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THE IMPORTANCE OF PUBLIC INVESTMENT FOR REDUCING RURAL POVERTY IN MIDDLE-INCOME COUNTRIES: THE CASE OF THAILAND

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ABSTRACT

This study estimates the impacts of different types of government expenditure on agricultural growth and rural poverty in Thailand. The results show that, despite Thailand's middle-income status, public investments in agricultural R&D, irrigation, rural education, and infrastructure (including roads and electricity), still have positive marginal impacts on agricultural productivity growth and rural poverty reduction.

Additional government spending on agricultural research and development improves agricultural productivity the most and has the second largest impact on rural poverty reduction. Investments in rural electrification reduce poverty the most and have the second largest growth impact. These two investments dominate all others and are win-win for growth and poverty reduction. Road expenditure has the third largest impact on rural poverty reduction, but only a modest and statistically insignificant impact on agricultural productivity. Government spending on rural education has only the fourth largest impact on poverty, but a significant economic impact through improved agricultural productivity. Irrigation investment has the smallest impact on both rural poverty reduction and productivity growth in agriculture. Additional investments in the Northeast region contribute more to reducing poverty than investments in other regions. This is because most of the poor are now concentrated in the Northeast and it has suffered from under investment in the past. The poverty reducing impacts of infrastructure investments, such as electricity and roads, are particularly high in this region. The growth impacts of many investments are also greatest in the Northeast than in other regions, hence there is no evident tradeoff between investments for growth and investments for poverty reduction.

Thailand is a middle-income country and it is insightful to compare these results with similar studies undertaken in low-income countries like India, China, and Uganda. Some of the results are similar, for example, the high returns to public investments in agricultural research and some kinds of rural infrastructure arise in most countries because of the inherent market failures associated with these types of public goods. But others results are different. For example, the returns to public investment in education in

Thailand are quite low, partly because of increasing private investment but also the inappropriate composition of much public spending on education. Within infrastructure, results from low-income countries often show higher returns to road investments than telecommunications and electricity. But in the case of Thailand, it is investment in electricity that shows the highest return. Thailand has invested heavily in rural roads and a dense road network has already been built, suggesting that additional investment may yield diminishing returns. Also, there has been significant investment by the private sector in rural telecommunication, leading to a much-reduced role for the public sector. This situation differs from many low-income countries, especially in Africa, where the private sector is still embryonic and the public sector must play a dominant investment role for the foreseeable future.

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I. INTRODUCTION

Thailand has achieved one of the highest economic growth rates in the world, averaging 7.5% per annum over 1977-1995. As a result, the country had rapidly transformed into a newly industrialized country by the mid-1990s. By 1995, per capita GNP had reached 7,540 US dollars measured in purchasing power parity (World Development Report, 1997). This rapid growth led to a large reduction in poverty. The percentage of the population falling below the poverty line declined from 45.2 percent in 1986 to 12.7 percent in 1996. Contributing to this rapid economic growth and subsequent poverty reduction were government pro-trade/business policies, improved human capital, and infrastructure development.

However, Thailand faces new challenges today. The financial crisis that began in 1997 triggered the depreciation of the Thai Baht and led to some reversal in economic growth. The economy shrunk by 1.8% in 1997 and by a further 10.8 percent in 1998. Although national GDP has now recovered somewhat, the average growth rate after the crisis has been only half of the growth rate achieved during the pre-crisis period. The incidence of poverty has also begun to rise, from 12.7 percent in 1996 to 15.6 percent in 2000. Thus, an important challenge for Thailand today is bringing its economic growth rate back up to the sort of levels achieved before the financial crisis of 1997. Another challenge is to implement policies that can lead to a more equal distribution of the gains

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from economic growth. Over the past three decades, the Gini coefficient has remained very high. In fact, it has increased marginally from 0.49 in 1988 to 0.51 in 1996, making Thailand one of the more unequal societies in the world. Finally, as a result of the government's urban-biased policy, the income and productivity gaps between rural and urban areas have enlarged over time. Productivity in the non-agricultural sectors is now 8 to 10 times larger than in agriculture. As a result, the poor in Thailand are increasingly concentrated in rural areas. In 2000, the incidence of rural poverty was 20.1 percent while the incidence of urban poverty was only 5.8 percent. Almost 90 percent of Thailand's poor reside in rural areas.

Despite Thailand's growing affluence and rapid growth in private investment, it is hypothesized that public investment still has a crucial role to play in providing many complementary public goods needed for economic growth and poverty reduction. The overall objective of this study is to measure the impact of public investment on poverty reduction in Thailand. Since poverty in Thailand is mainly a rural phenomenon, we will focus our study on rural poverty. Different types of public investment may have different impacts on economic growth and poverty reduction. Therefore, investments are disaggregated into different types: roads, electricity, education, etc. Although Thailand only has 514,000 square kilometers of land, the country is long, narrow and agro climatically and economically diverse, so it is useful to distinguish between four regions in our analysis: the Northeastern, Northern, Central Plain, and Southern regions. The Appendix to this paper highlights many of the important differences between these regions

II. GROWTH, EMPLOYMENT AND POVERTY IN RURAL THAILAND

For the past several decades, Thailand has experienced rapid economic growth that has transformed the country from a predominantly agrarian society to a newly industrialized economy, much like Singapore, South Korea, Taiwan and Hong Kong. In the early 1960s, more than 80 percent of the population was engaged in agricultural activities with rice as a major crop both for domestic consumption and export. Since then the Thai economy has achieved one of the highest long-term growth rates among all countries. GDP grew by 7.9 percent per year in the 1960s, slowing only slightly to 6.9 percent per year during the 1970s. In the first half of the 1980s, due to the energy crisis, the growth rate averaged 5.5 percent per year. In the second half of the decade, the government introduced several policy reforms to further liberalize the economy. These policies included: correcting fiscal imbalances, realigning the exchange rate, promoting incentives for export production, and improving the environment for private investment. These reforms enabled Thailand to benefit greatly from favorable external conditions, and thus resulted in a remarkable economic growth rate of 11 percent per year from 1986 to 1990. From 1991 to 1995, the economy continued to expand at a still remarkable rate of 8.5 percent per annum.

The annual growth rate of agricultural GDP was 5.5 percent in the 1960s but declined to 4.3 percent in the 1970s. During the 1980s and 1990s, the growth rate of the agricultural sector further declined to less than 4 percent per year. These growth rates are among the highest in the world for agriculture but they are much lower than the growth rates achieved in most non-agricultural sectors in Thailand. Consequently, agricultural GDP as a share of total GDP declined rapidly. In the 1960s, the share of the agricultural sector in GDP was 39.8 percent, compared to 60.2 percent for the industrial and service sectors. The share of agriculture decreased to 28.3 percent in the 1970s, to 18.7 and 15.2 percent during the first and second half of the 1980s, respectively, and reached 10.3 percent in 1995. Nevertheless, some 55 percent of the work force is still engaged in farm or nonfarm activities in rural areas. Therefore, this sector still plays a large role in providing income and employment to a majority of the Thai population.

Rural nonfarm employment has increased tremendously in Thailand over the past several decades. Today, more than one third of rural labor is engaged in rural nonfarm activities compared to only 13 percent in 1977. It is estimated that more than 60 percent of farmers' income is derived from nonfarm activities. But there is considerable regional variation. In the Central region, almost 60 percent of rural employment is in the rural nonfarm sector, but in the Northeast and North regions, the percentages are only 22 and 32 percent, respectively (Appendix Table A4).

Rapid economic growth has led to a sharp increase in per capita income. Development indicators such as infant mortality, malnutrition, and life expectancy have improved tremendously and have approached or even surpassed world averages. For example, the infant mortality in 2000 was 28 percent in Thailand, while the rate for Asia and the Pacific Region as a whole was 35 percent. Almost 90 percent of Thai residents have access to an improved water source, compared to an average of 75 percent for East Asia and the Pacific Region. The illiteracy rate was only 5 percent in Thailand, compared with 14 percent for the whole East Asia and Pacific region (World Development Report, 2001).

Poverty incidence, measured as the percentage of the population living below the poverty line, fell dramatically. In 1962, 57 percent of the total population lived in poverty. This ratio declined to 38.5 percent in 1976, 31.4 percent in 1990, and 12.7 percent in 1996. There is clearly a strong positive relation between overall economic growth and poverty reduction. However, the reduction in poverty has not been uniform across regions and between rural and urban areas. By 1996, the poverty rate was very low in the central region (only 4.4 percent). But more than one-fifth of the population in the Northeast remained poor. In all regions, the incidence of poverty was much higher in rural villages than in urban areas, defined as areas under the jurisdiction of municipality and sanitary district authorities. For the whole kingdom, the urban poverty rate was less than 5 percent in 1996, but the rural poverty rate was more than 16 percent (Table 1).

Moreover, the recent financial crisis increased rural poverty disproportionately more than urban poverty. Today, 88 percent of total poor reside in rural areas.

Table 1: Growth and Poverty In Thailand, 1975-2000

	GDP	AgGDP	Urban Poverty	Rural Poverty
	1988 Bn Baht		*%*	
1975	621	154		
1976	679	162	22.45	44.48
1977	731	163		
1978	816	184		
1979	872	181		
1980	914	185		
1981	968	194	18.25	39.11
1982	1,020	199		
1983	1,076	208		
1984	1,138	218		
1985	1,191	227		
1986	1,257	228	22.47	53.25
1987	1,377	228		
1988	1,560	252	19.29	42.65
1989	1,750	277		
1990	1,945	264	16.97	36.76
1991	2,112	283		
1992	2,283	296	10.02	32.13
1993	2,474	292		
1994	2,695	308	8.27	23.50
1995	2,946	319		
1996	3,120	331	4.96	16.12
1997	3,075	329		
1998	2,743	319	4.72	15.97
1999	2,859	327	5.65	19.89
2000	2,985	298	5.81	20.12

Source: GDP and Agricultural GDP are from National Economic and Social Development Board (NESDB). Poverty data are from TDRI.

III. DEVELOPMENT OF INFRASTRUCTURE, EDUCATION, AND R&D IN RURAL THAILAND

This section reviews the development of infrastructure, agricultural research and development (R&D) and education as well as government spending on these items. Since adopting a modern economic development strategy in the late 1960s, Thailand has continued investing in building infrastructures up until the present time. Such investments are a major source of long-term economic growth and poverty reduction. They have contributed not only to growth in agricultural production, providing an adequate food supply for an increasingly larger and richer population, but also have propelled development of the rural nonfarm sector. The latter has become crucial for further poverty reduction in rural areas of Thailand.

Infrastructure

For the past several decades, infrastructure has improved gradually (Table 2). Total length of roads increased from 38,244 kilometers in 1977 to 52,960 kilometers in 2000, equivalent to an annual growth rate of 1.4 percent. Rural roads experienced even faster growth, from 6,258 km in 1977 to 67,138 km in 2000, a ten-fold increase over two decades. Rural road density has increased from 12 km to 124 kilometers per 1000 km^2. In terms of regional distribution, the Northern region has the lowest density with 81 kilometers per 1000 km^2, while the Southern region has the highest density with 158 kilometer per 1000 km^2 (Appendix Table A10).

The number of rural telephone lines increased by 23 percent per annum between 1977 and 2000. In 1977, the number of telephone lines per 1000 rural residents was only 0.45, but it increased to almost 37 in 2000. Difference across regions is large. The number of telephone lines per thousand rural residents in the Northeast (13) is only 15 percent of the Central region (89).

Rural electricity consumption also shows high growth for the past several decades, although the rate was slower than for rural roads and telephone lines. In 1977, rural residents consumed only 29 kw of electricity on average, but this had increased to

772 kw in 2000. However, in the Central region the per capita consumption is 1,637 kw, which is more than 5 times that of the Northeast region (312 kw).

Table 2: Development of Infrastructure, Education and Irrigation in Thailand, 1970-2000

	Roads	Rural Roads	Rural Phone Lines	Rural Electricity Consumption	Rural Average Years of Schooling	Rural Literacy Rate	Irrigated Areas
	km	*km*	*1000s*	*billion kw*		*%*	*million ha*
1970							1.69
1971							1.73
1972							1.81
1973							1.96
1974							2.01
1975							2.06
1976							2.40
1977	38,244	6,258	14.42	0.94	3.7	77.5	2.51
1978	41,841	6,755	19.95	1.22	3.8	79.3	2.65
1979	43,301	7,210	22.65	1.54	3.9	80.6	2.82
1980	43,839	7,804	24.61	1.88	4.0	81.4	2.94
1981	43,916	8,576	27.14	2.26	4.1	82.1	3.11
1982	43,956	8,893	31.10	2.74	4.2	82.7	3.25
1983	44,265	9,354	37.21	3.38	4.3	83.2	3.40
1984	44,534	9,848	46.21	3.96	4.3	83.7	3.60
1985	45,337	10,077	58.75	4.44	4.4	84.2	3.77
1986	47,201	10,496	75.35	5.18	4.5	84.6	3.92
1987	47,811	10,939	96.27	6.06	4.6	85.1	4.01
1988	47,868	11,492	121.57	7.08	4.7	85.6	4.13
1989	49,282	12,500	151.41	8.55	4.8	86.0	4.16
1990	49,805	14,467	186.43	10.32	4.9	86.5	4.24
1991	49,961	17,738	228.09	12.40	5.0	87.0	4.36
1992	54,388	21,508	278.87	14.34	5.1	87.5	4.41
1993	56,902	26,138	342.28	16.65	5.2	87.9	4.54
1994	51,126	30,219	422.71	19.53	5.3	88.4	4.60
1995	51,242	36,763	525.25	22.88	5.4	88.9	4.65
1996	51,312	45,057	655.46	25.71	5.5	89.4	4.72
1997	51,477	54,900	819.15	28.21	5.6	89.9	4.76
1998	51,775	61,776	1022.37	28.34	5.7	90.3	4.80
1999	52,255	64,748	1271.69	29.52	5.8	90.8	4.96
2000	52,960	67,138	1574.95	32.96	5.9	91.3	5.01

In terms of government spending on infrastructure, roads have always been the top priority, accounting for 75 percent of total government expenditures on infrastructure in 2000 (Table 3). Electricity is the second most important expenditure but its share has declined over time to less than a quarter of the total government expenditure on infrastructure in 2000. The government spends very little on telecommunication. Most of the investment and management in this area is undertaken by the private sector.

Table 3: Government Spending on Infrastructure, Education and R&D in Thailand, 1970-2000

	Roads	Telecom	Power	R&D	Education	Irrigation
			1988 Million Baht			
1970	16584					4347
1971	10707					4076
1972	11068					2695
1973	7895					1188
1974	3835					1079
1975	2742					1465
1976	4145					1602
1977	8215			756		1467
1978	7397			714		1493
1979	4479			642		1250
1980	3466			766	31113	1114
1981	5029			859	35550	715
1982	4009			930	39207	1004
1983	3288		3950	995	43412	1045
1984	3449		7016	1016	44552	1494
1985	5012		5656	1031	45430	1794
1986	11940	52	6961	1052	43783	1736
1987	10968	51	4237	1045	43634	1621
1988	12033	69	6801	1102	43740	1470
1989	13660	57	7998	1134	44628	1948
1990	19531	52	9294	1272	53422	2117
1991	22490	61	10223	1511	63124	2400
1992	19058	221	6758	1633	69071	2677
1993	28441	140	5942	1966	84333	2028
1994	31607	199	6300	2100	90458	1904
1995	38800	189	3902	2101	95083	2431
1996	54995	244	3815	2130	113075	2737
1997	72892	309	10127	1889	138994	3406
1998	61248	393	9757	1403	127861	4708
1999	38307	243	10885	1316	128429	4409
2000	31682	176	10232	1452	134388	

Source: The Bureau of the Budget, Office of the Prime Minister.

Thailand has a very centralized system of finance and management of public infrastructure. Local governments and communities play a negligible role in financing and operating public services, and even this small involvement is mostly subsidized by the central government. However, the enactment of the Fiscal Decentralization Act in 1999 is going to bring a very significant change to the way infrastructure is built, maintained and financed. The transition to the decentralized fiscal system is scheduled to be completed by 2004.

Education

Thailand has made great achievements in rural education. The literacy rate of the rural population has increased from 77.5 percent in 1977 to 91 percent in 2000 (Table 2). This rate is one of the highest among developing countries. The average years of schooling for rural residents has shown an even greater improvement; from 3.7 in 1977 to 5.9 years in 2000, more than a 50 percent increase in two decades. Regional differences in both literacy rate and average years of schooling are small (Appendix Table A6). It is the Northern region where both literacy rate and average years of schooling are the lowest. Not surprisingly, the Central region has the highest average years of schooling, but surprisingly, the Northeast had the highest literacy rate.

As Thailand develops, the country faces new challenges in its education policy. In the 1970s and 1980s, Thailand succeeded in providing all children with access to good quality primary education. However, expansion of education at lower and upper secondary levels, and in post-secondary education proceeded more slowly. As the 1990s approached, Thailand's enrollment ratios at these levels lagged far behind those of competitive neighbors. While 80 percent of the Thai workforce has completed the primary level, less than 40 percent has completed secondary school.

Serious issues of curriculum relevance and quality have also received attention. At the tertiary level, science and engineering programs were weak, and graduates failed to meet labor market standards. This was partly due to the centralization of education planning and, more importantly, to the separation of education planning from market demands. As a result, a productivity gap emerged between Thailand and other newly industrializing nations. Secondary schools were dominated by remote learning and narrowly focused vocational courses and a concern was that generations of Thai students would find it difficult to adapt to rapidly changing occupations and jobs (World Bank, 2000).

In the early 1990s, the government began to address issues of access and quality in secondary and higher education. As a consequence, enrollment rates began to rise. With support from the World Bank, programs were launched to improve the quality of science, mathematics and foreign language instruction in teacher education colleges and secondary schools.

The sources of education expenditures are classified into 5 categories: central government budget, local funding, non-governmental budget, foreign loans and technical assistance, and provision of education by the private sector.[1] Central government funding has been the main source. The education sector has received the largest share of total public expenditure among all sectors since 1991 (Table 3). The Government budget for education was highest in 1997, amounting to 214,297 million Baht, or 4.1 percent of Gross Domestic Product (GDP). In 1998, due to the impact of the financial crisis, the total budget for education was reduced to 201,707 million Baht or about 3.5 percent of GDP. However, the share of education in total public expenditure actually increased to 25.2 percent, which was larger than ever before. Similarly, the budget appropriation for education approved by the Parliament for the fiscal year 1999 was 209,926 million Baht or 25.4 percent of the total budget. This reflected the Government's top priority to use education for economic rehabilitation.

Nearly half of educational funding in 1998 was allocated to pre-primary and primary education, while secondary level education accounted for about one quarter. The rest was accounted for by higher or informal education. With respect to local funding, the major source of educational expenditure comes from central government subsidies, which

[1] This part is heavily drawn from *Education in Thailand, 1998*, The Government of Thailand.

have increased from 2,693 million Baht in 1994 to 4,153 million Baht in 1997. The largest proportion of the central government subsidies was allocated towards primary education.

Agricultural Research[2]

Research capacity and scientific manpower in Thailand are relatively low compared to other dynamic Asian economies such as Korea, Taiwan, and Singapore (Fuglie, 2000). However, since the late 1970s the Thai Government has recognized that rapid economic growth could not be sustained without increased investment in science and technology aimed at raising productivity. In 1979, it established the Ministry of Science, Technology, and Energy (MSTE) to coordinate and implement science policy. The fifth national development plan of 1982-86 emphasized investment in science infrastructure and manpower. Subsequent development plans established a goal of increasing the level of science and technology investment from the 1998 level of 0.2 to 0.75 percent of GDP (Ministry of Science, Technology, and Energy, 1997). Government support for agricultural research precedes recent emphasis given to science and technology investment, and agriculture still accounts for most of the public expenditures for research.

Agricultural research in Thailand dates back to the establishment of the Rangsit Agricultural Experiment Station near Bangkok in 1916. At present, agricultural research is supported by a number of government ministries and agencies. The Ministry of Agriculture and Agricultural Cooperatives is the largest agency of agricultural research, with an annual research budget of $80-$90 million for research on crops, livestock, forestry, and fisheries (Fuglie, 2000). Public universities also have significant programs in agricultural research, funded through the Ministry of University Affairs, and through grants from the Thailand Research Fund and the National Research Council. A $10-million annual biotechnology research program, most of which is devoted to agriculture, is funded through the National Science and Technology Development Agency, an

[2] This section is heavily drawn from Fuglie, 2000.

autonomous public corporation under the Ministry of Science, Technology, and Energy. The 1995 pattern of public research expenditures indicates that priority is given to agriculture. Of total government research expenditures of $207 million (Ministry of Science, Technology, and Energy, 1997), an estimated $127 million was allocated for agriculture (Fuglie, 2000). Moreover, the share devoted to agriculture appears to have increased over the 1980s, from 40 percent of the total in 1987 to 60 percent in 1995. Within agriculture, the largest share of the research budget is for crop research with relatively small budgets for livestock, forestry, and fisheries. In addition to investing in public research, the Thai Government has also encouraged private investment in research, although these efforts appear to have had only limited success (Thailand Development Research Institute, 1990). Policies to support private research have included tax incentives and subsidized loans, but the overall demand for these subsidies appears to be small. However, public encouragement of the private seed industry does appear to be an important factor in stimulating private plant breeding in Thailand (Fuglie, 2000).

Irrigation

Irrigation has a long history in Thailand as the country depends on it for agriculture, both for subsistence and commercial markets. Although the country comprises 25 large river basins, water shortages during the dry season have often limited farmers' capacity to intensify and/or diversify their farming system and assist the national economy by producing surplus grain for export (Shaivakotig, 1999). Therefore, development of irrigation for agriculture has been crucial in several regions of the country.

As far back as 700 years ago there were many small-scale irrigation systems operated and maintained by farmers. As demands for water increased in the modern era, the Canal Department, later renamed as the Royal Irrigation Department (RID), was established in 1903. In its early days, the primary objective of RID was to design large- and medium-scale irrigation systems to increase productivity of rice in the Central Plain region (Shaivakotig, 1999).

More recently, Thailand's experience with irrigation development has been mixed. The 1970s saw the largest increase in irrigated area, almost doubling from 1.7 million hectares in 1970 to 3.1 million hectares in 1980 (Table 2). The irrigated area continued to expand in the 1980s, although at a more modest rate of 1.3 million hectares for the whole decade. Since the 1990s, the increase has been marginal. The percentage of irrigated area in relation to total arable area increased from 15 percent in 1970 to 30 percent in 2000.

Most of Thailand's irrigated land is concentrated in the Central Plain. This region has with almost half of the national total, although arable land in the region accounts for only a quarter of total arable land. Therefore, more than 60 percent of the arable land in the Central Plain is irrigated, compared with 13percent in the Northeast, 34 percent in the North, and 22 percent in the South.

IV. CONCEPTUAL FRAMEWORK AND MODEL

Public investment affects rural poverty through many channels.[3] It increases farmers' income directly by increasing agricultural productivity, which in turn reduces rural poverty. Indirect impacts come from higher agricultural wages and improved nonfarm employment opportunities induced by growth in agricultural productivity. Increased agricultural output due to public investment often yields lower food prices, again helping the poor indirectly because they are often net buyers of food grains. In addition to its productivity impact, public investment directly promotes rural wages, nonfarm employment and migration, thereby reducing rural poverty. For example, improved road access helps farmers set up small rural nonfarm businesses such as food processing and marketing enterprises, electronic repair shops, transportation and trade, and restaurant services.

Public investments in rural sectors not only contribute to growth, employment, and wages in rural areas, but also help the development of the national economy by providing labor, human and physical capital, cheaper food, and markets for urban industrial and service development. Growth in the national economy reduces poverty in both rural and urban sectors. Understanding these different effects provides useful policy insights to improve the effectiveness of government poverty reduction strategies. In particular, it provides information on how public investment can be used to strengthen weak links between poverty reduction channels and, thereby, increase efficiency in refocusing public resources on poverty reduction. More efficient investment targeting has become increasingly important in an era of macroeconomic reforms in which governments are under pressure to reduce budgets.

Most studies of the determinants of poverty reduction focus on the roles of economic growth and income distribution (for example, Datt and Ravallion (1997) on India, and Warr (2001) on Thailand). However, few studies have linked poverty reduction to the driving forces behind economic growth and income distribution. For

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[3] See Figure 1 p. 51 and Fan, Hazell and Thorat (1999).

example, it is growth in employment, wages, and other sources of income derived from economic growth that reduces poverty. The ratio of food prices to nonfood prices is also important to the poor since they often spend more than half of their income on food consumption.

The determination of rural poverty is even more complex. Rural residents draw their income from multiple sources. Farm activities are still major sources of income for many rural residents, but increasingly nonfarm activities such as rural industry and services have also become important. Another important income source is seasonal migration and employment in the urban sector. Building on earlier work by the senior author on India (Fan, Hazell and Thorat, 1999), we model the rural poverty determination as follows:

(1) $P = f(LP, AWAGE, NAWAGE, NAGEMPLY, URBANP, TT)$

Equation (1) models the determinants of rural poverty (*P*), which is defined as the percentage of the rural population living below the poverty line. They include agricultural labor productivity (*LP*), nonagricultural employment (*NAGEMPLY*), agricultural wages (*AWAGE*) and rural nonfarm wages (*NAWAGE*), the ratio of urban to total population (*URBANP*) (a proxy for rural-urban migration), and food price relative to nonfood prices or terms of trade (*TT*).

Agricultural labor productivity is included as a variable in the poverty equation because labor productivity is a good proxy for agricultural income per worker, which still accounts for a substantial share of the total income of rural households, especially in the less developed regions such as Northeast and North. Nonfarm employment income is the second most important source of income after agricultural production for rural residents. We use agricultural wages, rural nonagricultural wages, and the percentage of nonfarm workers in total rural employment as proxies for nonfarm income. Through this approach, we can distinguish the different impacts of changes in wages and the percentage of workers in the nonfarm sector on rural poverty reduction. These different impacts may have important policy implications for further poverty alleviation.

The urbanization variable measures the impact of rural-to-urban migration on rural poverty. Better economic and employment opportunities in urban areas lead to rural to urban migration with people looking for better opportunities in cities. The terms-of-trade variable measures the impact of changes in agricultural prices relative to nonagricultural prices on rural poverty. Farmers may be affected by changes in food prices in both the short and long run. In the short run, the poor benefit from higher prices if they are net sellers of food products, but may lose if they are net buyers. In the long run, increased agricultural prices may also induce government and farmers to invest more in agricultural production, shifting the supply curve rightward.

Equation (2) models the agricultural labor productivity function. The dependent variable is gross value of agricultural production per agricultural worker in the agricultural sector (*LP*). The independent variables are a set of technology, infrastructure, and education variables that are used to capture their impact on labor productivity growth. (Does not include crop area and fertilizer. Are these captured in the time trend variable?) These variables include agricultural research stock variables constructed from past government expenditures on agricultural research and development; an irrigation stock variable (*IRRIST*); average years of schooling of the rural population (*RSCHY*); length of rural roads per agricultural worker (*RROADS*); number of rural telephone sets per agricultural worker (*RPHONE*); and rural electricity consumption per agricultural worker *(RELECT*). [4]

$$(2) \qquad LP = f(RDS, IRRIST, RSCHY, RROADS, RPHONE, RELECT)$$

Equations (3) and (4) are wage determination functions. Agricultural and rural nonfarm wages are determined by development in infrastructure, improved education and growth in agricultural productivity, and GDP per capita in the urban sector (*UGDPP*). The impact of improved infrastructure on wages is often ignored in specifying wage determination equations. Ignoring this effect is likely to lead to underestimation of the

[4] The other variables such as land/labor ratios, private capital per labor, and fertilizer use per labor should also be included as in a typical labor productivity function. But these variables are highly correlated with regional dummies and time trend, leading to insignificant coefficients for these variables.

impact of government spending on poverty, since wage increases induced by improved rural infrastructure can be potentially large, benefiting workers in both agricultural and nonagricultural sectors. Growth in agricultural productivity is included to model the linkage between growth in the agricultural sector and rural wages[5]. GDP per capita in the urban sector is used to control the effects of growth in the urban sector on changes in both agricultural and nonagricultural wages.

(3) $AWAGE = f(LP, RROADS, RPHONE, RSCHY, RELECT, UGDPP)$

(4) $RNAWAGE = f(LP, RROADS, RPHONE, RSCHY, RELECT, UGDPP)$

Equations (5) and (6) determine rural nonagricultural employment and urbanization (rural to urban migration). Similar to the wage equations, they are modeled as a function of rural infrastructure and education, growth in agricultural productivity and per capita GDP in the urban sector.

(5) $NAGEMPLY = f(LP, RROADS, RPHONE, RSCHY, RELECT, UGDPP)$

(6) $\mathrm{URBANP} = f(\mathrm{LP}, \mathrm{RROADS}, \mathrm{RPHONE}, \mathrm{RSCHY}, \mathrm{RELECT}, \mathrm{UGDPP})$

Equation (7) determines the terms of trade. Growth in agricultural productivity increases the supply of agricultural products, and therefore reduces agricultural prices. World food price (*WFP*) is used to capture the transmission effect of world food price on domestic food price.

(7) $\mathrm{TT} = f(\mathrm{LP}, \mathrm{WFP})$

The marginal impact of public capital expenditures on poverty can be derived from this system of equation by taking the total derivatives as follows, taking agricultural research and rural education as examples:

(8) $$\begin{aligned} dP/dRDS = {} & (\partial P/\partial LP)(\partial LP/\partial RDS) \\ & +(\partial P/\partial NAGEMPLY)(\partial NAGEMPLY/\partial LP)(\partial LP/\partial RDS) \\ & +(\partial P/\partial AWAGE)(\partial AWAGE/\partial LP)(\partial LP/\partial RDS) \end{aligned}$$

[5] This is part of the so-called "agriculture-nonagriculture growth linkages theory " as modeled by Hazell and Haggblade (1991).

$$+(\partial P/\partial NAWAGE)(\partial NAWAGE/\partial LP)(\partial LP/\partial RDS)$$
$$+(\partial P/\partial URBANP)(\partial URBANP/\partial LP)(\partial LP/\partial RDS)$$
$$+(\partial P/\partial TT)(\partial TT/\partial LP)(\partial LP/\partial RDS);$$

$$(9)\quad dP/dRSCHY = (\partial P/\partial LP)(\partial LP/\partial RSCHY)$$
$$+(\partial P/\partial NAGEMPLY)(\partial NAGEMPLY/\partial LP)(\partial LP/\partial RSCHY)$$
$$+(\partial P/\partial AWAGE)(\partial AWAGE/\partial LP)(\partial LP/\partial RSCHY)$$
$$+(\partial P/\partial NAWAGE)(\partial NAWAGE/\partial LP)(\partial LP/\partial RSCHY)$$
$$+(\partial P/\partial URBANP)(\partial URBANP/\partial LP)(\partial LP/\partial RSCHY)$$
$$+(\partial P/\partial TT)(\partial TT/\partial LP)(\partial LP/\partial RSCHY)$$
$$+(\partial P/\partial NAGEMPLY)(\partial NAGEMPLY/\partial RSCHY)$$
$$+(\partial P/\partial AWAGE)(\partial AWAGE/\partial RSCHY)$$
$$+(\partial P/\partial NAWAGE)(\partial NAWAGE/\partial RSCHY)$$
$$+(\partial P/\partial URBANP)(\partial URBANP/\partial RSCHY)$$

Equation (8) measures the marginal effect on poverty reduction of the research stock variable. It also decomposes the different pathways through which impacts occur (see Fan, Hazell and Thorat (1999) for a more detailed discussion). The first term on the right hand side is the direct poverty impact of growth in agriculture due to agricultural research and extension, while the remaining terms measure the effects of agricultural research and extension through improved nonfarm employment, agricultural wages, rural nonfarm wages, and urbanization due to research-induced production growth in agriculture.

Equation (9) is the marginal poverty reduction effect of improved education. Similar to equation (8), the first six terms on the right hand side are poverty reduction effects of improved education through growth in agricultural production directly and indirectly by improving nonfarm employment opportunities, agricultural and rural nonfarm wages, and changes in agricultural prices. The last four terms capture the impact on poverty reduction by directly improving nonfarm employment, agricultural, rural nonfarm wages, and urbanization due to improved education.

To convert annual government expenditures on public capital into stocks in monetary terms, we use the following procedure:

$$(10) \qquad K_t = I_t + (1-\delta)K_{t-1}.$$

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 (10%). To obtain initial values for the capital stock, we used a similar procedure to Kohli (1982).

$$(11) \qquad K_0 = \frac{I_0}{(\delta + r)}.$$

Equation (11) implies that the initial capital stock in year 0 (K_0) is capital investment in year 0 (I_0) divided by the sum of real interest rate (r) and depreciation rate. In the case of Thailand, we assume a real interest rate of 3%. Sensitivity analyses were conducted to see whether different depreciation rates and real interest rates would affect our final results. We found the impact of different real interest rates to be negligible. But different depreciate rates do express some difference.[6] But the ranking of returns among different types of investment and among regions remains the same.

After we obtained stocks for various types of public investment, we ran the following regressions to determine the relationship between these stocks in monetary terms and physical stocks:

$$(12) \qquad P_{i,t}=f(K_{i,t}, Z_{i,t})$$

where $P_{i,t}$ is physical stock of public investment i in year t , for example road density, years of schooling, rural literacy rate, electricity consumption, or irrigated areas; and $K_{i,t}$ is capital stocks in monetary terms for investment i in year t constructed from equation (10). To control other factors that may be omitted from the equation ($Z_{i,t}$), both year and regional dummies are added during the estimation.

[6] Sensitivity analyses of different interest rates and depreciation rates for roads were conducted for the following scenarios: (a) 3% real interest rate and 10% depreciation rate, (b) 5% real interest rate and 10% depreciate rate, (c) 3% real interest rate and 5% depreciation rate, and (d) 5% real interest rate and 5% depreciation rate. The estimated marginal returns were 0.86, 0.84, 0.61 and 0.63, respectively.

To calculate the marginal return in terms of poverty reduction of different types of government spending such as roads, education, and irrigation, we use derivatives of the following form, using education as an example:

$$(13) \quad dP_t/dK_{e,t} = dP_t/dRSCHY_t * \partial RSCHY_t/\partial K_{e,t}$$

Equation (13) implies that marginal return to capital stock in education ($K_{e,t}$) is the product of marginal return to years of schooling (derived in Equation (9)) and marginal impact of capital stock on the years of schooling.

V. DATA, MODEL ESTIMATION AND RESULTS

Data

Most of the data used in this study come from either various agencies of the Thai government or the Thailand Development Research Institute (TDRI).

Poverty. The poverty variable is measured as the percentage of the rural population living below the poverty line. The percentage is calculated from rural household surveys in various years. For more details on poverty measures, refer to TDRI (2001).

Agricultural labor productivity. Agricultural labor productivity is measured as gross agricultural production value per agricultural worker.

Nonfarm employment. Rural nonfarm employment is measured as the percentage of the rural labor force engaged in nonfarm activities such as manufacturing, construction, trading, and services.

Wages. Agricultural wages are the average daily compensation for agricultural workers. Nonagricultural wages are the average daily compensation for rural nonagricultural workers.

Urbanization. Measured as the percentage of the urban population in the total population.

Terms of trade. The terms of trade is measured as agricultural prices relative to nonagricultural prices (or agricultural GDP deflator divided by non agricultural GDP deflator).

Agricultural research. Agricultural research in Thailand is conducted at the national level. But national research affects production throughout the country through so-called spillover effects. Therefore, we include the same agricultural research stock variable constructed from past expenditures in all regions. When we calculate returns to agricultural research investment, we also add agricultural extension to determine total investment in agricultural R&D.

Infrastructure. Most of the infrastructure and education variables used in the model are defined in physical terms (Table 4) and data for suitable measures are available at the national and regional levels. The greatest difficulties arose in collecting data on government expenditure by type of investment and region, which are needed for calculating the value of the existing stocks of these investments and their unit costs. Like many countries, Thailand compiles data on public spending by different types of investments at the national level, but there is much less data on how these expenditures are allocated to different regions and by rural and urban areas. Therefore, some techniques and assumptions had to be used to make these allocations.

Table 4: Definition of Exogenous and Endogenous Variables in the Model

Exogenous variables	
RDS	Stocks of agricultural R&D
RSCHY	Years of schooling of the rural population
RPHONE	Number of rural telephone sets per agricultural worker
RROADS	Length of rural roads per agricultural worker
IRRIST	Irrigation stock generated from past government investment
RELECT	Consumption of rural electricity per agricultural worker
UGDPP	Urban (or non-agricultural) GDP per capita
WFP	World food price
T	Time trend
Endogenous variables	
P	Percentage of rural population falling below poverty line
AWAGE	Wage rate of agricultural labor
NAWAGE	Wage rate of rural non agricultural labor in rural areas
NAGEMPLY	Percentage of nonagricultural employment in total rural employment
URBANP	The percentage of urban population in total population
LP	Labor productivity of agricultural labor
TT	Terms of trade, measured as agricultural prices divided by a relevant nonagricultural GNP deflator

Irrigation. Both irrigated areas and investment costs are available at the regional level.

Rural education. Data on years of schooling are available by region, but public expenditure data is only available at the national level. The Government of Thailand reported that 44.2 percent of the total education budget is used for primary education.

We used this percentage to calculate the budget for primary education. We then used the regional share of rural students in total students to calculate the expenditures for rural primary education by region, assuming per student expenditure in rural areas is one-fifth of expenditure per urban student.[7]

Rural electricity. Data on rural consumption of electricity in kilowatt units are available by region, but total public spending is only available at the national level. We used the electricity consumption data to apportion the total expenditures to different rural regions.

Roads. Road length and public expenditure data on roads are available by region from the government budget office. We used the share of the length of rural roads in the length of total roads to calculate the expenditures for rural roads, assuming the cost per unit of rural roads is one-fifth that of urban roads.[8]

Rural telephones. Most of the investment in telephones is made by the private sector, and we do not have data on that. Consequently we do not try to estimate a capital value or cost for telephones, but simply use the physical data to control for telephones in the model.

Model Estimation

We use the double-log functional forms for all equations in the system. More flexible functional forms such as translog or quadratic impose fewer restrictions on the estimated parameters, but many coefficients are not statistically significant due to multicollinearity problems. Regional dummies are added to equations of poverty, productivity, employment, migration, and terms of trade to capture the fixed effects of regional differences in agroclimatic and socio-economic factors. The time trend variable is also added to these equations except for the poverty equation to control for any

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[7] Personal communication with TDRI staff.

[8] This differential cost for different types of roads can be found and supported by the World Bank Road Information System, which provides unit costs for World Bank-funded road projects in different countries.

macroeconomic polices that have the same impact on every region. The model is estimated for the period of 1977 to 2000.

In our estimation, all endogenous variables on the right hand side of equation 1 to 7 are lagged for one year. This has two advantages. First, it allows weak exogeneity of the endogenous variables. Second, since every equation has its own predetermined variables, the model is identified, which means it is possible to obtain an estimate of each parameter.

There are two approaches in estimating an equation system: the single equation approach and the multiple equations system approach. Single equation techniques such as instrumental variable estimators, two-stage least squares, and limited information maximum likelihood are easy to estimate and requires only limited information. However, the single equation technique often neglects information contained in the other equations of the system. For this reason, we use the full information maximum likelihood (*FIML*) estimation technique. Among all estimators, FIML is the most efficient. The only disadvantage is its estimation complexity but with the rapid development of econometric softwares, this task has become increasingly easier and more accessible.[9]

Model Estimation Results

The results of the estimated equations are presented in Table 5. During our estimation, we found that agricultural wages, rural nonfarm wages, urbanization, and rural nonfarm employment are highly correlated. When we include all these variables in the poverty equation, some of them become statistically insignificant. However, when we include them separately in the equation, all of them are statistically significant at the 1% level. It is obvious that we cannot include all these variables in the equation. We used the principle component technique to determine which variable should be included, following Mundlak (1981). Through this technique, we kept the nonagricultural employment and urbanization variables in our final estimation for the poverty equation.

[9] We use SAS window version 8.0 in our estimation.

In this case, when we interpret the estimated results, the nonagricultural employment is a proxy for all rural wages and nonagricultural employment variables.   Since all infrast-

Table 5: Estimated Equations

(1) P	=	– 0.417 *LP*	– 0.955*NAGEMPLY*	– 0.117 *URBANP*	– 2.42 *TT*		R^2 = 0.862
		(–1.68)*	(–4.23)*	(–0.12)	(–3.99)*		
		– 0.797 *RD1*	– 0.490 *RD2*	+ 0.134 *RD3*			
		(-2.05)*	(-3.30)*	(0.15)			
(2) LP	=	0.099 *IRRI*	+ 8.63 *RSCHY*	+ 0.464 *RDS*	+ 0.140 *RROADS*	+ 0.175 *RELECT*	R^2 = 0.921
		(1.03)	(4.81)*	(2.21)*	(0.50)	(1.68)*	
		+ 0.272 *RPHONE*	– 0.265 *T*	+ 0.239 *RD1*	+ 1.068 *RD2*	– 0.684 *RD3*	
		(2.52)*	(-5.24)*	(0.73)	(3.83)*	(-3.48)	
(5) NAGEMPLY	=	– 0.120 *LP*	– 1.527 *RSCHY*	+ 0.820 *RROADS*	+ 0.388 *RELECT*	– 0.068 *RPHONE*	R^2 = 0.956
		(-1.09)	(-0.81)	(3.75)*	(4.18)*	(-0.64)	
		+ 2.97*UGDPP*	+ 0.030 *T*	+ 0.609 *RD1*	+ 0.338 *RD2*	+ 0.925 *RD3*	
		(5.03)*	(0.69)	(2.23)*	(1.30)	(2.70)*	
(7) TT	=	– 0.068 *LP*	+ 0.438 *WFP*	+ 0.022 *T*	– 0.001 *RD1*	– 0.083 *RD2*	R^2 = 0.420
		(-1.29)	(5.54)*	(5.92)*	(-0.02)	(-3.31)*	
		– 0.083 *RD3*					
		(-3.31)*					

Notes: RD1 is the dummy variable for the Northeast region, RD2 for the North region, and RD3 for the Central region. The South is the base region. Asterisk indicates that coefficients are statistically significant at the 10 percent level. Estimates of equations (3) and (4) are not reported because they are not used in calculation of productivity and poverty effects of government spending.

ructure and education variables affect poverty through non-agricultural employment, we do not need to report the results of wage equations.[10]

The estimated poverty equation, Equation (1) shows that growth in agricultural labor productivity, nonfarm employment and changes in agricultural prices are the most important factors in rural poverty reduction in Thailand. For every one percent growth in agricultural production, rural poverty is reduced by 0.4 percent. The effect of nonfarm employment on rural poverty reduction is even larger than the effect of agricultural labor productivity growth. For a one percent growth in nonagricultural employment, rural poverty is reduced by 1%. Higher agricultural prices are correlated with lower rural poverty even when agricultural labor productivity is already included in the poverty function. This is because most farms in Thailand are net sellers of food. The average farm size is still over 3 hectares and only about 20% of farms are less than 1 hectare. This is consistent with Thailand being a major agricultural exporter. The urbanization variable (a proxy for rural to urban migration) is not statistically significant. This does not mean rural-to-urban migration is not important in reducing rural poverty. The insignificance is caused by its high correlation (0.8) with nonfarm employment. When we drop the nonfarm employment variable, the urbanization (migration) variable becomes significant at the 1% level.

The estimated agricultural productivity function, Equation (2), shows that agricultural research, improved rural education and rural telephones have contributed significantly to growth in agriculture. But improved irrigation, rural roads, and rural electricity show no significant impacts on agricultural labor productivity, although rural electricity is marginally significant at the 15% level.

The estimates for Equation (5) show that nonfarm employment is highly correlated with rural roads and electricity. Rural education and telephone are not statistically significant. The linkage effect of agricultural productivity on rural nonagricultural employment is weak, as evidenced by the insignificant coefficient of

[10] The estimated results of wage equations are similar to those of the nonagricultural employment equation.

labor productivity in the equation. However, urban growth has a very strong and significant impact on rural nonfarm employment.

The estimated terms of trade equation, Equation (7), indicates that agricultural prices are mainly determined by international food prices. Thailand is a small trading country in the world market and domestic prices are closely linked with international prices. As such, increases in agricultural productivity (hence production) have a statistically insignificant impact on the terms of trade for agriculture.

Table 6 reports the results of estimates of the relationship between monetary stocks and physical stocks for various public investments (except for agricultural R&D). All coefficients are statistically significant, implying that we can use these relationships to calculate the returns in agricultural growth and poverty reduction per unit of capital stock. The coefficient of 0.981 for the irrigation stock justifies the use of an irrigation stock variable in the productivity function since the coefficient is assumed to be one.

Table 6: Estimated Relationships between Monetary Stocks and Physical Stocks

Irrigation:	*IRRIA*	=	0.980 *IRRST* (10.87)*	$R^2 = 0.444$
Education:	*RSCHY*	=	0.067 *EDUST* (4.53)*	$R^2 = 0.173$
Roads:	*ROADS*	=	0.852 *ROADST* (11.66)*	$R^2 = 0.546$
Rural Electricity:	*RELECT*	=	1.13 *ELECST* (26.33)*	$R^2 = 0.893$

Notes: IRRST, EDUST, ROADST, and ELECST are stock variables measured in monetary terms using Equation 11.

Marginal Returns of Public Investment

Using estimated Equations (1) to (7) in Table 5 and the estimated relationship between monetary stocks and physical stocks in Table 6, we can use Equations (8), (9) and (13) to derive the marginal returns to different types of government expenditures in terms of growth in agricultural labor productivity and reductions in rural poverty. We calculated marginal returns for different types of investments in four regions and for Thailand as a whole for 1999 (Table 7). In doing so, the estimated lagged relationships between investments and their impacts have been considered. For example, the returns to investment in agricultural research in 1999 are calculated as the increase in agricultural output due to all relevant past investments in agricultural research, where past investments have been inflated to 1999 prices.

Table 7: Marginal Returns to Government Investment in Rural Thailand

Investment	Northeast	North	Central	South	Thailand
		Benefit-Cost Ratio (Bhat/Bhat)			
Agricultural R&D	n.a	n.a.	n.a.	n.a.	12.62
Irrigation	0.76	1.11	0.55	0.62	0.71
Roads	1.23	1.23	0.44	1.24	0.86
Education	1.26	2.92	2.89	2.51	2.12
Electricity	8.66	8.04	2.59	5.48	4.89
		No. of Poor Reduces per Million Bhat			
Agricultural R&D	n.a	n.a	n.a	n.a	138.10
Irrigation	21.05	5.22	1.74	4.53	7.69
Roads	394.09	67.43	15.88	106.08	107.23
Education	34.74	13.71	9.08	18.53	22.75
Electricity	1253.02	198.57	42.79	211.99	276.07

Notes: Marginal returns are calculated for 1999. Only statistically significant coefficients are used in the calculation of marginal returns.

Productivity impacts are measured in Baht of additional output per additional Baht of spending, and poverty reduction is measured as the number of poor people raised above the poverty line for an additional one million Baht of spending. These measures provide useful information for comparing the relative benefits of additional investments in different items in different regions. Such information can be helpful for informing future priorities for government expenditure to further increase production and reduce rural poverty. We cannot, however, generate this kind of information for rural telephones because the vast majority of the investment is made by the private sector and relevant expenditure data are not available. As indicated earlier, in this case we simply incorporate the number of rural telephones in the estimated model to control for their growth. As shown in Table 5, telephones had a strong and statistically significant impact on growth in agricultural labor productivity.

An important feature of the results in Table 7 is that all the investments considered reduce poverty and increase agricultural labor productivity. However, there are sizable differences in productivity gains and poverty reductions across various types of expenditures and across regions.

Agricultural research has by far the largest productivity impact. For every additional Baht invested in agricultural research, agricultural productivity increases by 12.6 Baht. Rural electricity and education also have favorable returns, ranking second and third, respectively, although their effects are only 20-30 percent as large as for agricultural research. Investments in irrigation and rural roads have the lowest productivity returns, and their benefit-cost ratios are less than one, suggesting additional investments will not fully pay for themselves. The returns to road investments are weaker than estimated for some other Asian countries like China, and this may be because Thailand has already invested heavily in rural roads.[11]

In terms of poverty reduction effects, government expenditure on rural electricity has the largest marginal returns for the country as a whole. For every million Baht spent on rural electricity, 276 people are lifted out of poverty. The poverty reduction effect of agricultural research and extension ranks second. For every million Baht invested, 138 poor would be lifted from poverty. Road expenditure ranks third (107), education expenditure fourth (23), and irrigation investment ranks last (8 persons lifted from poverty per one million Baht of public expenditure).

The poverty reduction effects of agricultural research and irrigation come solely from increased agricultural production, while the effects of electricity, roads, and education come from growth in agricultural labor productivity as well as improvements in rural nonfarm employment and rural-urban migration. Using the decomposition of

[11] The current model also does not fully capture their impact on rural nonagricultural production Fan *et al.* (2002) found that investment in roads has the highest returns in the nonfarm sector among all types of investment in China.

impacts derived in Equations (8) and (9), it can be shown that the latter has become increasingly important in alleviating rural poverty. For example, among total effects of rural electricity investments on rural poverty, improved nonfarm employment accounts for 75 percent of the effects, growth in agricultural labor productivity accounts for 20 percent and the rest is accounted for by rural to urban migration. Among all road effects, improved rural nonfarm employment accounts for 60 percent, and growth in agricultural productivity for 40 percent, while urbanization (or rural to urban migration) has no impact on poverty reduction.

There is large regional variation in the marginal returns to government spending in both agricultural productivity growth and poverty reduction.[12] In terms of poverty reduction effects, all kinds of investments had the highest returns in the Northeast region. For example, for every million Baht invested in irrigation, roads, education, and electricity, the numbers of poor reduced were 21, 483, 34, and 1253, respectively. These effects are 2.7, 3.8, 1.5, and 4.5 times higher than their national averages. The highest returns are to electricity and road investments. These types of investments in the Northeast should be the government's top priority in the future to gain maximum poverty reduction. In terms of growth effects, it is the Northeast and North that have the largest impact for all investments except education, indicating there is little or no trade-off between growth and poverty reduction by investing more in the less-developed regions of the country. The lower returns to education may be due to the fact that improved average years of schooling has a statistically significant impact on agricultural production, but not on rural nonagricultural employment, and growth in agricultural productivity accounts for only a small share of total poverty reduction. Moreover, the average number of years of schooling in the Northeast is already similar to the national average (5.9 years), implying that further improvement in the rural literacy rate in the rural Northeast will have diminishing economic returns in the future.

[12] Because agricultural research is conducted at the national level, it is impossible to calculate the effects at the regional level.

VI. CONCLUSIONS

Using pooled time series (1977-2000) and cross section (region) data, this study has modeled the effects of different types of government rural spending on agricultural growth and rural poverty reduction in Thailand. The results show that despite Thailand's middle income status, most government investments such as agricultural R&D, irrigation, rural education, and infrastructure (including roads and electricity), have positive marginal impacts on agricultural productivity growth and rural poverty reduction. However, variations in their marginal effects were large, both across different types of spending and across regions.

The estimated model indicates that additional government spending on agricultural research and extension improves agricultural productivity the most and is the second most powerful way of reducing rural poverty. Government spending on rural electricity reduces poverty the most and has the second largest impact on agricultural productivity growth. Road expenditure has the third largest impact on rural poverty reduction, but only a modest and statistically insignificant impact on agricultural productivity. The large poverty reduction effects for electricity and roads are due to improved access to nonfarm employment. Government spending on rural education has only the fourth largest impact on poverty, but a significant economic impact through improved agricultural productivity. Irrigation investment has the smallest impact on both rural poverty reduction and labor productivity in agriculture.

Additional investments in the Northeast region contribute more to reducing poverty than investments in other regions. This is because most of the poor are now concentrated in the Northeast and it has suffered from under investment in the past. The poverty reducing impacts of infrastructure investments, such as electricity and roads, are particularly high in this region. The growth impacts of many investments are also greatest in the Northeast than in other regions, hence there is no evident tradeoff between investments for growth and investments for poverty reduction.

Thailand is a middle-income country and it is insightful to compare these results with similar studies undertaken in low-income countries like India, China, and Uganda. Some of the results are similar. For example, high returns to public investments in agricultural research and infrastructure were also found in China, India and Uganda (Fan, Hazell and Thorat 1999, Fan, Zhang and Zhang 2002, and Fan Zhang and Rao 2004). The public goods nature of much agricultural research and rural roads explains why there is persistent under investment by the private sector and hence favorable returns to public investment, even in a middle income country like Thailand. On the other hand, the returns to public investment in education in Thailand are quite low, possibly because of increasing private investment and the inappropriate composition of much public spending on education. The country has been very successful in wiping out rural illiteracy, but higher priority should now be given to improving the quality of secondary and high school education. Farmers' technical (or vocational) education should also receive more attention.

Within infrastructure, research results from low-income countries often show higher returns to road investments than telecommunications and electricity. But in the case of Thailand, it is investment in electricity that shows the highest return. Thailand has invested heavily in rural roads and a dense road network has already been built, suggesting that additional investment may yield diminishing returns. Also, there has been significant investment by the private sector in rural telecommunication, leading to a much-reduced role for the public sector. Government should now focus on providing an enabling legal and regulatory framework for telecommunications rather than making additional investments of its own. This situation differs from many low-income countries, especially in Africa, where the private sector is still embryonic and the public sector must play a dominant investment role for the foreseeable future. As in India and China, low returns from additional public investments in irrigation arise because the government has already invested heavily in irrigation. Rather than simply expanding capacity, future public spending on irrigation should be geared towards improving the efficiency of the existing irrigation system through reforming pricing incentives and the institutions that manage irrigation water.

This study suffers from some limitations. The most critical is the quality and coverage of the available data. While we have used econometric techniques to correct for some of these problems, improved analysis requires that better data be collected in the future on government spending by sector and region, with desegregation by rural and urban areas and by current and capital expenditures. Without such data, it will be difficult for the government to monitor and evaluate the impacts of its various investments or to set better investment priorities in the future.

Second, a more general-equilibrium analysis is needed to capture the broader impacts of rural investments on the nonagricultural economy. Ignoring these impacts must lead to some under estimation of the total impact of public investments on poverty. A similar effort is also needed to analyze the impact of urban investment on rural poverty reduction.

Finally, in order to suggest improvements in the efficiency of public investments, it would be desirable to undertake an analysis. Research is especially needed on the political and institutional context for different types of public spending, especially how the government might better mobilize public resources to invest in rural areas, and how public provision can be made more efficient by improving incentive systems, accountability, human capital, and management.

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APPENDIX: REGIONAL DATA FOR RURAL THAILAND

Table A1: Rural Poverty by Region

Unit: Percent

	North-Eastern	Northern	Central Plain	Southern	Whole Kingdom
1976	57.92	44.28	21.00	41.85	44.48
1977					
1978					
1979					
1980					
1981	53.44	33.72	21.73	30.67	39.11
1982					
1983					
1984					
1985					
1986	70.36	44.15	33.83	45.68	53.25
1987					
1988	53.93	36.94	28.41	39.44	42.65
1989					
1990	49.80	28.10	22.69	32.75	36.76
1991					
1992	45.60	28.60	14.66	25.16	32.13
1993					
1994	34.38	17.39	9.64	22.10	23.50
1995					
1996	23.44	12.08	7.20	14.34	16.12
1997					
1998	24.25	9.40	6.90	15.15	15.97
1999	31.68	10.89	7.26	17.80	19.89
2000	32.17	15.05	6.33	13.66	20.12

Source: Thailand Development Research Institute (TDRI)

Table A2: Real Wages for Agricultural Labor by Region

Unit: Baht per month

	North-Eastern	Northern	Central Plain	Southern
1977	1,584	1,196	1,923	1,866
1978	1,366	1,085	1,896	2,033
1979	1,367	1,197	1,785	2,341
1980	1,100	1,163	1,704	2,401
1981	1,038	1,155	1,830	1,717
1982	967	1,089	1,762	1,584
1983	889	1,075	1,732	1,817
1984	1,112	984	2,108	3,274
1985	1,125	1,194	1,844	2,139
1986	1,219	1,238	1,749	2,062
1987	1,219	1,176	1,773	2,462
1988	1,158	1,249	1,694	2,226
1989	1,196	1,317	1,762	2,205
1990	1,337	1,577	1,881	2,079
1991	1,350	1,493	1,809	2,314
1992	1,429	1,620	1,877	2,647
1993	1,539	1,829	2,202	2,354
1994	1,663	1,930	2,265	2,970
1995	1,929	2,016	2,335	2,967
1996	2,131	2,121	2,459	2,538
1997	2,057	2,178	2,326	3,018
1998	1,704	1,837	2,084	2,539
1999	1,759	1,850	2,156	2,535
2000	1,902	2,024	2,185	2,773

Table A3: Real Wages for Non-Agricultural Labor by Region

Unit: Baht per month

	North-Eastern	Northern	Central Plain	Southern
1977	2,405	1,570	2,750	2,185
1978	2,216	1,418	2,641	2,054
1979	1,916	1,564	2,696	2,174
1980	1,614	1,485	2,536	2,264
1981	1,594	1,580	2,555	2,018
1982	1,631	1,342	2,733	1,922
1983	1,493	1,561	2,615	2,353
1984	2,235	1,743	3,675	2,722
1985	1,825	1,803	2,801	2,349
1986	1,831	1,755	2,543	2,584
1987	1,812	1,579	2,545	2,476
1988	1,867	1,780	2,637	2,427
1989	1,921	1,929	2,582	2,210
1990	2,112	2,053	2,843	2,426
1991	2,182	2,015	2,836	2,708
1992	2,148	2,278	2,934	2,746
1993	2,488	2,501	3,615	3,019
1994	2,711	2,673	3,587	3,150
1995	2,845	2,699	3,591	3,169
1996	2,767	2,664	3,582	3,086
1997	2,736	2,768	3,434	3,351
1998	2,192	2,392	3,107	2,904
1999	2,430	2,362	2,946	3,024
2000	2,308	2,678	3,102	3,073

Source: Labor Force Survey (round 3, various year), National Statistical Office, Thailand.

Table A4: Non-Agricultural Employment as Percentage of Total Rural Employment by Region

Unit: Percent

	North-Eastern	Northern	Central Plain	Southern	Whole Kingdom
1977	8.18	9.84	23.53	18.36	13.22
1978	4.62	13.90	23.53	15.51	12.20
1979	6.43	12.78	28.90	21.71	14.55
1980	7.00	13.34	27.61	20.37	14.49
1981	6.68	12.67	30.27	22.12	15.34
1982	10.08	15.93	34.79	24.38	18.82
1983	8.17	15.61	36.20	22.46	17.94
1984	8.30	15.73	33.41	22.58	17.45
1985	8.72	16.64	27.84	24.32	16.66
1986	8.04	17.72	33.13	26.18	17.93
1987	10.29	20.83	34.97	28.93	20.78
1988	9.85	18.43	31.20	26.30	18.69
1989	7.53	16.62	38.27	25.42	18.46
1990	9.52	19.07	41.89	27.30	20.92
1991	13.18	22.05	44.92	30.69	24.37
1992	11.45	24.19	44.27	31.26	24.05
1993	13.83	28.12	48.95	31.93	27.07
1994	15.86	29.29	48.01	33.84	28.29
1995	19.84	31.45	52.12	38.19	31.82
1996	22.34	33.66	56.06	34.22	33.89
1997	18.53	35.85	56.82	35.05	32.84
1998	18.63	30.03	54.82	37.38	31.82
1999	25.05	30.54	56.31	37.31	35.10
2000	22.17	31.89	56.31	38.83	34.33

Source: Labor Force Survey (round 3, various years), National Statistical Office, Thailand.

Table A5: Average Years of Schooling of Rural Population (age 15 and over) by Region

Unit: Year

	North-Eastern	Northern	Central Plain	Southern	Whole Kingdom
1977	3.8	3.4	4.1	3.8	3.7
1978	3.9	3.5	4.2	3.9	3.8
1979	3.9	3.5	4.3	3.9	3.9
1980	4.0	3.6	4.4	4.0	4.0
1981	4.1	3.7	4.5	4.1	4.1
1982	4.1	3.8	4.5	4.2	4.2
1983	4.2	3.8	4.6	4.3	4.3
1984	4.3	3.9	4.7	4.4	4.3
1985	4.4	4.0	4.8	4.5	4.4
1986	4.5	4.1	4.9	4.6	4.5
1987	4.6	4.2	5.0	4.7	4.6
1988	4.7	4.3	5.0	4.8	4.7
1989	4.7	4.4	5.1	4.9	4.8
1990	4.8	4.5	5.2	5.0	4.9
1991	4.9	4.6	5.3	5.1	5.0
1992	5.0	4.7	5.4	5.2	5.1
1993	5.1	4.8	5.5	5.4	5.2
1994	5.2	4.9	5.6	5.5	5.3
1995	5.3	5.0	5.7	5.6	5.4
1996	5.4	5.1	5.8	5.7	5.5
1997	5.5	5.2	5.9	5.9	5.6
1998	5.7	5.3	6.0	6.0	5.7
1999	5.8	5.4	6.1	6.1	5.8
2000	5.9	5.5	6.2	6.2	5.9

Source: Labor Force Survey (round 3, various years), National Statistical Office, Thailand.

Table A6: Literacy Rate of the Rural Population by Region

Unit: Percent

	North-Eastern	Northern	Central Plain	Southern	Whole Kingdom
1977	84.3	68.7	81	72.5	77.5
1978	85.7	71.4	81.5	73.2	79.3
1979	86.6	72.9	81.9	73.9	80.6
1980	87.2	73.9	82.4	74.6	81.4
1981	87.7	74.6	82.9	75.3	82.1
1982	88.1	75.3	83.3	76	82.7
1983	88.5	75.8	83.8	76.7	83.2
1984	88.9	76.4	84.2	77.4	83.7
1985	89.3	76.9	84.7	78.1	84.2
1986	89.7	77.5	85.2	78.9	84.6
1987	90.1	78	85.6	79.6	85.1
1988	90.5	78.6	86.1	80.4	85.6
1989	90.9	79.2	86.6	81.1	86.0
1990	91.2	79.7	87.1	81.9	86.5
1991	91.6	80.3	87.5	82.6	87.0
1992	92.0	80.8	88.0	83.4	87.5
1993	92.4	81.4	88.5	84.2	87.9
1994	92.8	82.0	89.0	85.0	88.4
1995	93.2	82.6	89.5	85.8	88.9
1996	93.6	83.2	90.0	86.6	89.4
1997	94.0	83.8	90.5	87.4	89.9
1998	94.4	84.3	91.0	88.2	90.3
1999	94.8	84.9	91.5	89.1	90.8
2000	95.3	85.5	92.0	89.9	91.3

Note: Population age 15 and over and education level; primary and over
Source: Labor Force Survey (round 3, various years), National Statistical Office, Thailand.

Table A7: Irrigated Area by Region

*Unit: 1000 Rai**

	North-Eastern	Northern	Central Plain	Southern	Whole Kingdom
1970	1,074	1,448	7,644	349	10,516
1971	1,074	1,670	7,649	372	10,766
1972	1,077	1,820	8,000	372	11,268
1973	1,100	2,113	8,617	379	12,209
1974	1,173	2,198	8,639	564	12,573
1975	1,179	2,215	8,904	564	12,861
1976	1,502	2,341	10,189	937	14,969
1977	1,612	2,601	10,362	1,094	15,669
1978	1,826	2,865	10,593	1,221	16,505
1979	2,042	3,170	10,911	1,447	17,569
1980	2,264	3,425	11,129	1,558	18,375
1981	2,447	3,849	11,451	1,662	19,408
1982	2,736	4,232	11,534	1,786	20,287
1983	2,957	4,685	11,594	1,993	21,229
1984	3,258	5,072	12,060	2,090	22,481
1985	3,611	5,504	12,136	2,256	23,508
1986	3,746	6,104	12,254	2,343	24,447
1987	3,881	6,318	12,404	2,451	25,053
1988	3,897	6,800	12,522	2,536	25,756
1989	3,935	6,773	12,651	2,630	25,989
1990	4,123	6,922	12,719	2,725	26,488
1991	4,371	7,083	13,014	2,714	27,182
1992	4,499	7,194	12,953	2,858	27,504
1993	4,726	7,441	13,277	2,912	28,356
1994	4,803	7,563	13,374	2,946	28,685
1995	4,955	7,643	13,448	2,967	29,013
1996	5,114	7,805	13,516	3,025	29,461
1997	5,149	7,863	13,584	3,084	29,680
1998	5,176	7,942	13,679	3,135	29,932
1999	5,371	8,019	14,337	3,199	30,927
2000	5,326	8,258	14,400	3,255	31,239

Note: 6.24 Rais = 1 Hectare
Source: Agricultural statistics of Thailand (various years) and TDRI.

Table A8: Rural Electricity Consumption by Region

Unit: Million Kwh

	North-Eastern	Northern	Central Plain	Southern	Whole Kingdom
1977	55.7	107.5	709.9	67.3	940.4
1978	84.9	144.9	891.6	99.2	1,220.6
1979	121.9	186.8	1,090.8	139.5	1,539.0
1980	166.1	231.8	1,296.5	186.4	1,880.8
1981	218.2	281.3	1,514.9	240.9	2,255.3
1982	286.3	345.4	1,796.6	312.0	2,740.4
1983	376.6	430.0	2,163.4	406.2	3,376.2
1984	466.9	509.9	2,483.0	500.3	3,960.2
1985	549.7	579.1	2,729.1	586.6	4,444.5
1986	667.3	683.4	3,115.3	711.1	5,177.1
1987	810.1	811.6	3,577.4	864.1	6,063.1
1988	976.8	962.6	4,099.5	1,044.9	7,083.8
1989	1,211.9	1,180.0	4,853.0	1,302.6	8,547.4
1990	1,500.5	1,449.0	5,751.3	1,623.0	10,323.9
1991	1,842.5	1,770.3	6,777.4	2,008.2	12,398.4
1992	2,174.6	2,084.0	7,692.2	2,391.0	14,341.8
1993	2,570.8	2,462.6	8,760.2	2,854.3	16,648.0
1994	3,066.5	2,941.4	10,080.3	3,440.8	19,529.1
1995	3,648.7	3,509.4	11,583.6	4,140.4	22,882.2
1996	4,157.8	4,014.7	12,759.7	4,774.1	25,706.3
1997	4,623.7	4,486.4	13,726.9	5,374.8	28,211.9
1998	4,701.6	4,587.8	13,511.4	5,535.3	28,336.2
1999	4,954.3	4,864.8	13,788.6	5,909.4	29,517.2
2000	5,591.5	5,527.9	15,077.5	6,759.0	32,955.8

Source: National Energy Policy Office (NEPO).

Table A9: Number of Rural Main Telephone Lines

Unit: Lines

	North-Eastern	Northern	Central Plain	Southern	Whole Kingdom
1977	2,297	4,153	7,006	962	14,418
1978	3,188	5,894	8,898	1,973	19,952
1979	3,524	6,597	9,691	2,838	22,649
1980	3,701	6,962	10,389	3,556	24,608
1981	3,956	7,433	11,485	4,263	27,137
1982	4,418	8,258	13,305	5,114	31,095
1983	5,189	9,614	16,157	6,253	37,213
1984	6,362	11,656	20,383	7,806	46,207
1985	8,030	14,521	26,327	9,872	58,749
1986	10,270	18,304	34,275	12,502	75,350
1987	13,130	23,040	44,406	15,692	96,268
1988	16,639	28,722	56,808	19,401	121,570
1989	20,839	35,366	71,608	23,597	151,410
1990	25,843	43,100	89,159	28,324	186,425
1991	31,883	52,236	110,228	33,738	228,086
1992	39,341	63,304	136,103	40,122	278,871
1993	48,761	77,045	168,612	47,862	342,280
1994	60,836	94,372	210,084	57,415	422,707
1995	76,387	116,326	263,268	69,266	525,247
1996	96,340	144,011	331,217	83,889	655,455
1997	121,691	178,548	417,193	101,715	819,147
1998	153,511	221,069	524,655	123,131	1,022,366
1999	192,992	272,772	657,412	148,516	1,271,692
2000	241,557	335,075	820,005	178,316	1,574,952

Source: Telephone Organization of Thailand and SES.

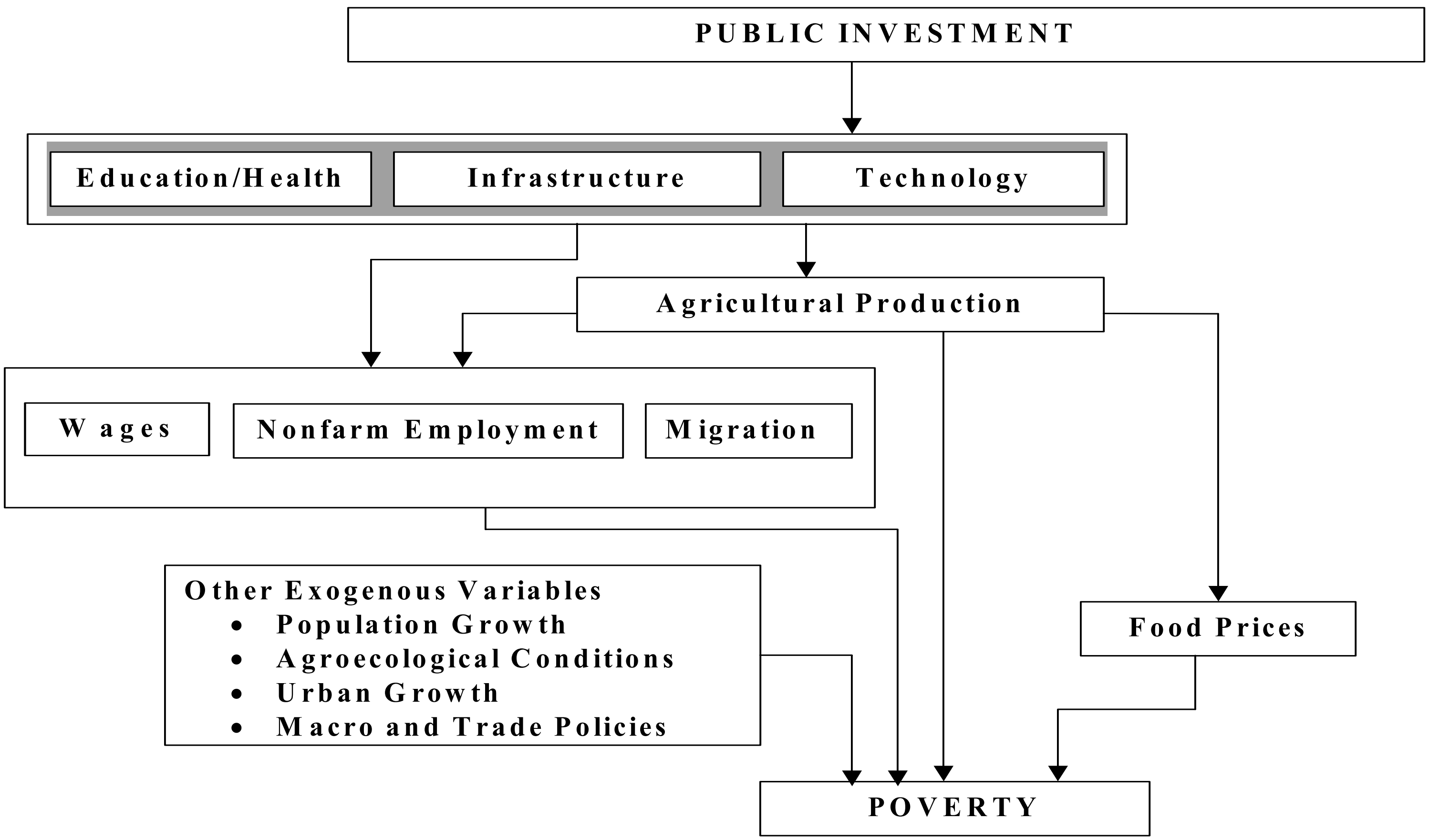
Table A10: Length of Rural Roads (unpaved roads and asphalt)

Unit: K ms

	North-Eastern	Northern	Central Plain	Southern	Whole Kingdom
1977	2,510	457	1,744	1,547	6,258
1978	2,879	514	1,765	1,596	6,755
1979	3,128	651	1,781	1,650	7,210
1980	3,393	831	1,853	1,727	7,804
1981	3,808	936	1,964	1,868	8,576
1982	3,907	996	2,003	1,987	8,893
1983	4,204	1,084	2,016	2,050	9,354
1984	4,345	1,168	2,086	2,250	9,848
1985	4,390	1,251	2,147	2,289	10,077
1986	4,592	1,281	2,230	2,392	10,496
1987	4,683	1,413	2,329	2,513	10,939
1988	4,854	1,534	2,485	2,620	11,492
1989	5,129	1,651	2,914	2,806	12,500
1990	5,608	1,882	3,776	3,202	14,467
1991	6,930	2,440	4,615	3,754	17,738
1992	8,177	3,323	5,573	4,436	21,508
1993	9,661	4,349	6,893	5,235	26,138
1994	10,901	5,347	8,047	5,924	30,219
1995	12,889	7,052	9,754	7,069	36,763
1996	15,671	9,096	11,891	8,398	45,057
1997	19,236	11,432	14,407	9,826	54,900
1998	21,782	13,084	16,079	10,831	61,776
1999	22,916	13,762	16,906	11,164	64,748
2000	23,641	14,458	17,584	11,455	67,138

Source: Public Works Department, Ministry of Interior.

Figure 1: Effects of Public Investment on Poverty Reduction



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