al in rural India, China and Thailand also estimate the effect of infrastructure investments on economic growth and poverty. By estimating a system of equations, these studies explicitly account for the simultaneous effects of infrastructure investment in factor and product markets. Results from these studies consistently show the importance of road investments in promoting production growth and poverty reduction. In rural India, public investment in rural roads was found to have had the largest positive impact on agricultural productivity growth (Fan, Hazell and Thorat, 1999). In China and Thailand, road investments were found to have contributed significantly to growth in non-farm and total economic growth as well as in agricultural growth (Fan, Zhang and Zhang, 2002; Fan, Jitsuchon and Methakunnavut, 2002). .

Explaining Productivity Differentials

Economic performance and income levels often differ greatly between regions within a country. Lagging regions (such as the northwest of China and northeast of Brazil) are commonly associated with poor infrastructure, which isolates local populations from educational, social, and economic opportunities and contributes to the rise of poverty traps. Nagaraj et al (2000), Deichmann et al (2002), and Stephan (2000) have investigated the determinants of regional economic disparities. Nagaraj et al assessed whether differences in the availability of physical, social, and economic infrastructure explained growth performance differentials among 17 Indian states from 1970 to 1994. Using instrumental variable estimation techniques to account for reverse causality, they found that a 10% increase in the road network (defined as kilometers of road per square kilometer of land) would lead to a 3.4% increase in income per capita. They also found that power consumption and health conditions are positively correlated with the availability of road infrastructure.

Disparities in the productivity of manufacturing firms between the Southern states of Mexico and the rest of the country were the focus of the study by Deichmann et al. Specifically, Deichmann et al aimed to assess the importance of differences in the quality of infrastructure in explaining productivity differentials. To account for quality, the authors developed a market access indicator defined as the size of the potential markets that can be reached from a particular point given the density and quality of the transportation network within that region. The econometric results presented in the study show that a 10% increase in market access increases labor productivity by 6%.

Stephan also found that differences in the level and quality of transportation infrastructure are significant in explaining differentials in regional economic performance. He studied the effects of road infrastructure on productivity for 21 French regions and 11 West German Federal States and concluded that regional road infrastructure has a significant impact on regional output.

Access to Trade and Price Effects

The above studies have established links between the availability of transportation infrastructure and differences in economic performance among regions. Differences in regional economic performances can also be partly explained by a country or region's ability to trade as a result of better infrastructure. Limao and Venables (1999) elaborated on how the presence or absence of infrastructure influences access to trade. They constructed an infrastructure index that combines road, rail, and telecommunications densities. Using econometric methods, Limao and Venables studied the determinants of transportation costs. They showed that infrastructure is a significant determinant of transportation costs, and that when a region is landlocked, transport costs can by 50% higher. Using these findings along with detailed data on trade and transportation costs in Sub-Saharan Africa, they calculated that most of Africa's poor trade performance is the result of poor infrastructure. This finding concurs with similar findings by Delgado et al (1995).

The availability and quality of road infrastructure can also influence food prices. Using survey data collected from itinerant traders, Minten and Kyle (1999) analyzed the causes of food price variation in Kinshasa, the capital of former Zaire. They paid particular attention to the impact of distance and road quality on food price behavior and on the food collection system. Differences in road quality were accounted for by differentiating between paved roads and dirt roads. They reached the following conclusions. First, variations in food prices are significant across products and across regions. Second, transportation costs explain most of the differences in food prices among producer regions. Third, road quality was an important factor in determining transportation costs: transportation costs were on average two times greater on dirt roads than on paved roads.

Impacts of Road Investments on Poverty

The studies reviewed above highlight the importance of roads in promoting economic growth and development. However, few of them provided information on the distributional and poverty impacts of road investments. To gain further insights on how road investments affect inequality and poverty reduction we turn to evidence from more micro-level studies. Most of the studies reviewed rely on analysis of household survey data. We also draw on evidence from project evaluation and appraisal reports on road projects.

Non-Farm Employment and Income Diversification

Road investments can help the poor in a number of ways and one of the most important is through their impact on the rural nonfarm economy. For example, rural road investments can promote the development of small nonfarm enterprises, which in turn can increase the demand for rural labor. Using a reduced-form estimation technique and a panel dataset covering 85 districts in India over the period 1961-1981, Khander found that government investment in roads had a positive effect on crop output, rural non-farm employment and agricultural wages, all of which were beneficial to the poor. Malmberg et al (1997), Fan and Rao (2002), and Escobal (2001) have also explored the impact of roads on nonfarm employment and the consequences for the poor. Malmberg et al (1997) found that infrastructure investments contribute to economic growth in both the farm and non-farm sectors, generating economic opportunities for the rural population in general, including the poor. Likewise, Fan and Rao (2002) concluded that non-farm employment became increasingly important in helping the poor during the post-green revolution period in many Asian countries. One of the consequences of greater non-farm employment is income diversification. Escobal (2001) established the link between roads and income diversification. He analyzed the determinants of rural household decisions to undertake off-farm activities in rural Peru. Using a Tobit doubled-censored estimation, Escobal showed that access to roads, along with other public assets such as rural electrification and education, is a significant determinant of income diversification. He also found that access to roads and other public assets raises the profitability of both farm and non-farm activities, but especially the latter.

Determinants of Poverty

Kwon (2001) and Dercon et al (1998) have investigated the role of roads as one of several factors contributing to changes in the incidence of poverty. Kwon sought to identify the factors that contributed to the decline of poverty in 25 Indonesian provinces between 1976 and 1996. His study showed that provinces with adequate road services were more prone to receive better irrigation services and produce more crops. People in these provinces seemed to have more job opportunities in the non-farm sector either because they had easier access to labor markets or had more jobs available to them in the region. Using OLS and an instrumental variable estimation technique, Kwon found that roads have a significant impact on poverty alleviation. His results also show that the impact of roads was bigger in provinces with good access to roads than in provinces with bad access to roads.

Dercon et al used household data collected in rural Ethiopia in 1989, 1994, and 1995 to examine changes in poverty levels and to assess the factors driving the changes. By decomposing changes in poverty by sub-groups of the population, they found that households endowed with greater human and physical capital and with better access to roads had lower poverty levels. Dercon et al also noted that these factors reduce fluctuations in poverty over seasons.

The Distribution of Benefits from Rural Roads

The studies reviewed above confirm the importance of roads in poverty alleviation. However, the size and nature of the poverty effects and the distributional consequences remain unclear. In a rare study on this issue, Jacoby (2000) analyzed the distributional effects of rural roads in Nepal using household survey data. Jacoby developed a method for estimating benefits from road projects to households by assuming that lower transportation costs from better roads will be reflected in wages and farmland values. Based on these assumptions, Jacoby calculated the benefit that accrued to each household from a hypothetical road project and examined the distribution of these benefits across income classes. Using econometric estimation techniques, he found that providing improved road access to markets would generate substantial total benefits, a large share of which would be captured by poorer households. However, the benefits would not be large enough or targeted enough to significantly reduce income inequality.

To assess how road investments benefit the poor, Songco (2002) surveyed the impacts of rural infrastructure investments on household welfare. In addition to a literature review, Songco conducted a field survey in two provinces of the Central Highlands region of Vietnam to assess how poor households perceived benefits from upgrading low-grade roads to year round access. The benefits identified by households and by local authorities are numerous and include: improved mobility; reductions in the price of goods; and the elimination of health hazards from dusty roads. Moreover, Songco noted that for the poorest households the perceived impacts are mostly social benefits (such as year round access to school for children) rather than in economic benefits. The rural poor acknowledged the importance of road improvements but indicated that interventions in other areas such as expanded credit opportunities for the poor are also important for improving household welfare. Songco cautioned that these results are specific to the Central Highlands of Vietnam and should not be extrapolated to other regions.

Another study that assessed the impact of a specific road project was undertaken by Khandker et al. (1994). They reviewed the impact of a road project financed by the World Bank in Morocco and found increases had occurred in agricultural production and land productivity as well in the use of agricultural inputs and extension services. The road project also led to a shift towards the production of high-value crops and an increase in off-farm employment opportunities. On the social front, benefits included improvements in access to health services and increased attendance at schools.

Rural road projects do not always improve the well being of local communities and help the poor as discussed in Mahapa and Mashiri (2001), Fishbein (2001), and Riverson et al (1991). Mahapa and Mashiri assessed the impact of a road upgrading project in the village of Tshitwe in the Northern Province of South Africa. They surveyed about 140 households and found that the road improvement project was not cost efficient and it failed to improve land productivity, off-farm employment, or to shorten the travel time to reach markets and other socio-economic services. Mahapa and Mashiri also noted that road maintenance was neglected as people did not receive the necessary training. Fishbein, in his review of the role of rural infrastructure in Africa's rural transformation process, found that the use of public funds has been inefficient and has left many people without basic access to roads. Riverson et al reviewed 127 World Bank projects that involved rural roads in Sub-Saharan Africa. They found that the approaches used for planning and evaluation of rural roads had not paid sufficient attention to maintenance and had not fostered community participation. They also found that institutional problems were endemic to rural road projects. On the basis of these findings, Mahapa and Mashiri, Fishbein, and Riverson et al stressed the importance of targeting interventions to local conditions as well as obtaining the participation of local communities for increasing the success of road projects. Howe (1981), Howe (1997), Howe and Richards (1984), and Van de Walle (2000) reached similar conclusions.

Robinson (2001) pointed out that targeting and involving local communities in rural road projects—or decentralizing—is not always successful. Drawing on the literature and on field surveys in Nepal, Uganda, and Zambia, Robinson studied the effect of decentralizing transportation in developing countries. He found a number of constraints to successful devolution, including the lack of local government powers to exercise political influence, insufficient financial resources, and lack of management capability. He also found little evidence that existing decentralized systems address the needs of the rural poor. Robinson concluded that increased participation of the poor in the planning, financing, and implementation process is important. Devres, in a comprehensive survey of the literature on the socio-economic and environmental impact of roads in developing countries, found that the larger and wealthier farmers are more likely to take advantage of new inputs, better technology and extension services, and to respond to new market opportunities following road improvements.

Impact of Road Investments in China

The literature on the impact of road investments on economic growth and poverty reduction in China is comparatively sparse. Using provincial level data, Démurger (1999) and Felloni et al (2001) assessed the consequences of infrastructure investments on production and productivity in China. Démurger emphasized the role of infrastructure endowments—that is the length of railways, roads, and inland waterways per square kilometer of land—to explain growth performance differentials across provinces. Démurger's econometric results showed that cross-sectional differences in transportation infrastructure contribute significantly to the observed variation in growth performance among provinces. She also found a concave relationship between infrastructure endowment and economic growth. This suggests that expanding the transportation network will promote economic development in provinces with poor infrastructure endowment. On the other hand, upgrading or improving the quality of infrastructure may be more suitable for provinces with better transportation infrastructure. Hence, Démurger concluded that policies supporting infrastructure improvements could have substantial impacts in reducing disparities in the level of per capita income among Chinese provinces.

While Démurger assessed the overall economic impact of roads, Felloni et al focused on the agricultural sector. Echoing Démurger's findings, Felloni et al showed that the density of roads per hectare of agricultural land has a significant and positive effect on agricultural production and on land and labor productivity. Given that roads and energy are central to technology diffusion and production intensification and for facilitating access to the input and output markets, Felloni et al argued that the availability of roads and electricity are crucial to the modernization of Chinese agriculture. However these two studies fail to consider the impact of road investments on poverty reduction as well as the simultaneous effects of infrastructure investments on factor and product markets.

Fan et al (2002) take a more comprehensive approach to the problem. Using a system of equations model to account for endogeneities, Fan et al quantify the effects of rural infrastructure on growth and poverty reduction in rural China between 1970 and 1997. The authors found that public investments in roads, together with investments in education and agricultural research, helped to reduce rural poverty and regional inequality. Investments in roads also contributed to growth in agricultural production.

In contrast to the above studies, Lin and Shunfeng (2002) focused on the urban sector. Using data for 189 Chinese cities from 1991 to 1998, they found that growth in paved roads is positively and significantly related to growth in GDP per capita in urban areas. Benziger (1996) provides interesting evidence on the linkages between the urban and rural sectors. Benziger tested whether greater access to infrastructure and to urban markets increases the intensity of input use and productivity in the rural sector in the province of Hebei. His econometric results show that road density and distance to the nearest city positively affect the use of fertilizer per unit of land, machinery per worker, and land and labor productivity.

There is very little literature available in Chinese on the impact of road investments. The impact of highway construction in China was the topic of investigations by Zhu (1990) and Liu (1999). Zhu observed that different phases of a highway project have different impacts. The construction period creates not only tremendous work opportunities, but also improves the skill of local people employed on the project. In the post-construction period, Zhu found that highways promote the development of goods production in poor regions, increase the volume of trade, reduce transportation costs, and improve social services. Liu reported the findings of a study on the macroeconomic impact of highway investment. Highway construction was found to have significant impacts on the economy by promoting employment and increasing farm incomes: for every 100 million of yuan invested in highways, total output increased by

300 million of yuan and created 7000 jobs in the highway construction sector and related industries. On the other hand, Zhou (2001) found that corruption in China acts to reduce the economic efficiency of public investments.

Summary

Despite differences in methodology, in research objectives and in temporal and spatial coverage, the reviewed studies generally support the hypothesis of favorable impacts of roads on production and productivity, as well as on poverty alleviation. They also suggest that road investments can contribute to spatial inequities among regions. However, our survey also reveals several shortcomings in the literature, especially in its relevance to China. First, most studies focused on rural poverty. Until the beginning of the 1990s, poverty in China was considered largely a rural phenomenon and the rural poor were the focus of anti-poverty policies. Urban poverty mushroomed and came to be seen as a problem only in the past decade as China shifted to a market economy and enjoyed rapid economic development. Second, nearly all the reviewed studies failed to take into account road quality in their specification. While the total length or density of road is a useful indicator of the road infrastructure available in a country, it is important to account for quality as different types of roads can have different economic returns and different impacts on poverty.

V. CONCEPTUAL FRAMEWORK AND MODEL

Our conceptual framework is formulated to test the hypothesis that infrastructure investments in China promote economic development and growth and help reduce poverty. In urban areas, poor residents are hypothesized to benefit from increased employment opportunities and higher wages brought about by economic growth. In rural areas, infrastructure investments are hypothesized to affect rural poverty through various channels.[11] Infrastructure investment increases agricultural productivity, which in turn directly increases farm incomes and helps reduce rural poverty. Higher agricultural productivity also helps to lower rural poverty by increasing agricultural wages and improving nonfarm employment opportunities. Moreover, improved agricultural productivity often leads to lower food prices which help the poor since they are typically net buyers of foods. In addition to their productivity impact, infrastructure investments directly increase rural wages, nonfarm employment, and migration to urban or other rural regions. Understanding these different pathways can lead to useful policy insights for improving the effectiveness of government investments designed to promote growth and reduce poverty

The Model

To systematically assess the impact of different types of public investment and different qualities of roads on both growth and poverty reduction, we develop a multi-equations model based on Fan et al (2002). The first equation is an economy-wide labor productivity function[12]:

$$(1) \qquad GDPL = f(KSL, SCHY, ROAD1T, ROAD2T),$$

where *GDPL* is the gross domestic product per worker measured in 1980 prices and *KSL* is capital stock per worker. The variable *SCHY* is average years of schooling of the general population 15 years or older. To capture the impact of different types of roads, we use *ROAD1T* to represent the higher quality roads per worker, i.e., sum of

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[11] For more details see Fan et al (2002)

[12] For definitions of variables used, refer to Table 6.1.

length of expressway and class 1 and class 2 roads divided by the total number of workers, and *ROAD2T* to represent lower quality roads, i.e., sum of length of class 3, class 4, and substandard roads divided by total number of workers. To control for other factors not included in the equation, both year and provincial dummies are added. [13]

The second, third and fourth equations represents labor productivity in urban, agricultural, and rural nonfarm sectors. Agricultural labor productivity and nonfarm labor productivity are functions of inputs as well as infrastructure and other public investment variables. Similarly, urban labor productivity growth is modeled as a function of urban inputs (labor and capital), infrastructure development, education, and other public investment variables in the urban sector. Different types of roads (by class) are included as separate variables in the production functions.

(2) *UGDPL = f(UKSL, USCHY, ROAD1U, ROAD2U),*

(3) *AGDPL = f(LANDP, FERTP, MACHP, RDSP, IRRIP, RSCHY, RTRP, RELECP, ROAD1A, ROAD2A),*

(4) *NFGDPL =f(NFKSL, RSCHY, ROAD1NF, ROAD2NF).*

Where *UGDPL, AGDPL,* and *NFGDPL* are labor productivity in urban, agricultural, and rural nonfarm sectors, respectively; *UKSL* and *NFKSL* are capital stocks in the urban and rural nonfarm sectors, respectively; *RSCHY* and *USCHY* are average years of schooling for rural and urban residents, respectively. *LANDP, FERTP, MACHP, RELECP, RTRP,* and *RDSP* are land input, fertilizer use, machinery input, rural electricity consumption, number of rural telephone sets, and agricultural research (measured in stock terms) all expressed on a per agricultural laborer basis. *IRRIP* is the percentage of arable land under irrigation. *ROAD1U* and *ROAD2U* are the length of high and low quality of roads per worker, respectively, in the urban sector; *ROAD1A* and

[13] Canning and Bennathan (2000) argued that there may exist an reverse causality between GDP growth and infrastructure development. We followed Canning's approach by using one lead and two lags of differences of independent variables (KSL, ROAD1T, ROAD2T, and SCHY). Only capital variable shows a strong reverse causality (i.e., the coefficients of one lead and two lags are significant). This may be due to the fact that region and year dummies may have wiped out the potential endogeneity effect.

ROAD2A are the lengths of high and low quality roads per worker, respectively, in the agricultural sector; and *ROAD1NF* and *ROAD2NF* are the length of high and low quality roads per worker, respectively, in the rural nonfarm sector.

Agricultural prices are modeled as a function of agricultural GDP per worker (supply side factor), and urban GDP per worker (demand side factor).[14]

(5) *APRICE=f(AGDPL, UGDPL).*

Where *APRICE* are real agricultural prices deflated by consumer price index. A world or border price variable is not included because China's food staple markets were closed during most of the time period of analysis[15].

The next two equations model the determinants of rural and urban poverty. The urban poverty equation is a function of labor productivity in the urban sector, the Gini coefficient of income distribution of urban residents, and the agricultural terms of trade, controlling for other factors. Rural poverty is modeled as a function of growth in agricultural productivity, nonfarm labor productivity, urbanization, and the agricultural terms of trade.

(6) *UPOVERTY=f(UGDPL, UGINI, APRICE),*

(7) *RPOVERTY=f(AGDPL, NFGDPL, APRICE, URBANP).*

where *RPOVERTY* and *UPOVERTY* are rural and urban poverty measured as the percentage of the relevant population under the poverty line; *URBANP* is the percentage of urban people in the total population. *UGINI* is the urban gini coefficient of per capita expenditure.

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[14] We also used a similar specification as Fan, Zhang and Zhang (2002). That is, we estimate the poverty equation as a function of growth in agricultural labor productivity, rural wages, the percentage of rural nonfarm employment, and the terms of trade of agricultural prices relative to nonagricultural prices. Agricultural labor productivity, rural wages, and nonfarm employment are modeled as functions of public investment variables such as education, infrastructure, and agricultural R&D, together with other variables. The current specification allows us to calculate the economic returns and poverty reduction impact in both rural and urban sectors.

[15] When a border price variable was included, it proved to be statistically insignificant.

Marginal Impact

The marginal impact of roads on growth in GDP, agricultural GDP and urban GDP can be derived as:

(8) *dGDP/dROADS = ∂GDPL/∂ROADSL,*

(9) *dUGDP/dROADS = ∂UGDPL/∂ROADSUL,*

(10) *dAGDPL/dROADS = ∂AGDPL/∂ROADSAL,*

(11) *dNFGDP/dROADS = ∂NFGDPL/∂ROADSNFL*

Here *ROADSL* can be either high or low quality of roads. The coefficient of the length of roads per worker in the labor productivity function is the same as the coefficient of the length of roads in the GDP function when constant returns to scale are assumed. The marginal return per unit of length of roads is simply *dGDP/dROADS*(GDP/ROADS).*

Similarly, the marginal impact of roads on rural poverty can be derived as:

(12) *dRPOVERTY/dROADS =*

(*∂RPOVERTY/∂AGDP*)(*∂AGDP/∂ROADS*) +

(*∂RPOVERTY/∂NFGDP*)(*∂NFGDP/∂ROADS*) +

(*∂RPOVERTY/∂APRICE*) (*∂APRICE/∂AGDP*) (*∂AGDP/∂ROADS*)

The first term on the right hand side measures the impact of agricultural growth on rural poverty reduction while the second term captures the impact on rural poverty of improvements in rural nonfarm GDP resulting from investment in roads.[16] The last term measures the impact on poverty due to changes in agricultural prices induced by increased agricultural production.

The marginal impact of improved roads on urban poverty is derived as:

(13) *dUPOVERTY/dROADS =*

(*∂UPOVERTY/∂UGDPP*)(*∂UGDPP/∂ROADS*)+

[16] The terms are separated by "+".

$$(\partial UPOVERTY/\partial APRICE)\ (\partial APRICE/\partial AGDPP)\ (\partial AGDPP/\partial ROADS).$$

The first term of equation (13) is the impact of improved roads on urban poverty through urban growth. The second term captures the impact on urban poverty of lowered food or agricultural prices from increased production induced by road investments.

VI. DATA, MODEL ESTIMATION AND RESULTS

Data

The sources of the data used in this study are, unless otherwise indicated, official data published by the Chinese statistical agency and the National Statistical Bureau. Most of labor, capital, public expenditures, education, and infrastructure variables are available annually at the provincial level from the 1950s to 2003. But poverty data are only available at the provincial level for selected years in the 1980s and 1990s. Therefore, certain statistical procedures and estimation techniques have to be used to fill data gaps and maximize the estimation efficiency.

Rural Poverty

There are several estimates of rural poverty in China. Official statistics indicate that the number of poor declined to about 30 million by 2000 (MOA, *China Agricultural Development Report* 2001). A second source is the estimates from the World Bank (World Bank, 2000), which are similar to China's official statistics. A third set of estimates, based on a much higher poverty line (Ravallion and Chen 1997), shows a far greater proportion of the total population subject to poverty, with a poverty incidence of 60 percent in 1978 and 22 percent in 1995. However, the declining trend of rural poverty in this last set of estimates is steeper than that in the official Chinese statistics. Finally, Khan (1997), using samples of the national household survey, obtained 35.1 percent for 1988 and 28.6 percent for 1995.[17] Although these poverty rates are higher than the official rates, they confirm the declining trend showed in the official statistics.

Xian and Sheng (2001) provide the most recent estimates of rural poverty by province using a more rigorous approach. They used a poverty line of 860 yuan in terms of per capita consumption for 1998, which is actually higher than the one dollar per day poverty line commonly used by the World Bank.[18]

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[17] The dataset included 10,258 rural households in 1998 and 7,998 in 1995.

[18] This is equivalent to 1.15 dollar per day measured in purchasing power parity.

We use 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. We obtained 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 by province are available for more years, specifically from 1985 to 1989, and for 1991 and 1996

Urban Poverty

The urban poverty and income variables were constructed by Fan, Fang, and Zhang (2001) from China's urban household survey. The urban household survey is conducted annually by the National Statistical Bureau to monitor changes in urban household expenditures and consumption. A total of 40,000-50,000 households were surveyed annually between 1992 and 1998. We were able to access to 10% of the total sample, taken from one representative city in each province.

To obtain appropriate poverty measures, we first had to convert our chosen poverty lines ($1.0, 1.5 and 2.0 per capita per day, measured in 1985 purchasing power parity) into local currency at nominal prices. To do this, we first converted the poverty line from 1985 PPP dollars into Chinese currency based on the 1985 PPP exchange rate. Then we used the Chinese consumer price index to calculate the national poverty lines at current prices. Finally, provincial level poverty lines were calculated by adjusting for differences in the cost of living by province.

To measure urban poverty, we used the percentage of the urban population falling below the chosen poverty line measured in 1985 purchasing power parity. There are good reasons to use a higher poverty line when measuring urban poverty (ADB 2002). One prominent reason is the much higher cost of living for urban than rural residents. Consequently, in this study we use poverty lines of $1.5 and $2.0 per capita per day. This leads to significant increases in the estimated number of urban poor in 1998, from 6.32

million when using the $1.0 poverty line to 27.17 million and 60.04 million, respectively, when using the $1.5 and $2.0 poverty lines.

One important characteristic of the urban poor in China is the high share of total consumption expenditure spent on food. If the $2.0 per capita per day poverty line is used, then the urban poor spent about 58% of their total expenditures on food in 1998 compared to 50% for the average urban population. Clearly the urban poor would suffer the most from higher food prices.

Agricultural and Nonagricultural GDP19

Both nominal GDP and real GDP growth indices for various sectors are available from *The Gross Domestic Product of China* (SSB 1997a). Data sources and construction of national GDP estimates were also published by the State Statistical Bureau in *Calculation and Methods of China's Annual GDP* (SSB 1997b). According to this publication, the SSB used the UN (United Nations) standard SNA (System of National Accounts) definitions to estimate GDP for 29 provinces for 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 for the same three sectors. Both nominal and real growth rates are available from SSB publications.

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 nominal GDP for rural industry and services to obtain their GDP in real terms.

[19] There have been numerous debates about the accuracy of GDP measures in China. Rawski (2001) claimed that China's GDP growth rate has been overestimated by a large extent. For example between 1997 and 1998, the official statistics reported a 7% growth, while Rawski claimed only a 2% growth. However, many Chinese scholars rebuffed his assertion. In recent years, the census has reached that China's GDP may have been overestimated, but the magnitude of overestimation is only around 1-2% per annum. The objective of this study is not to resolve this debate. The regional and year dummies added in our regression may have largely reduced the potential bias on our estimated parameters.

Labor

Labor input data for the primary, secondary, and tertiary sectors at the provincial level after 1989 can be found in SSB's *Statistical Yearbooks* (various issues), while provincial labor data prior to 1989 are available in SSB [1990]. Labor is measured in stock terms as the number of persons at the end of each year. For rural industry and services, prior to 1984, labor input data at the township and village level, but not at the individual household level, are available in SSB's *Rural Statistical Yearbooks*. The omission of individual-household, non-farm employment data will not cause serious problems, as the share of this category in rural employment was minimal prior to 1984. Urban industry labor is estimated by subtracting rural industry labor from total industry labor, and urban service labor is similarly estimated as total service labor net of rural service labor. The labor input for the nonfarm sector is calculated simply by subtracting agricultural labor from total rural labor.

Capital Stock

Capital stocks for the agricultural and nonagricultural sectors in rural areas are calculated from data on gross capital formation and annual fixed asset investment. The SSB (1997) published data on gross capital formation by province for our three sectors 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 define the capital stock in time t as the stock in time t–1 plus investment minus depreciation,

$$(15) \qquad K_t = I_t + (1-\delta)K_{t-1},$$

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. *China Statistical Yearbook* (SSB 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 Kohli (1982). 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,

$$(16) \qquad K_{1978} = \frac{I_{1978}}{(\delta + r)}.$$

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.

To obtain the capital stock for the urban industrial sector, capital stock for rural industry is subtracted from the total industry capital stock (or secondary industry as classified by the SSB). 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 enterprises is the sum of 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.

Roads

Based on the expected use, function and the number of vehicles passed per day, highways are classified into five categories: expressways and classes 1 to 4 highways. Expressways can be classified into four-line, six-line and eight-line expressways, with associated increases in their vehicle carrying capacity. The designed carrying capacities for expressways are designated as follows: 25,000 -55,000 mini-buses or their equivalent per 24 hours for 4-lane expressways; 45,000-80,000 mini-bus equivalents per 24 hours for 6-lane expressways; and 60,000–100,000 mini-bus equivalents per 24 hours for 8-lane expressways. Other highways typically have two lanes and are classified by class with the following designed capacities: 15,000-30,000 mini-buse equivalents per 24 hours for class 1 highways; 3,000-7,500 mini-bus equivalents for class 2 highways; 1500-3000 mini-bus equivalents per 24 hours for class 3 highways; and less than 1,500 mini-bus equivalents per 24 hours for double lines, or less than 200 mini-bus equivalent for single lines for class 4 roads.

Substandard roads are usually rural roads connecting county seats with towns and those connecting towns and villages. They are usually not paved but are usually passable even when raining.

The designed length of life for roads also varies by type of road. For expressways and class 1 roads, the designed life is usually 20 years; for class 2 roads, 15 years, for class 3 and class 4 roads, 10 years. Substandard roads normally have a lifespan of less than 10 years.

Agricultural R&D Expenditure

Public investment in agricultural R&D is accounted for in the total national science and technology budget. Several government agencies invest in agricultural R&D. Science and technology commissions at different levels of government allocate funds to national, provincial, and prefectural institutes, primarily as core support. Institutes use these funds mainly 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 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 (1997) and various publications from the Government Science and Technology Commission and the State Statistical Bureau. 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 sub-national 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 the province's extension expenditures.

Education

We use the percentage of population 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. The population census and the Ministry of Education report education levels by province for population above age 7.

Rural Electricity

Total rural electricity consumption for both production and residential uses by province from 1970 to 2002 are available in various issues of the *China Rural Statistical Yearbook* and the *China Agricultural Yearbook*. In more recent years, the *China Rural Energy Yearbook* (MOA 1995–2003) began publishing the use of electricity separately for residential and production purposes by province. We use this newly available information to backcast the different uses by province for earlier years.

Rural Telephones

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*.

Model Estimation

We used double-log functional forms for all equations in the system. More flexible functional forms such as the translog or quadratic impose fewer restrictions on the estimated parameters, but many interaction coefficients are not statistically significant because of multicollinearity problems. Model estimates also proved sensitive to slight alterations in the sample period or to deletion of non-significant variables. The use of a double-log functional form was deemed preferable as it imposes some restrictions on the parameters and reduces the number of parameters to be estimated. This increases the number of degrees of freedom available and the reliability of the estimated coefficients.[20] Regional dummies were added to all equations to capture fixed effects arising from regional differences in agroclimatic and social economic factors. Year dummies were also added to control for any macroeconomic polices that may have had similar impacts on each region.

The literature review in the previous section indicates that if reverse causality is not considered then the effects of road investment may be overstated. Fan, Hazell, and Thorat (2000) used a difference approach, i.e., taking first differences for all variables before estimation, to minimize any potential bias from reverse causality in their study on India. However, the first difference approach may eliminate all long-term relationships between public capital and economic growth. Fan, Zhang, and Zhang (2002) in their study on China used the level approach to preserve the long-term relationship between

[20] Fuss, McFadden and Mundalak (1978) argue that functional forms chosen should satisfy the following criteria: (1) the functional forms should contain no more parameters than are necessary to agree with the maintained hypotheses; (2) the parameters should have intrinsic and intuitive economic interpretations, and a functional structure; (3) the trade-off between the computational requirements of a functional form and the roughness of empirical analysis should be weighted carefully in the choice of a model; (4) the chosen functional form should be well-behaved, and should be consistent with such maintained hypotheses as positive marginal products or convexity, within the range of observed data; and finally the functional form should be compatible with the maintained hypothesis outside the range of the observed data. The double-log function seems reasonable when judged against these criteria

investment and growth. They minimize potential bias by estimating an equation system in which they endogenize the public capital variables. Furthermore, they argued that public capital variables used in the production function are usually the results of past investments over many years while output or productivity is a function of the current capital stock. Therefore, the reverse causality should not exist unless investors or policymakers make their decisions based on the growth potential of each region. However, regional dummies included in the model should minimize the potential bias from this regional targeting. [21]

Equations (1) to (7) form a recursive system. Since there are nonzeros for some off-diagonal terms, a systems approach to estimation is still needed. As rural poverty data are only available for seven years at the provincial level (1985–89, 1991, and 1996) and urban poverty are only available at the provincial level for 1992 to 1998, a two-step procedure was used in estimating the full equations system. The first step involved estimating all the equations except for the poverty equations using the provincial-level data from 1982 to 1999 with a full information likelihood estimation technique. Then the values of the independent variables in both the rural and urban poverty equations at the provincial level were predicted using the estimated parameters. In the second step, we estimated the rural and urban poverty equations using the predicted values of the independent variables at the provincial level based on the available poverty data. The advantage of this procedure is that it fully uses the information available for all the non-poverty equations, therefore increasing the reliability and efficiency of the estimates and avoiding endogeneity problems that can arise with the poverty equations.

Estimation Results

Table 13 summarizes variable definitions and Table 14 presents the estimated equations. In this section and thereafter we use low quality roads and rural roads

[21] Using the data from rural India, Zhang and Fan (2001) tested the two directions of causality between productivity growth and road capital. To avoid the reverse causality of road development to productivity growth, they used an instrumental variable approach, and found that the coefficient of roads changed very little when compared to the original model. One of the reasons was that road capital such as length of roads at the current level is a result of past government investments.

interchangeably as low quality road are found mainly in rural areas. Similarly, we use high quality roads and urban roads interchangeably.

The results for equation (1) (GDP per worker) show that the capital stock, and human and infrastructure investments are all statistically significant in determining China's overall labor productivity. Both types of roads, high and low quality, are statistically significant with elasticities of 0.036 and 0.165, respectively. This means that for each one percent increase in high quality roads, GDP per worker will grow by 0.036%, while for every one percent increase in low quality roads, GDP per worker will grow by 0.165%.

The results for equation (2) show that urban capital plays a dominant role in urban labor productivity growth, with an elasticity of 0.547. Both types of roads contribute to urban labor productivity growth, though low quality roads have the larger elasticity. This may be because low quality roads help rural laborers to migrate to urban centers, and also provides markets for urban industrial products. The average years of schooling has a larger elasticity than the road variables.

The estimated agricultural labor productivity equation (equation (3)) shows that arable land per worker, fertilizer use, rural electricity consumption, rural education, agricultural research and low quality roads are all statistically significant. But high quality roads do not show any statistically significant impact on agricultural productivity.

All the included variables are significant in the equation for rural nonfarm labor productivity (equation (4)), but the elasticity of low quality roads is much larger than that of high quality roads. Rural education has a particularly large elasticity of 1.875.

The estimated terms-of-trade equation (equation 5) confirms that increases in agricultural production exert a significant downward pressure on agricultural prices, worsening the terms of trade for agriculture.

Table 13: Definition of Variables

Variables	Definition
GDPL	GDP per worker
UGDPL	Urban GDP per worker
AGDPL	Agricultural GDP per worker
NFGDPL	Nonfarm GDP per worker
KSL	Capital stock per worker
NFKSL	Capital stock per worker in the rural nonfarm sector
UKSL	Urban capital stock per worker
LANDP	Arable land per agricultural worker
FERTP	Chemical fertilizer use per worker
RDSP	Agricultural research stock per worker
RPOVERTY	Percentage of rural population below poverty line
UPOVERTY	*Percentage of urban population below poverty line*
UGINI	Gini coefficient of per capita expenditure for urban residents
SCHY	Average years of schooling of general population 15 years and older
RSCHY	Average years of schooling of rural population 15 years and older
ILLITE	Rural illiteracy rate
ROAD1T	Length of high quality of roads per worker
ROAD2T	Length of lower quality of roads per worker
ROAD1A	Length of high quality of roads per agricultural worker
ROAD2A	Length of lower quality of roads per agricultural worker
ROAD1U	Length of high quality of roads per urban worker
ROAD2U	Length of lower quality of roads per urban worker
ROAD1NF	Length of high quality of roads per nonfarm worker
ROAD2NF	Length of lower quality of roads per nonfarm worker
IRRIP	Percentage of total cropped area that is irrigated
RELECP	Rural electricity consumption per agricultural worker
RTRP	Number of rural telephone sets per agricultural worker
URBANP	Percentage of urban population in total population
APRICE	Terms of trade, measured as agricultural prices divided by a relevant nonagricultural GNP deflator

Table 14: Estimates of the Equations System

(1)	GDPL	=	0.512 KSL	+ 0.036 ROAD1T	+ 0.165 ROAD2T	+ 0.299 SCHY		$R^2 = 0.664$
			(12.81)*	(2.68)*	(3.30)*	(2.71)*		
(2)	UGDPL	=	0.547 UKSL	+ 0.043 ROAD1U	+ 0.172 ROAD2U	+ 0.386 SCHY		$R^2 = 0.914$
			(15.1)*	(3.36)*	(3.65)*	(2.62)*		
(3)	AGDPL	=	0.023 LANDP	+ 0.032 IRRIP	+ 0.026 MACHP	+ 0.179 FERTP	- 0.001ROAD1A	$R^2 = 0.833$
			(0.22)*	(0.34)	(0.50)	(2.76)*	(-0.39)	
			+0.203 ROAD2A	+ 0.014 RTRP	+ 0.105 RELECP	- 0.223 ILLITE	+ 0.071RDSP	
			(2.12)*	(0.84)	(2.09)*	(-2.13)*	(2.14)*	
(4)	NFGDPL		0.526 NFKSL	+ 0.052ROAD1NF	+ 0.374 ROAD2NF	+ 1.875 RSCHY		$R^2= 0.921$
			(15.03)*	(2.11)*	(6.02)*	(6.54)*		
(5)	APRICE	= -	0.087 ADGPL	+ 0.095 UGDPL				$R^2= 0.941$
			(-3.55)*	(1.59)				
(6)	UPOVERTY	-	0.941 UGDPL	+ 1.233 GINI	+ 0.519 APRICE			$R^2= 0.578$
			(-5.67)*	(3.60)*	(5.63)*			
(7)	RPOVERTY	= -	1.637 AGDPL	– 0.761 NFGDPL	– 0.126 URBANP	– 0.236 APRICE		$R^2= 0.994$
			(–2.17)*	(–2.28)*	(–1.26)	(–0.18)		

Note: Region and year dummies are not reported. Asterisk indicates that coefficients are statistically significant at the 10 percent level. The coefficients for the technology, education, and infrastructure variables are the sum of those for past government expenditures

The results for the urban poverty equation (equation 6) show that increases in urban GDP significantly reduce urban poverty, while increases in urban inequality (as measured by the Gini coefficient) or agricultural prices significantly worsen urban poverty.

For rural poverty, the estimated results (equation (7)) show that improvements in labor productivity in the agricultural and rural nonfarm sectors contribute significantly to rural poverty reduction. However, agricultural prices and the extent of urbanization are not significantly correlated with rural poverty.

Marginal Returns of Roads per Kilometer

Using the estimated equations (1) to (7) in Table14, the derived equations (8) to (13), we derived the marginal returns for different types of roads in terms of economic growth and rural poverty reduction. This implicitly assumes that the model relationship estimated for 1982 to 1999 in Table 14 also holds for 2001. The estimated marginal returns for most recent year will provide immediate policy insights for the government in setting its investment priorities. We calculated the marginal returns for different types of investments by region and for China as a whole. We divided China into seven regions according to geographic location, agricultural production structure, and the level of economic development at the provincial level as shown in Table 5.

Total GDP

Table 15 shows the marginal impacts on total GDP, urban GDP, agricultural GDP, and rural nonfarm GDP of another kilometer of high and low quality roads. One more kilometer of high quality roads (average of express and class 1 and class 2 roads) yields more than 1.7 million yuan worth of total GDP. Surprisingly, the returns to road investments deviate little from the mean across regions. The southeast region has the largest return (2.2 million yuan), followed by the south (1.8 million yuan) and the southwest (1.7 million yuan), while the northwest region has the lowest return (1.1 million yuan). Other regions fall in between. For low quality roads, every additional

Table 15: Economic Returns to Additional Length of Roads

	High Quality	Low Quality
	(yuan per kilometer)	
Returns in Total GDP		
Average	1,730,748	1,158,072
Northeast	1,573,205	1,326,067
North	1,576,821	1,605,599
Northwest	1,109,934	416,690
Central	1,605,763	891,822
Southeast	2,245,363	3,651,586
Southwest	1,726,213	457,053
South	1,786,413	1,391,885
Returns in Urban GDP		
Average	1,104,335	682,088
Northeast	1,102,441	857,776
North	1,033,951	971,835
Northwest	673,675	233,456
Central	840,450	430,870
Southeast	1,494,834	2,244,016
Southwest	947,638	231,607
South	1,223,394	879,885
Returns in Agricultural GDP		
Average	N.S	285,399
Northeast	N.S	237,030
North	N.S	329,720
Northwest	N.S	129,162
Central	N.S	339,018
Southeast	N.S	558,810
Southwest	N.S	197,963
South	N.S	326,284
Returns in Rural Nonfarm GDP		
Average	729,893	1,032,245
Northeast	595,471	875,066
North	671,564	1,244,221
Northwest	440,485	345,300
Central	797,611	1,081,150
Southeast	1,042,353	2,941,662
Southwest	487,823	330,103
South	701,359	1,141,634

Note: Except returns in agricultural GDP to high quality roads, all estimates are statistically significant at the 10% level. The returns are calculated for 2001 by using 2001 data kilometer yields 1.1 million yuan of total GDP on average, about 66% of the corresponding return from high quality roads. Further, in contrast to high quality roads, returns to low quality roads show much larger regional differences. An additional kilometer of low quality roads produces more than 3.6 million yuan worth of GDP in the southeast, compared to only 0.4 million yuan in the northwest.

Urban GDP

The marginal impact of another kilometer of high quality roads is 1.1 million yuan in terms of urban GDP. As with total GDP, the return to high quality road investments in urban GDP varies little among regions. It ranges from 0.67 million yuan in the northwest to 1.49 million yuan in the southeast. Low quality roads have a lower return on average (0.68 million yuan of urban GDP) and this ranges from 0.23 million yuan in the northwest and southwest to 2.2 million yuan in the southeast. In general, road investments have lower returns in the less-developed areas.

Agricultural GDP

As higher quality roads have only a small and insignificant impact on agricultural GDP (equation (3), we do not calculate their marginal returns. For low quality roads, every additional kilometer generates 0.29 million of agricultural GDP. The highest return occurs in the southeast (5.6 million yuan) while the lowest return occurs in the northwest (1.3 million yuan).

Rural Nonfarm GDP

Low quality roads yield higher marginal returns to rural nonfarm GDP than high quality roads. On average, every additional kilometer of high quality roads yields 0.73 million yuan of rural nonfarm GDP, while low quality roads yield more than 1 million yuan. Not surprisingly, returns to both types of roads are highest in the southeast, while the lowest returns occur in the southwest and northwest.

Urban Poverty

The estimated marginal impact of road investments on urban poverty reduction tells a different story (Table 16). The highest returns occur in poor regions like the northeast, northwest and southwest. Each additional kilometer of high quality roads lifts about 10 to 15 urban poor out of poverty in the northwest, northeast, and southwest. In the southeast and the south, less than 2 urban poor would be affected. For China as a whole, each additional kilometer of high quality roads lifts about 6 urban poor out of poverty. Turning to low quality roads, each additional kilometer raises about 4 urban poor above the poverty line. Low quality roads have the largest impact on urban poverty in the northeast while the lowest impact occurs in the south.

Rural Poverty

Two sources of rural poverty data are used to calculate the effects of road investments on rural poverty: the poverty rate by province reported by Chinese official statistics (SSB), and the poverty rate estimated by Xian and Sheng (2001). Using the official data, Table 16 shows that 9 rural poor would be lifted above the poverty line in China by each additional kilometer of high quality roads. The largest impacts arise in the southwest and northwest regions with 37 and 28 rural poor lifted above the poverty line, respectively. In contrast, each additional kilometer of low quality road lowers rural poverty by about 22 people in China. Again, the largest poverty reduction effect occurs in the southwest, followed by the northwest.

If Xian and Sheng's poverty data are used, the marginal impact of high quality roads on rural poverty increases to 35 poor people per additional kilometer.[22] The largest poverty reduction impact from high quality road expansion takes place in the southwest, followed by the northwest and the north. In the southwest and the northwest, the poverty effects are particularly large with 91 and 57 rural poor lifted above the poverty line per

[22] This calculation is based on the assumption that the estimated relationship between investment and poverty reduction holds in 2001. It also assumes that this relationship estimated based on a lower poverty line ($0.66 per day) holds for the higher poverty line ($1.15 per day).

kilometer of road. Interestingly, the north has the largest marginal impact per kilometer of low quality road followed by the southwest. For the northern region, our estimates indicate that 226 rural poor would be lifted out of poverty for every additional kilometer of low quality road. The marginal impacts of low quality road investments on rural poverty are similar in the central and southeast regions, whereas the impact on rural poverty is the lowest in the south and the northeast.

Table 16: Returns in Poverty Reduction to Additional Length of Roads

	High Quality	Low Quality
	(number per kilometer)	
Returns in Urban Poverty Reduction		
Average	5.53	3.61
Northeast	13.23	10.87
North	3.18	3.16
Northwest	14.84	5.43
Central	5.16	2.79
Southeast	1.79	2.84
Southwest	9.52	2.46
South	0.72	0.55
Returns in Rural Poverty Reduction, Official Data		
Average	8.97	21.59
Northeast	4.36	13.22
North	6.99	25.60
Northwest	27.91	37.69
Central	4.36	8.72
Southeast	1.07	6.23
Southwest	36.63	34.90
South	2.94	8.25
Returns in Rural Poverty Reduction, Xian and Sheng Data		
Average	34.96	109.61
Northeast	16.52	53.65
North	55.14	226.30
Northwest	57.57	98.29
Central	32.92	97.75
Southeast	14.06	92.02
Southwest	91.75	135.77
South	10.79	39.81

Note: All estimates are statistically significant at the 10% level. The returns are calculated for 2001 by using 2001 data.

Marginal Returns of Roads per Unit of Investment

Using the unit costs of constructing different types of roads in different regions, we can express the marginal economic and poverty effects of additional road investments on a unit cost basis. The unit costs for different types of road construction are shown by region in Table 17. The unit cost of expressway construction varies little among regions, with the highest cost occurring in the southeast and the lowest cost in the north. The high cost in the southeast may reflect the high cost of land while the lower cost in northern China may arise from its flat topography and lower cost of land. On the other hand, large regional variations are observed in the unit construction costs of lower quality roads. For class 4 and substandard roads, the lowest cost is found in the southwest while the highest cost occurs in the south. We calculated the average unit cost for expressways and class 1 and class 2 roads as the average cost for high quality roads while we treat the rest as low quality roads. At the national level, high quality roads cost 6-8 times more than low quality roads.

Table 17: Unit Cost of Construction by Type of Roads

	Expressway	Class 1	Class 2	Class 3	Class 4	Substandard	High Quality	Low Quality
					10,000 yuan			
Average	2611	910	285	142.5	50	38	560	67
Northeast	2,978	1,038	307	153.5	54	40	581	83
North	2,065	720	333	166.5	58	44	531	66
Northwest	2,248	784	345	172.5	60	45	490	73
Central	2,594	904	255	127.5	45	34	469	34
Southeast	3,495	1,218	252	126	44	33	699	50
Southwest	2,344	817	128	64	22	17	453	15
South	2,687	936	373	186.5	65	49	693	46

Source: *Estimated from Mr. Zhao's data (Ministry of Transportation).*

Two assumptions were made in estimating the total annual costs of roads per kilometer. First, we assume that high quality roads lasts for 16 years and low quality for 10 years.[23] . Second, we assume the maintenance cost is equivalent to the annualized capital cost. For example, the unit cost of construction of one kilometer of high quality roads is 5.6 million yuan. Since the maintenance and service cost is the same as the annualized capital cost, the total cost for one kilometer of high quality roads is 11.2 million.

Table 15 indicates that every kilometer of high quality roads would increase urban GDP by 1.73 million yuan. This effect is assumed to begin in fifth year when the investment was made. Once this effect takes place, it will last for 16 years. Using the 5% discount rate, the total present value amounts to 16.2 million yuan. This can now be expressed on a unit cost basis, or as a marginal benefit/cost ratio. For every yuan invested in high quality roads,1.45 yuan (16.2/11.2) of urban GDP would be added as shown in Table 18.[24] For low quality roads, we assume the once the investment is made, it will begin to have impact in the third year and it will last for 10 years. Similar calculations are made for the poverty reduction effects. Table 16 shows that each additional kilometer of high quality roads lifts 5.53 urban poor above the poverty line, and when expressed on a unit cost basis, Table 19 shows that for every 10,000 yuan, the poverty reduction effect in urban area is 0.08 (or 5.53/11.2*16//100). As both assumptions are very conservative, our estimated returns to road investments are almost certainly lower bounds.

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[23] The expressways and class 1 roads have 20 years of lifespan while class 2 has 15 years. We use length of these different types of roads as weights in calculating the weighted average of lifespan for high quality roads. For low quality roads, the lifespan is 10 years.

[24] Alston *et al.* (2000) developed an approach to convert a benefit-cost ratio to an internal rate of return or vice versa. It is assumed that the benefit stream is a perpetual annual flow, B, per year while the cost is a one time spending, C at time t. Thus the net present value of B is:

$\mathrm{PV}(B)_t = \sum_{j=0}^{\infty} B_{t+j} / (1+i)^j \approx \sum_{j=0}^{\infty} B/(1+i)^j = B/i$ and the net present value of cost is

$\mathrm{PV}(C)_t \approx C_t = \mathrm{PV}(B)_t (\text{at IRR}) \approx \text{B/IRR}$. Therefore, the benefit-cost ratio is:

$\mathrm{BC_t = PV(B)_t \div PV(C)_t \approx (B/i) \div (B/IRR) = IRR/i}$.

Where *i* is the discount rate, IRR is the internal rate of return, and BC is the benefit cost ratio. Hence we can also approximate the IRR as *BC*i*. If BC>1, then IRR is always greater than *i*.

Table 18: Returns in Total GDP to Road Investment

	High Quality	Low Quality
	(yuan per yuan)	
Returns in Total GDP		
Average	1.45	6.37
Northeast	1.27	5.25
North	1.39	8.89
Northwest	1.06	2.09
Central	1.60	9.57
Southeast	1.50	27.09
Southwest	1.78	10.86
South	1.21	11.02
Returns in Urban GDP		
Average	0.92	3.75
Northeast	0.89	3.40
North	0.91	5.38
Northwest	0.64	1.17
Central	0.84	4.62
Southeast	1.00	16.65
Southwest	0.98	5.50
South	0.83	6.96
Returns in Agricultural GDP		
Average	N.S	1.57
Northeast	N.S	0.94
North	N.S	1.83
Northwest	N.S	0.65
Central	N.S	3.64
Southeast	N.S	4.15
Southwest	N.S	4.70
South	N.S	2.58
Returns in Rural Nonfarm GDP		
Average	0.61	5.68
Northeast	0.48	3.47
North	0.59	6.89
Northwest	0.42	1.73
Central	0.80	11.60
Southeast	0.70	21.83
Southwest	0.50	7.84
South	0.47	9.04

Note: Except returns in agricultural GDP to high quality roads, all estimates are statistically significant at the 10% level. The returns are calculated for 2001 by using 2001 data.

Table 19: Returns in Poverty Reduction to Road Investment

	High Quality	Low Quality
	(number per 10,000 yuan)	
Returns in Urban Poverty Reduction		
Average	0.08	0.27
Northeast	0.18	0.59
North	0.05	0.24
Northwest	0.24	0.37
Central	0.09	0.41
Southeast	0.02	0.29
Southwest	0.17	0.79
South	0.01	0.06
Returns in Rural Poverty Reduction, Official Data		
Average	0.13	1.61
Northeast	0.06	0.71
North	0.11	1.93
Northwest	0.46	2.57
Central	0.07	1.27
Southeast	0.01	0.63
Southwest	0.65	11.27
South	0.03	0.89
Returns in Rural Poverty Reduction, Xian and Sheng data		
Average	0.50	8.20
Northeast	0.23	2.89
North	0.83	17.05
Northwest	0.94	6.71
Central	0.56	14.27
Southeast	0.16	9.28
Southwest	1.62	43.86
South	0.12	4.28

Note: All estimates are statistically significant at the 10% level. The returns are calculated for 2001 by using 2001 data.

Total GDP

For the country as a whole, the marginal benefit-cost ratio for high quality roads was 1.45 in 2001. The southwest region has the highest return, followed by the central region, which are two relatively poor regions in China. The lowest returns occurred in the northwest and the south. The returns to low quality roads are much higher. The average return to low quality roads was 6.37 yuan for each yuan invested in China in 2001. This is more than four times larger than the return to investment in high quality roads. The southeast region has the highest return, followed by the south and southwest, whereas the lowest return occurs in the northwest.

Urban GDP

One surprising finding is the low urban GDP return of high quality roads. For every yuan invested, high quality roads yield 0.92 yuan of urban GDP for China as a whole. The benefit-cost ratio is about one. This implies that building more high quality roads will not result in economically meaningful returns to urban GDP. But for lower quality roads, the average return is 3.75 yuan per yuan invested, more than four times the effects of high quality roads. The southeast region has by far the highest return.

Agricultural GDP

High quality roads do not have a statistically significant impact on agricultural GDP. For low quality roads, every yuan invested yields 1.57 yuan worth of agricultural GDP. Again, the patterns among regions are similar to those estimated for total GDP and urban GDP. The southeast, southwest, and central regions have higher returns than the national average, while the northwest, northeast, and north have lower returns than the national average.

Rural Nonfarm GDP

For every yuan invested in high quality roads, the average return in rural nonfarm GDP in China is 0.61yuan. In contrast, low quality roads yield 5.68 yuan worth of nonfarm GDP for every yuan invested in roads. Moreover, the marginal returns from high quality roads differ little across regions, whereas large regional variations exist for low quality roads. The highest return occurs in the southeast, while the lowest arises in the northwest.

Urban Poverty

For every 10,000 yuan invested in high quality roads, 0.08 urban poor would be lifted above the poverty line. Low quality roads are more beneficial to the urban poor, raising 0.27 urban poor above the poverty line for each 10,000 yuan invested in 2001.

This larger impact arises primarily because low quality roads, being mostly rural, induce a larger increase in national food production and hence reduce food price more. Roads have a bigger impact on urban poverty in the less-developed western regions (both the southwest and northwest) and the northeast region.

Rural Poverty

For high quality roads, every 10,000 yuan invested raises 0.13 rural poor above the official poverty line. Again, low quality roads are much more beneficial, raising 1.61 rural people out of poverty for every 10,000 yuan invested. For both high quality and low quality roads, the poverty impacts are largest in the southwest and northwest regions when the official poverty line is used. However, when Xian and Sheng's poverty line is used, the number of rural poor helped is much larger: 0.50 and 8.21 rural poor are raised above the poverty line for each 10,000 yuan invested in high and low quality roads, respectively. These effects are about 4 times larger than those estimated with the official poverty line. For high quality roads, the largest impact is found in the southwest, followed by the northwest, and the north. For low quality roads, the largest impact also occurs in the southwest followed by the north, and then the central and southeast regions.

VII. CONCLUSIONS

China has been very successful in achieving rapid economic growth and poverty reduction in recent decades. Driving this success was a series of policy and institutional reforms and massive public investments in roads and other key infrastructures. The primary objective of this report has been to analyze the contribution of road investments to China's successful transformation.

Using provincial-level data for 1982-1999, an analytical framework was developed that extends earlier work by Fan, et al by differentiating amongst different quality roads, and by disaggregating the measured effects of road investments by rural and urban areas. The results show that road development, together with agricultural R&D, irrigation, education, electricity, and telecommunications, made significant contributions to economic growth and poverty reduction. But variations in the marginal impact of roads on growth and poverty reduction were large, both between different types of roads and between regions.

The most significant finding of this study is that low quality (mostly rural) roads have benefit/cost ratios for national GDP that are about more than four times larger than the benefit/cost ratios for high quality roads. Even in terms of urban GDP, the benefit/cost ratios for low quality roads are much greater than those for high quality roads. As far as agricultural GDP is concerned, high quality roads do not have a statistically significant impact while low quality roads are not only significant but generate 1.57 yuan of agricultural GDP for every yuan invested. Investment in low quality roads also generates high returns in rural nonfarm GDP. Every yuan invested in low quality roads yields more than 5 yuan of rural nonfarm GDP.

In terms of poverty reduction, low quality roads raise far more rural and urban poor above the poverty line per yuan invested than do high quality roads.

Another significant finding of the study is the trade-off between growth and poverty reduction when investing in different parts of China. Road investments yield their highest economic returns in the eastern and central regions of China while their contributions to poverty reduction are greatest in western China (especially the southwest region). This implies different regional priorities depending on whether economic growth or poverty reductions are the most important goals for the country.

The results of this study have important implications for future road project investments. China has invested heavily in the past in building expressways and inter-city highways. These investments have been a major force in China's economic transformation during the 1980s and 1990s. However, as more and more investments are being poured into these projects, the marginal returns are beginning to decline, although they are still positive and economically sound. At the same time, low quality roads or rural roads have received less attention than high quality roads and as a result their marginal returns are much larger today than the returns to high quality roads. Low quality roads also raise more poor people out of poverty per yuan invested than high quality roads, making them a win-win strategy for growth and poverty alleviation. The government should now consider giving greater priority to low quality and rural roads in its future investment strategy.

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