ROAD IMPROVEMENT AND POVERTY REDUCTION:

A General Equilibrium Analysis for Lao PDR*

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Executive Summary

The effect that improvement of rural roads has on poverty incidence is a central issue for assistance to poor countries and for their own public investment policies. However, studying this issue is difficult and several approaches have been used in the literature, all of them imperfect. This paper studies the effect that rural road improvement in Lao PDR has on poverty incidence in that country using a general equilibrium modeling approach. A feature of the analysis is that it differentiates between three categories of rural villages according to the quality of road access available to them: (i) no vehicular access; (ii) dry season only access; and (iii) all weather access. Household survey data available for Lao PDR make it possible to divide rural households into these three categories.

The approach taken in this study is to use information on transport costs in these three types of roads to estimate the transport cost margins facing rural people in villages serviced by these three categories of roads. We then simulate the effect of upgrading category (ii) roads to category (i) roads, on the one hand and category (iii) roads to category (ii) on the other. The results indicate that both forms of road improvement reduce poverty incidence. They do this by improving the income earning opportunities of rural people and through reducing the costs of the goods they consume.

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A feature of the results is that when no vehicle access areas are provided with dry season access roads (dirt and gravel), the reduction in poverty incidence is about 17 times the reduction that occurs when dry season access only roads are upgraded to all weather access (paved and improved gravel) roads. The ratio of the effect on GDP is about 6. Reducing transport costs for households without road access is highly pro-poor.

These results do not demonstrate that road improvement should be shifted away from upgrading dry season access roads to providing road access to villages currently lacking it. Both forms of road improvement are important. Moreover, the costs of road building in the two cases need to be taken into account in determining the most appropriate road building strategy. This paper has not looked into these costs. However, our results confirm that there is considerable scope for reducing poverty incidence in Lao PDR by reducing rural transport costs through improving the quality of rural roads.

1. Introduction

It is obvious that low quality roads impose costs on people living far from market centers. In the Lao PDR this is a particular problem. The country is mountainous and for historical reasons roads in many rural areas remain badly maintained or even non-existent. Because the poorest people often reside far from urban centers, these people are the most disadvantaged by the high transport costs resulting from bad roads. Over the past two decades Lao PDR has made considerable progress in reforming the legal and administrative obstacles to market-based development that were a legacy of earlier policies. But for people facing very high transport costs arising from inadequate roads, these reforms may be of limited value. For them, markets cannot be accessed except at high cost. Bad roads are clearly an obstacle to attaining the potential benefits from market-based economic reform.

Considerable effort is being invested in the improvement of rural roads in Lao PDR. The expected benefits include reductions in the incidence of poverty within rural areas. But the quantitative relationship between road improvement and poverty reduction is not well understood. The present study focuses on this relationship. The analysis uses a general equilibrium modeling approach in which road improvement is modeled as a reduction in transport costs. The modeling framework used in the study is specially designed to analyze the manner in which transport cost reductions impact on poor people.

In Section 2 we describe the information available on the relationship between road improvement and transport cost. We then use this information to analyze the effects of road improvement using a general equilibrium model of the economy of Lao PDR, especially constructed for this purpose. This model is described in Section 3. Three features of the model are important. First, it distinguishes four categories of households, one urban and three rural categories, the latter differentiated by the quality of roads which service the villages in which these rural households are located. Second, each of these four categories of households contains 100 household sub-categories, arranged by real expenditures per household member. Third, the three rural household categories differ according to the transport costs that they face, commensurate with the quality of roads servicing them, and using the information summarized in Section 2. Road improvement is then modeled as a reduction in these costs. The results of the analysis are presented in Section 4. Finally, Section 5 draws out the major conclusions that follow from the study.

2. Road Quality and Transport Costs

2.1 The Road Network in Lao PDR: Some Basic Facts

The road system in Lao PDR, which totals just above 31,000 kilometers in length, is mostly in a bad state of disrepair. Putting aside urban and purpose-built special roads, the road network generally consists of national and local roads, with the latter being subdivided into provincial, district and rural roads (Table 2.1).

At present, less than 20 percent of this total network is paved. The national roads, linking major towns and provincial capitals and providing connections to neighboring countries, total about 3700 kilometers in length, or about 23 percent of the road network. As a result of substantial investment by the Government of Lao PDR and bilateral and multilateral donors over the last decade and a half or so, about half of this road network is now paved, with the remainder having gravel or earth surfaces. Although this is a significant improvement in road quality, the fact remains that only about half of the best segment of the overall road network – the national roads – can be relied upon to provide all weather connectivity.

Table 2.1: The Lao PDR Road Network

Road type	Road Surface							
	Paved		Gravel		Earth		All surfaces	
	km	%	Km	%	km	%	km	%
National	3,771	53	2,244	31	1,126	16	7,141	23
Provincial	198	3	3,038	47	3,249	50	6,485	21
District	31	0.8	1,826	47	2,008	52	3,865	12
Rural	14	0.1	1,815	16	9,527	84	11,356	36
Urban	429	24	871	49	465	26	1,765	6
Special	54	9	304	50	249	41	607	2
Total	4,497	14	10,098	32	16,624	53	31,219	100

Source: MTCPC (2003)

Local roads run about 21,700 kilometers in length and make up about 70 percent of the entire network, but only about 4 percent is paved. The provincial road network is about 6500 kilometers in length, of which even less is paved (3 percent). District roads are about 6,500 kilometers and are almost equally divided into either gravel or earth surfaces. Rural roads are the most important category in the network, and comprise more than 11,000 kilometers in length. Hardly any of it is paved, and almost 85 percent is earth. All of this suggests that almost the entire local road network may not be passable during the wet season.

Table 2.1 does not provide any indication of the condition of the various road surfaces. Although the relatively small share of the network that is paved is in generally good condition, given that most have only recently been upgraded, the same cannot be said about non-paved surfaces. World Bank (2001) estimated that about 60 percent of the District and Rural road network is in either "poor" or "bad" condition. A more recent study, MTCPC (2004), suggests that little has changed since the World Bank study, and that only 38 percent of the total Local road network is in a "maintainable" condition.

These facts suggest that the cost of land transport in Lao PDR is currently high, and could be reduced significantly by improving the existing network and expanding it, especially in rural areas. The need to do this is further strengthened by the fact that motorized vehicles are the dominant mode of transport, carrying 91 per cent of total freight ton-kilometers and 95 per cent of total passenger-kilometers.

2.2 All Weather, Dry Season, and No Vehicular Access Roads

In the analysis, three types of road quality are distinguished in terms of accessibility. These are: (i) no vehicular access; (ii) dry season only access; and (iii) all weather access.

No vehicular access means that the pathways through which the village is normally reached cannot accommodate conventional motorized vehicles. It does not mean that the village is completely isolated, however. It may still be able to accommodate low-cost vehicles and carrying devices appropriate to local-level transport tasks. These are collectively called intermediate means of transport (IMTs)—intermediate, that is, between walking (with loads carried on the head, or headloading) and conventional, motorized transport (see Dawson and Barwell, 1993). IMTs include simple devices to facilitate the carrying of loads by people, such as the shoulder pole and the backpack frame; human-powered vehicles such as wheelbarrows, handcarts and bicycles; animal-powered devices such as donkeys with panniers, and animal drawn carts and sledges; and perhaps some two-wheeled motorized vehicles such as mopeds and motorcycles.

Dry season only access roads consist predominantly of unpaved roads that are accessible to conventional motorized vehicles during the dry season but not necessarily during the wet season. For such roads during the wet season, vehicles will be forced to find alternative routes or use alternative paths along the existing road that would facilitate passage but would result in higher transport costs due to a change in travel distance, road roughness, and speeds. Depending on its condition, this covers most, but not all, earth and gravel road surfaces.

Finally, all weather access roads can be used by conventional motorized vehicles during the dry and wet seasons. In other words, unlike dry season access roads, these roads would not be subject to frequent closure as a result of flooding during the wet season. This covers almost all paved roads.

The Lao Expenditure and Consumption Survey (LECS), which has now been conducted for 1992-93 (LECS 1), 1997-98 (LECS 2) and 2002-03 (LECS 3) provides a classification of roads into these categories and records the category of road servicing each village. Table 2.2 summarises information about the importance of these three categories of rural villages, classified by road access. One point that comes across clearly from this table is that over the five year interval between these two surveys there was a decline in the proportion of rural households living in villages with "dry season access only" road access and a corresponding increase in the proportion with "all season access". But there was no change in the proportion having "no access any season". This implies that the road improvement that occurred during this interval consisted overwhelmingly of upgrading "dry season access only" roads, making them accessible during all seasons. But no upgrading of "no access any season" roads can be detected from these data. In 2002-03 almost one third of all rural households lived in villages without roads that support motorized vehicle access.

Table 2.2 Lao PDR: Numbers of rural households by road access

Road access	Code	Number of households		Per cent of households	
		LECS 2 1997-98	LECS 3 2002-03	LECS 2 1997-98	LECS 3 2002-03
No access any season	HR1	2,146	2,052	31.2	31.6
Dry season access only	HR2	1,934	1,050	28.1	16.2
All season access	HR3	2,794	3,386	40.7	52.2
All rural households		6,874	6,488	100	100

Source: Authors' calculations from LECS 2 and LECS 3 survey data.

The socio-economic status of rural households living in these three types of villages are quite different. Table 2.3 summarizes some information on these differences, based on the LECS 3 survey for 2002-03. Villages without road access have lower mean consumption expenditures per person and higher rates of poverty incidence than households with dry season access only, which are in turn less well off by both measures than villages with all weather access.[1] Other socio-economic indicators, relating to education and health, also support the importance of road access for the well-being of rural people. Areas with poorer roads have lower rates of school attendance for both male and female children, lower per capita expenditures on education, higher rates of sickness and lower likelihood of seeking treatment when they are ill.

[1] For comparison with these data, in 2002-03 urban households had poverty incidence of 23.64 per cent and poverty incidence for the whole of the Lao population was 31.4 per cent.

Table 2.3 Lao PDR: Welfare of rural households by road access, 2002-03

Welfare indicator	No Road Access	Dry Season Access Only	All Season Access	All rural
	HR1	HR2	HR3	HR
Real consumption expenditures per person (thousand kip)	1,712.6	1,917.0	2,280.2	2,070.1
Poverty incidence	45.57	36.05	28.64	34.17
School Attendance	51.90	70.48	80.67	69.41
Females (%)	47.54	67.82	80.00	67.06
Males (%)	56.27	72.98	81.37	71.72
Average expenditure on education (kip per student per month)	65,152	86,973	111,963	96,209
Proportion of persons who ecame ill in the last 4 weeks (%)	15.63	13.37	13.31	14.07
Of those ill, those who did not seek treatment (%)	89.80	83.16	80.69	84.35

Source: Authors' calculations from the LECS 3 survey data.

2.3 Transport costs by road type

Our interest is in identifying changes in transport cost associated with road improvement that changes road quality between these three categories of road access.

The most straightforward of these changes is represented by road improvement that converts a dry season only access road to an all weather access road. This could involve, for instance, converting a deteriorated gravel or unengineered earth track condition road to a paved or asphalt surface. As mentioned in Section 2.1, most of the road improvement that has occurred in Lao PDR over the recent past, and particularly during the period covered by this study (i.e., between LECS 2 (1997-98) and LECS3 (2002-03)) has involved the conversion of dry season only access roads to all weather access roads. The other forms of road improvement that we study involves moving from no vehicular access to dry season access.

In order to compute the effects of these changes, we need first to identify a base level of transport cost associated with each road type. This is most easily done for all weather and dry season access roads. Project performance evaluation reports of multilateral development agencies such as ADB and World Bank usually include such computations based on vehicle operating costs (VOCs), before and after the project.

A recent project by ADB, the Champasack Road Improvement Project (ADB 2003), is particularly appropriate for the computation of changes in transport costs that we are interested in. This project comprised the rehabilitation and improvement of a 200 kilometer road in Lao PDR to improve transport services in the southern region. The project is mainly focused on upgrading of roads to provide all weather connectivity between Thailand and Cambodia via the Lao PDR.[2]

Transport costs are represented by vehicle operating cost (VOC) estimates, which are themselves based mainly on road roughness as measured by the international roughness index (IRI) and a number of other factors such as utilization rates and capital costs.[3]

Table 2.4 summarizes the VOCs for dry season and all weather access roads, and the percentage change in them, for three different categories of motorized vehicles. The base level of transport costs in dry season access roads is represented by the VOC for roads classified in the gravel and earth category with an IRI of 15. This is the highest level of roughness in this category for which data are reported. The base level of transport costs for all weather access roads, on the other hand, is proxied by the VOC for paved roads with an IRI of 2.2. This is the lowest level of roughness in this category for which data are reported.

Based on these base levels of transport costs, road improvement that transforms a gravel and earth dry season access road to a paved all weather access road implies quite a significant reduction in transport costs. The last column of Table 2.4 points to some minor variation across vehicle type, with the average reduction in VOC being about half or 50 percent. In other words, transport costs are 2.01 times as high on dry season only access roads compared to all weather access roads. This is the multiple that we use in conducting our simulation relating to the impact of upgrading from dry season to all weather access in Section 4.

Table 2.4
VOC Estimates for All Weather and Dry Season Access Roads.

	VOC Estimates (in US$)		Percentage change
	Paved	Gravel and earth	in VOC

[2] The road connects Chong Mek on the Thai border to Veun Kham on the Cambodian border via Pakse in southern Lao PDR. The works comprised pavement rehabilitation, replacement of 32 bridges, improvement of feeder roads and spur roads, and periodic maintenance of key national and provincial roads in the Lao PDR. See ADB (2003) for more details.

[3] For a useful discussion on the computation of VOCs, and the relationship with the IRI, see Archondo-Callao (1999).

Vehicle\IRI	2.2	15	
Cars	0.141	0.297	52.53
Light truck	0.12	0.221	45.70
Heavy truck	0.316	0.641	50.70
Simple average	0.192	0.386	49.643

Source: Authors' computations based on data in ADB (2003).

The project performance evaluation report also presents separate estimates of changes in travel times associated with all weather and dry season access roads. Based on discussions with the Department of Communications, Transport, Posts, and Construction (DCTPC) and local villagers, the average speed of vehicles before the road improvement was estimated at 25 km/hour to 30 km/hour. After project completion, the average speed increased sharply to about 50 km/hour, amounting to a 40–50% reduction in travel time. These reductions in travel times are consistent with the reductions in VOCs reported in Table 2.4.

A number of international studies lend support to these findings from the Champasack Road project. Minten and Kyle (1999), for instance, analyze the causes of food price variation in Kinshasa (the capital of the former Zaire) using survey data collected from itinerant traders. They find that transportation costs were on average two times greater on dirt roads than on paved roads. A study by Levy (1996) on the impact of converting dry season access to all season access roads in Morocco found that travel times, in most cases, were cut by at least 50 percent. Other studies that focus on the link between infrastructure and trade such as Limao and Venables (1999) and Delgado *et al.* (1995) also report reductions in transport costs along the same order of magnitude.

Next we consider the no vehicular access case. Identifying a base level of transport cost for this case is more difficult, for various reasons. This is a residual category and the surfaces that belong to this classification can vary significantly and are not as well defined as those in the all weather and dry season access categories. The binding constraint however relates to difficulties associated with measuring or estimating the roughness of such "roads" and determining the grading frequency to be applied to it in computing VOCs. Because of this constraint, there is no easy way of computing VOCs directly, and an indirect approach is required. We use some interesting work by Starkey (2001, 2006) to estimate the relative magnitudes between no vehicular access and dry and all weather access cases.

Starkey (2001) analyzes how VOCs for different modes of transport change with distance and tonnage. Using his work, we proxy the type of road access by type of vehicle used. When there is no road access, we represent transport cost with the VOC for bicycles. Dry season access roads are proxied by pickups, on the assumption that they are better suited to navigate such roads, even during the wet season. All weather access roads are represented by the VOC for trucks. Trucks generally carry heavier loads than pickups, and thereby require a better surface condition to operate on. The VOC estimates for these three modes of transportation, and how they vary with load, are summarized in Table 2.3. The VOC estimates reported in Table 2.5 are measured in US dollars as the cost per ton of output per kilometer traveled.

Table 2.5
VOC Estimates for No Vehicular Access, Dry Season Access, and All Weather Roads

	VOCs (per km per ton, in US$)						
Tonnage	10	50	250	500	1000	1500	2000
Bicycle	1.2	1.15	1.15	1.15	1.15	1.15	1.15
Pickup	<1.25	<1.25	0.8	0.5	0.38	0.35	0.35
Truck	<1.25	<1.25	1.25	0.7	0.4	0.25	0.2
	Percentage difference in VOCs compared to Bicycle						
Pickup	--	--	30.43	56.52	66.96	69.57	69.57
Truck	--	--	-8.70	39.13	65.22	78.26	82.61

Source: Authors' computations based on data in Starkey (2001).

Assuming a 10 kilometer distance traveled, Starkey finds that the VOC for transport via bicycle remains relatively unchanged at about 1.15 irrespective of tonnage. This is probably due to the fact that there are no cost savings to be generated as a result of scale economies with this medium of transport.

For pickups, the VOC remains above that of bicycles for loads up to 50 tons. The fixed cost associated with operating a pickup needs to be spread over a larger load before the VOC drops below that of bicycles. This occurs at about the 100 ton load level. Beyond this level, the VOC drops quite sharply, reaching a low of 0.35 when the load reaches 1500 tons. This is about a 70 percent reduction in VOC compared to bicycles, or about one-third the relative cost.

Since the fixed cost associated with operating trucks is higher than pickups, the VOC remains above that of pickups until the load exceed 1000 tons. It continues to fall until the load reaches 2000 tons, where it is at a minimum of 0.2. This is about an 83 percent reduction in VOC compared to bicycles, or about one-sixth the relative cost.

For the simulations that we conduct in Section 4 on the impact of reductions in transport costs, we use the VOCs associated with a load of 2000 tons because this is when they are at their minimum for all three types of vehicles.

3. A General Equilibrium Model of the Economy of Lao PDR

This section describes *LaoGEM* (Lao General Equilibrium Model), a 20 sector, 400 household general equilibrium model of the Lao economy, constructed specifically for the analysis of the effect of road improvement on rural poverty incidence in Lao PDR. Unless otherwise stated, the database of the model refers to the year 2002. The model's main features are as follows.

3.1 Model structure

The theoretical structure of *LaoGEM* is relatively conventional. It belongs to the class of general equilibrium models which are linear in proportional changes, sometimes referred to as Johansen models. The highly influential *ORANI* general equilibrium model of the Australian economy (Dixon, *et al.* 1982) also used this approach. The detailed structure of *LaoGEM* is based on the *PARA* and *Wayang* general equilibrium models of the Thai and Indonesian economies, respectively, described in detail in Warr (2001) and Warr (2005), respectively.[4] However, this general structure is adapted to reflect the specific objectives of the present study and important features of the Lao economy.

The microeconomic behaviour assumed within *LaoGEM* is competitive profit maximisation on the part of all firms and competitive utility maximisation on the part of consumers. Each industry has a constant returns to scale technology and there is at least one industry-specific factor present in each industry. In the simulations reported in this paper, the markets for final outputs, intermediate goods and factors of production are all assumed to clear at prices that are determined endogenously within the model.[5] The nominal exchange rate between the Lao *kip* and the US dollar is fixed exogenously. The role within the model of the exogenous nominal exchange rate is to determine, along with international prices, the nominal domestic price level. The model is homogeneous (degree one for prices and degree zero for quantities) with respect to this exchange rate. This means that because domestic prices adjust flexibly to clear markets, a 1 percent increase in the kip/dollar exchange rate will result in a 1 percent increase in all nominal domestic prices, leaving all real variables unchanged.

Industries

The model contains 20 industries, listed in Appendix Table 1. They include three agricultural industries: crops; livestock and poultry; forestry and logging. Non-agricultural industries include: mining and quarrying; seven manufacturing industries; and nine services and utilities industries, one of which is transport. The transport industry will be important for the present study. Each industry produces a single output, and the set of commodities therefore coincides with the set of industries. Exports are not identical with domestically sold commodities. In each industry the two are produced by a transformation process with a constant elasticity of transformation.

The core of the production side of the model is a 20 sector input-output table for Lao PDR, estimated especially for this study. No input-output table is currently available for Lao PDR and the table constructed for the present study is thus the first publicly available input-output table for the country. It is based on information from two sources. First, there is a 20 sector input-output table for Savannaket Province of Lao PDR, relating to the year 2003, recently constructed in a detailed study by researchers at the Asian Development Bank (Abuzar, et al 2005). This table is then adjusted using data from the Lao National Accounts for 2002. The method of adjustment may be understood as follows. The value added totals for the various sectors of the Savannaket table are compared with those for Lao PDR, derived from the National Accounts. The Savannaket table is then amended using a method called RAS (row and column sum) to force the value added totals to match those for Lao PDR.

The resulting table has a structure which reflects the industry structure of Lao PDR, as reflected in its National Accounts, but within each industry the input-output

[4] The structure also draws on elements of a revised version of the *ORANI* model of the Australian economy called *ORANI-G* (Horridge 2004).

[5] Variations to this assumption are possible. For example, the possibility of unemployment can be introduced by varying the closure to make either real or nominal wages exogenous, thereby allowing the level of employment to be endogenously determined by demand.

technology reflects that of Savannaket Province. The method thus assumes that the input-output technology for each industry in Lao PDR is similar to that of Savannaket, even though the relative importance of these various industries in Lao PDR is quite different from that of Savannaket. Fortuitously, Savannaket Province seems a suitable basis for this kind of exercise in that it is roughly intermediate within the provinces of Lao PDR in terms of its level of technology, neither the most nor the least advanced. The resulting table seems to make sense. When a properly constructed input-output table for Lao PDR becomes available, it should presumably replace the table constructed as above. In the meantime, this table is considered the best available. The cost structures of these 20 industries, derived from this IO Table, are summarized in Appendix Table 2 and their sales structures are summarized in Appendix Table 3.

Commodities

Although the sets of producer goods and consumer goods have the same names, the commodities themselves are not identical. Each of the 20 consumed goods consists of a composite of the domestically produced and imported version of the same commodity, where the two are imperfect substitutes. The proportions in which they are combined reflect consumer choices and depend on both (a) the relative prices of these imported and domestically produced versions of the good and (b) the (Armington) elasticity of substitution between them.

Factors of production

The mobility of factors of production is a critical feature of any general equilibrium system, where the term 'mobility' here means mobility across economic activities (industries), rather than geographical mobility. The greater the factor mobility that is built into the model, the greater is the flexibility of the economy, as reflected in its simulated capacity to respond to changes in the economic environment. It is clearly essential that assumptions about the mobility of factors of production be consistent with the length of run that the model is intended to capture.

Labor is assumed to be fully mobile across all sectors. These assumptions imply that wages must be equal in all sectors, and move together. There are three kinds of capital: capital that is immobile across industries but mobile within industries, referred to subsequently as fixed capital; capital that is mobile among agricultural industries but not mobile between agriculture and the non-agricultural industries, referred to as agricultural mobile capital; and capital that is mobile among the non-agricultural industries but not between these industries and the agricultural industries, referred to here as non-agricultural mobile capital.

In this treatment, fixed capital in agriculture is thought of as including some land, but also some light machinery and equipment of an industry-specific kind. Mobile capital in agriculture includes some land but also machinery such as light tractors and also draft animals that can be used in the production of a range of agricultural commodities. Neither agricultural land nor agricultural capital (machinery and draft animals) are usable in the non-agricultural industries. Non-agricultural capital is thought of as including industrial machinery and buildings.

Technology

In every sector, it is assumed that there is constant elasticity of substitution (CES) production technology with diminishing returns to scale to variable factors alone. However, there is also a sector specific fixed factor (immobile capital or land) in every sector to assure that there are constant returns to scale in production to all factors. For convenience, we shall refer to the set of specific factors in the agricultural sectors as 'land', and to the set of those in the non-agricultural sectors as 'fixed capital', but for the reasons described above, this language is accurate only in an approximate way. The assumption of constant returns means that all factor demand functions are homogeneous of degree one in output. In each sector, there is a zero profit condition, which equates the price of output to the minimum unit cost of production. This condition can be thought of determining the price of the fixed factor in that sector.

Factor mobility and length of run

The mobility across sectors of labor, but only partial immobility of capital, means that the analysis refers to a short-run to intermediate-run period of adjustment – not very short-run, or else labor would not be fully mobile and capital might not be mobile at all – and not very long run, or else capital would be more fully mobile. The period of adjustment consistent with these assumptions is thus between 2 and 5 years.

Households

The model contains four major household categories – one urban (subsequently HU) and three rural. The three rural categories are differentiated by the quality of road access shared by the members of the village concerned. The three categories of road access are summarized in Table 3.1.

Table 3.1 Naming of household categories

Description	Classification
Urban	HU
Rural, no road access	HR1
Rural, dry season access	HR2
Rural, all season access	HR3

Category HR1 refers to villages not serviced by a road at all, meaning that the only access to the village is by foot or by motorcycle, along pathways, but not reachable by vehicles. Category HR2 refers to dirt roads which are not usable during the wet season. Category HR3 refers to sealed roads or well maintained dirt or gravel roads which can be used by vehicles at all times of the year.

The incomes of each of these three household types depend on their ownership of factors of production, the returns to those factors, and their non-factor incomes, mainly consisting of transfers from others. Since our focus is on income distribution, the sources of income of the various households are of particular interest. These differ among the four household categories. The data are extracted from the 2002-03 household income and expenditure survey, the Lao Expenditure and Consumption

Survey, commonly called LECS 3.[6] The SAM is based on data from this survey, the input-ouput table described above, the Lao National Accounts for 2002 and Lao trade data.

Within the *LAOGEM* model, each of the four household categories is sub-divided into a further 100 sub-categories (centile groups) each of the same population size, arranged by real consumption expenditures per capita, giving a total of 400 sub-categories.[7] The consumer demand equations for the various household types are based on a Cobb-Douglas demand system, using data on expenditure shares extracted from the LECS 3 survey. Within each of the 4 major categories, the 100 sub-categories thus differ according to both (i) their budget shares in consumption and (ii) their sources of factor and non-factor incomes.

Elasticity estimates

The elasticity estimates used in *LaoGEM* for the factor demand systems were taken from empirical estimates derived econometrically for a structurally similar model of the Thai economy, known as *PARA*. These parameters were amended to match the differences between the data bases for *LaoGEM* and *PARA* so as to ensure the homogeneity properties required by economic theory. All export demand elasticities were set equal to 20. The elasticities of supply of imports to Lao PDR were assumed to be infinite and import prices were thus set exogenously. All production functions are assumed be CES in primary factors with elasticities of substitution of 0.5 except for the paddy production industry where this elasticity is set at 0.25, reflecting the empirical observation of low elasticities of supply response in this industry. The Armington elasticities of substitution in demand between imports and domestically produced goods were set equal to 2 for all commodities.

Treatment of transport costs

The information on transport costs described in Section 2, above, is used to allocate the output of the "transport" industry in the input-output table to transport margins between consumer and producer prices in each of the four household categories. The relative magnitudes of total transport costs for each category of rural household are estimated as total tonnage of goods transported multiplied by distance to nearest market multiplied by vehicle operating cost per kilometer on this type of road. Transport costs are assumed to be incurred primarily between the local market and the village concerned.

The distribution of total tonnage of goods transported is proxied as the distribution of total expenditure across the household groups, calculated as mean expenditure per person estimated in the LECS 3 survey multiplied by total population of the household group. Distance to the nearest market is proxied as distance from the village to the nearest post office, as recorded in the LECS 3 survey. Vehicle operating costs are estimated for HR2 to HR3 from an ADB study of Champassak province

[6] As noted above, the "3" in LECS 3 signifies that it is the third (and currently the most recent) such survey to be conducted. The previous two (LECS 1 and 2) were for 1992-93 and 1997-98, respectively.

[7] The population sizes of the 4 major categories are not the same, but *within* each of these 4 categories the population sizes of the 100 sub-categories are the same.

(ratio = 2.01) and the ratio for HR1 to HR2 is taken from Starkey (2001) (ratio = 2.86, implying a ratio to HR3 of 5.75).

This gives the ratio of total transport costs for the three categories of rural households shown in the final row of Table 3.2. These proportions are then used to allocate the total output of the "transport" sector of the input output table to transport margins in the three categories of rural households. Transport margins thus differ across the three categories of rural households but within each of these categories they are the same for all households. Within each household category, the transport margins are the same for all commodities as proportions of consumer prices.

There are two other categories of margins between consumer and producer prices defined within the model – trade and tax margins. As Appendix Table 3 shows, trade margins are even larger in total magnitude than transport margins. It is assumed in this study that trade margins (meaning costs of warehousing, retailing and advertising) do not depend on the type of road servicing a particular village. Trade and tax margins are therefore assumed to be the same for all households and as proportions of consumer prices trade margins are the same for all commodities, while tax margins differ according to the tax rates concerned.

Table 3.2 Lao PDR: Estimating total transport costs by rural household category

Household group		HR1 (No Road)	HR2 (Dry Season)	HR3 (All season)	HU (Urban)
Mean expenditure per capita (Kip)		106,971	118,799	145,704	260,646
Population		949,698	708,054	2,197,436	1,374,542
Population share (%)		18%	14%	42%	26%
Total expenditure (million Kip)	A	101,590	84,116	320,176	358,269
Distance to nearest post office (KM)	B	36.67	29.61	13.47	0
Ratio to HR3		**2.64**	**1.84**	**1**	**0**
Vehicle operating cost ($/KM)	C	1.104	0.386	0.192	0
Ratio to HR3		**5.75**	**2.01**	**1**	**0**
Total transport cost = A×B×C	D	4,284,121	871,736	862,553	0
Ratio to HR3	E	**4.97**	**1.16**	**1.00**	**0**

Note: Row D = Rows A×B×C

Source: Authors' calculations based on data from National Statistical Centre, Vientiane, *Lao Expenditure and Consumption Survey, 2002-03* (LECS 3), ADB (2003) and Starkey (2001).

In summary, the estimates of the relative magnitudes of total transport costs shown in row E of Table 3.2 are used as the basis for allocating total transport margins among the three rural household categories defined in the model. This is relevant for the construction of the *data base* of the model. The vehicle operating costs shown in row C are used as the basis for calculating the *shocks* which are described below.

4. Simulating the Effects of Transport Cost Reductions on the Poor

4.1 The shocks

The *shocks* are summarized in Table 4.1. The shocks are interpreted as changes in vehicle operating costs per kilometer. Of course, upgrading a road does not change the distance it has to cover, so the shocks change only the per kilometre costs of operating vehicles on them. Four simulations are reported in this paper. The magnitudes of the shocks used draw upon the vehicle operating costs summarized in row C of Table 3.2.

Simulation S1 represents a reduction of transport costs per kilometer in households currently serviced by dry season access only roads (HR2 households) from their current levels to the transport cost levels per kilometer of all weather access roads (HR3 households). The simulation estimates the effects of making this change in all households currently serviced by dry season access only roads. As shown in the discussion of Table 2.2 above, this change captures the type of road improvement that has dominated in Lao PDR, at least over the five years between the LECS 2 survey period (1997-98) to the LECS 3 survey period (2002-03). Dry season access roads have been converted to all weather access roads. Thus, in Simulation 1 transport costs facing HR2 households are reduced by 100(0.386 – 0.192)/0.386 = 50.25 %. Other households' transportation costs do not change.

In Simulation S2, the transport cost faced by household HR1 (no road access) is reduced sufficiently to make it match that of household HR2 (dry season access), or 100(1.104-0.386)/1.104 = 65.04 %.

As will be seen when the results are discussed, Simulation S2 produces a much larger reduction in poverty than Simulation S1. The remaining two sets of experiments, Simulation S3 and Simulation S4 thus experiment with arbitrarily smaller reductions in the transport cost facing HR1 households than is represented by S2. S3 simulates the effect of transport cost reduction half as large as S2 and S4 shows the effect of transport cost reductions one quarter of S2.

Table 4.1 Summary of simulations

Simulation	Interpretation
Simulation S1	Reduce margin to HR2 by 50.25%
Simulation S2	Reduce margin to HR1 by 65.04%
Simulation S3	Reduce margin to HR1 by 32.57%

Simulation S4	Reduce margin to HR1 by 16.26%

4.2 Model closure

Since the real consumption expenditure of each household is chosen as the basis for welfare measurement, and is the basis for the calculation of poverty incidence, the macroeconomic closure must be made compatible with both this measure and with the single-period horizon of the model. This is done by ensuring that the full economic effects of the shocks to be introduced are channeled into current-period household consumption and do not 'leak' into other directions, with real-world intertemporal welfare implications not captured by the welfare measure. The choice of macroeconomic closure may thus be seen in part as a mechanism for minimizing inconsistencies between the use of a single-period model to analyze welfare results and the multi-period reality that the model represents.

To prevent intertemporal and other welfare leakages from occurring, the simulations are conducted with balanced trade (exogenous balance on current account). This ensures that the potential benefits from the export tax do not flow to foreigners, through a current account surplus, or that increases in domestic consumption are not achieved at the expense of borrowing from abroad, in the case of a current account deficit. For the same reason, real government spending and real investment demand for each good are each held fixed exogenously. The government budget deficit is held fixed in nominal terms. This is achieved by endogenous across-the-board adjustments to personal income tax rates so as to restore the base level of the budgetary deficit.

The combined effect of these features of the closure is that the full effects of changes in policy are channeled into household consumption and not into effects not captured within the single period focus of the model.

4.3 Simulation results

The estimated effects are summarized in Tables 4.2 and 4.3. In each case, real GDP increases and both rural poverty incidence and total poverty incidence decline. But it is notable in Simulation S2 the stimulus to GDP and the reduction in poverty incidence are both much larger. Shock S2 increases real GDP by 6 times as much as shock S1 (1.41 vs. 0.22). But it reduces total poverty incidence by 17 times as much (1.01 vs. 0.06). Indeed, when the transport cost reduction represented by Simulation S2 is reduced to one quarter of the S2 level, the reduction in poverty incidence is still four times as large as occurs under S1.

One seeming anomaly must be explained. General equilibrium models are capable of detecting small indirect effects of external shocks that might not otherwise be obvious. Transport cost reductions produce substantial benefits for the direct recipients, but there are small, indirect effects on non-recipients that can be positive or negative. For example, in Simulation S1, households in the HR2 category (dry season access only) are the direct beneficiaries and a large reduction in poverty incidence occurs in this group. But there is also a small reduction in poverty in the

HR1 category (no road access) while small increases occur in the HR3 (all weather access) and HU (urban) household groups. The main reason for these effects is that the income gains for HR2 households shift the demand pattern for final consumer goods. Households which consume similar patterns of final goods to HR2 tend to incur small indirect negative effects because their costs of living increase. In this case, this explains the small negative effect on poverty incidence among HR3 and HU households.

5. Conclusions: How Improving Roads Affects Poverty Incidence

Our analysis indicates that reducing transport costs through rural road improvement generates significant reductions in poverty incidence. It does this through improving the income earning opportunities of rural people and through reducing the costs of the goods they consume. A feature of our results is that when no vehicle access areas are provided with dry season access roads (dirt and gravel), the reduction in poverty incidence is about 17 times the reduction that occurs when dry season access only roads are upgraded to all weather access (paved and improved gravel) roads. The ratio of the effect on GDP is about 6.

Reducing transport costs for households without road access is highly pro-poor. These results do not demonstrate that road improvement should be shifted away from upgrading dry season access roads to providing road access to villages currently lacking it. Both forms of road improvement are important. Moreover, the costs of road building in the two cases need to be taken into account in determining the most appropriate road building strategy. This paper has not looked into these costs. However, our results confirm that there is considerable scope for reducing poverty incidence in Lao PDR by reducing rural transport costs through improving the quality of rural roads.

References

Codsi, G., K.R. Pearson, and P.J. Wilcoxen (1991). 'General Purpose Software for Intertemporal Modeling', *Impact Working Paper* , No. IP-51 University of Melbourne, Melbourne, Victoria, Australia, May.

Datt, Guarav and Limin Wang (2001). 'Poverty in Lao PDR: 1992/93 – 1997/98', World Bank, Washington DC, mimeo.

Dixon, P.B., B.R. Parmenter, J. Sutton and D.P. Vincent (1982). *ORANI: A Multisectoral Model of The Australian Economy*, Amsterdam: North-Holland.

George Fane and Peter Warr (2002). 'How Economic Growth Reduces Poverty: A General Equilibrium Analysis for Indonesia', in A. Shorrocks and R. Van der Hoeven (eds.), *Perspectives on Growth and Poverty*, United Nations University Press, 217-34.

Horridge, M. (2004). 'ORANI-G: A Generic Single-Country Computable General Equilibrium Model', Centre of Policy Studies, Monash University, Melbourne, available at: http://www.monash.edu.au/policy/oranig.htm (accessed 6 October, 2006).

Kakwani Nanak, Guarav Datt, Bounthavy Sisouphanthong, Phonesaly Souksavath and Limin Wang (2002). 'Poverty in Lao PDR during the 1990s', Asian Development Bank, Manila, mimeo.

Richter, Kaspar, Roy van der Weide and Phonesaly Sopuksavath (2005). Lao PDR Poverty Trends 1992/3 – 2002/3, Draft Report, Committee for Planning and Investment, National Statistical Center and World Bank, Vientiane, March.

Warr, Peter (2001). 'Welfare Effects of an Export Tax: Thailand's Rice Premium', *American Journal of Agricultural Economics*, vol. 83 (November), 903-920.

Warr, Peter (2005). 'Food Policy and Poverty in Indonesia: A General Equilibrium Analysis', *Australian Journal of Agricultural and Resource Economics*, vol. 49 (December), 429-451.

Table 4.2 Simulated Macroeconomic Effects of Road Improvements

(Units: per cent change)

Simulation		**S1**	**S2**	**S3**	**S4**
Overall economy					
Gross Domestic Product					
Nominal (local currency)		-0.24	-1.19	-0.61	-0.31
Real		0.22	1.41	0.70	0.35
Consumer Price Index		-0.46	-2.60	-1.32	-0.66
GDP Deflator		-0.46	-2.56	-1.30	-0.65
Wage (nominal)		-0.40	-2.15	-1.05	-0.51
Wage (real)		0.06	0.46	0.27	0.15
External sector (foreign currency)					
Export Revenue		0.30	1.56	0.77	0.38
Import Bill		0.09	0.52	0.25	0.12
Government Budget (local currency)					
Revenue	Total revenue	0.05	0.39	0.17	0.08
	Tariff revenue	0.09	0.52	0.25	0.12
Expenditure	Nominal	-0.22	-1.18	-0.58	-0.29
Household sector					
Consumption	Nominal (local currency)	-0.26	-1.26	-0.65	-0.33
	Real (CPI deflator)	0.20	1.38	0.68	0.33

Table 4.3 Simulated Distributional Effects of Road Improvements

(Units: as indicated in parentheses)

Simulation			**S1**	**S2**	**S3**	**S4**
Real consumption expenditures per person, deflated by household-specific CPI (% change, except ex-ante levels)						
		Ex-ante level	**Per cent change**			
		(thousand kip)	**S1**	**S2**	**S3**	**S4**
Rural households	HR1	1,712.6	0.27	15.40	7.48	3.68
	HR2	1,917.0	2.83	0.13	0.03	0.00
	HR3	2,280.2	-0.04	-0.14	-0.09	-0.05
Total rural population		2,070.1	0.47	3.05	1.51	0.75
Total urban population	HU	5,598.6	-0.13	-0.66	-0.34	-0.17
Total population		2,882.3	0.20	1.38	0.68	0.33
Poverty Incidence (level, % population concerned)						
		Ex-ante level	**Ex-post level**			
			S1	**S2**	**S3**	**S4**
Rural households	HR1	45.57	45.47	39.15	41.49	43.72
	HR2	36.05	35.37	36.07	36.07	36.06
	HR3	28.64	28.67	28.74	28.70	28.67
Total rural population		34.17	34.04	32.65	33.20	33.73
Total urban population	HU	23.64	23.76	24.05	23.95	23.80
Total population		31.40	31.34	30.39	30.77	31.12
Change in poverty Incidence (absolute change, % of population concerned)						
			Ex-post level – Ex-ante level			
			S1	**S2**	**S3**	**S4**
Rural households	HR1		-0.10	-6.42	-4.08	-1.85
	HR2		-0.68	0.02	0.02	0.01
	HR3		0.03	0.10	0.06	0.03
Total rural population			-0.13	-1.52	-0.97	-0.44
Total urban population	HU		0.12	0.41	0.31	0.16
Total population			-0.06	-1.01	-0.63	-0.28

Figure 4.1 Changes in the cumulative distribution of real expenditures in Simulation S1

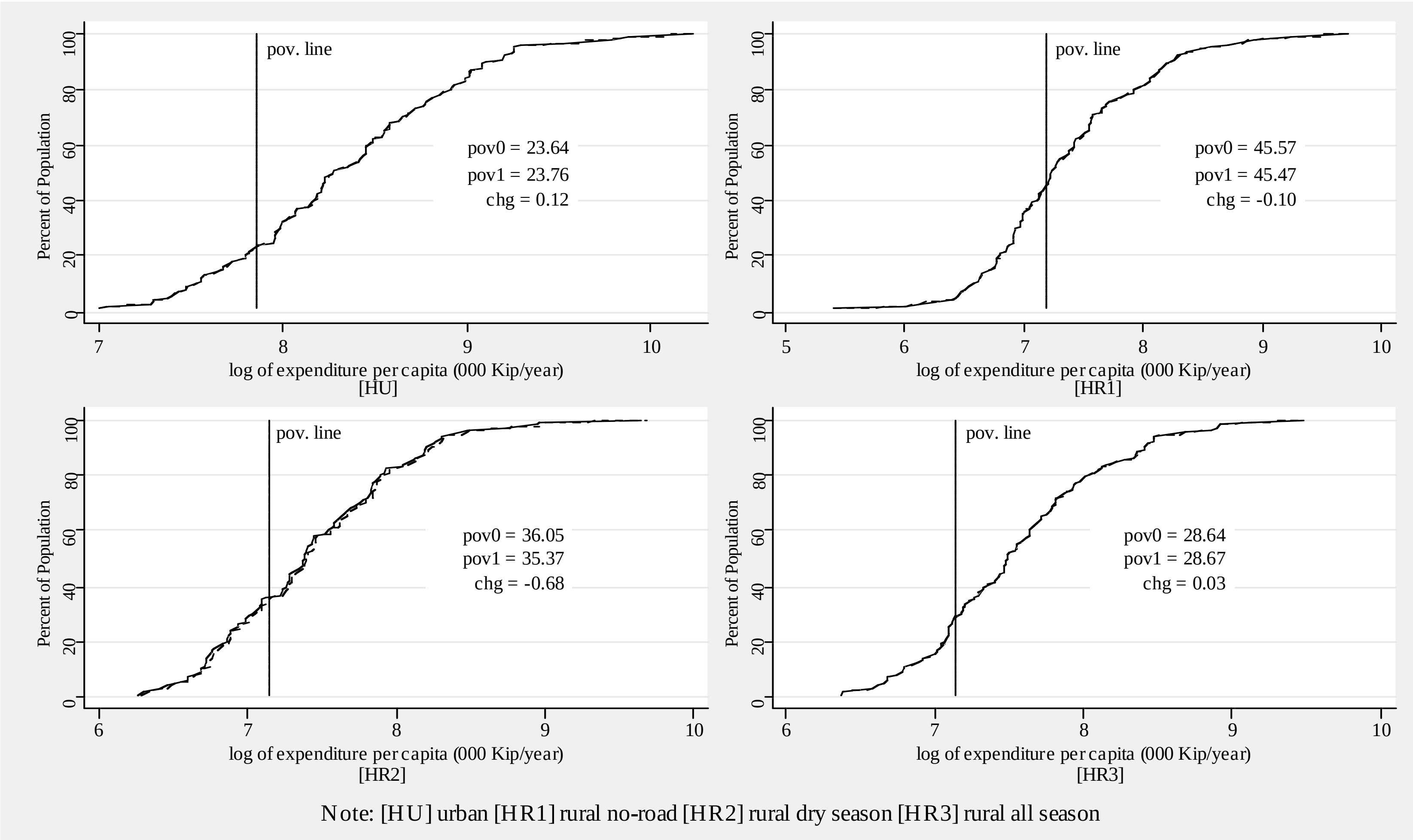


Figure 4.2 Changes in the cumulative distribution of real expenditures in Simulation S2

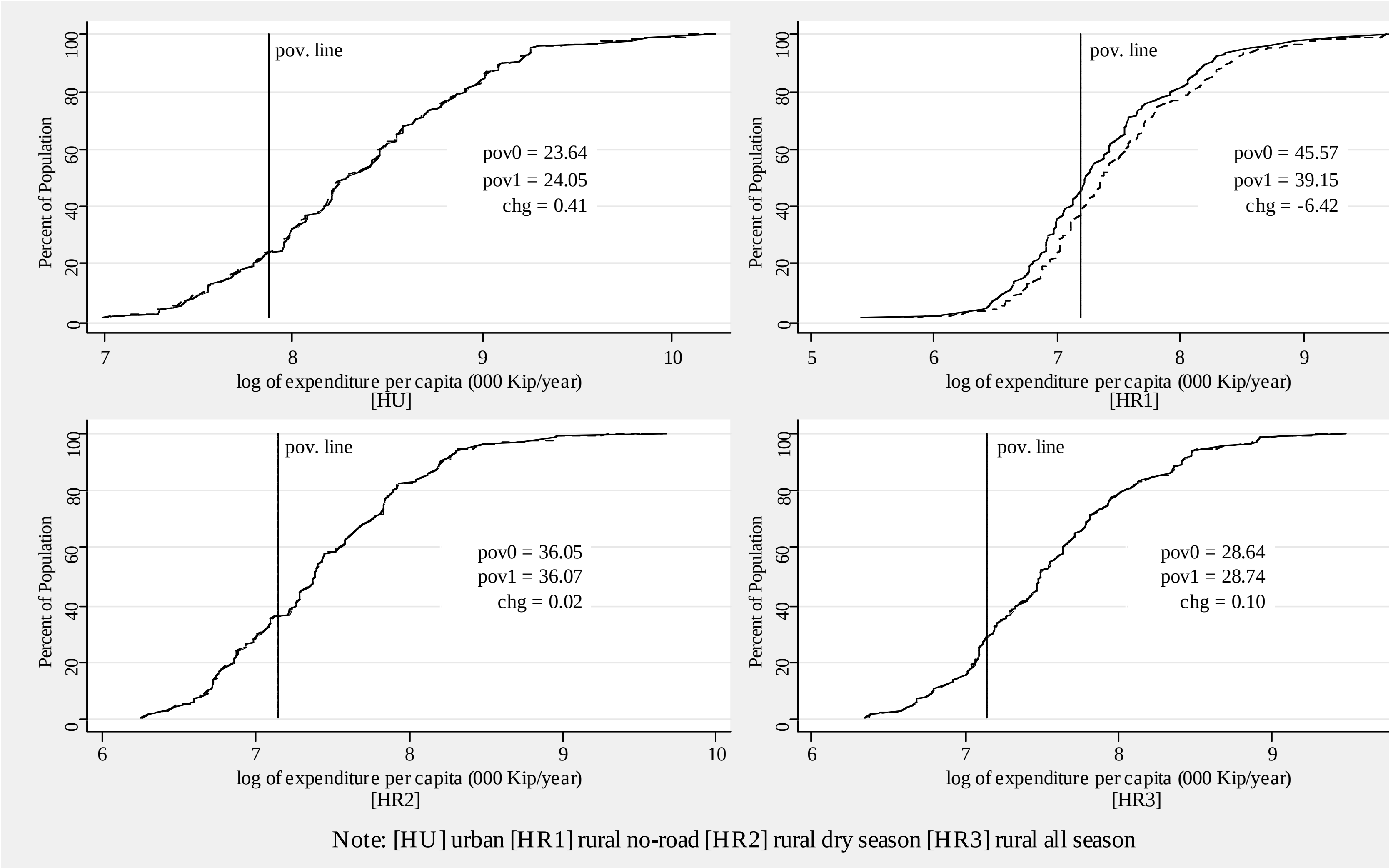
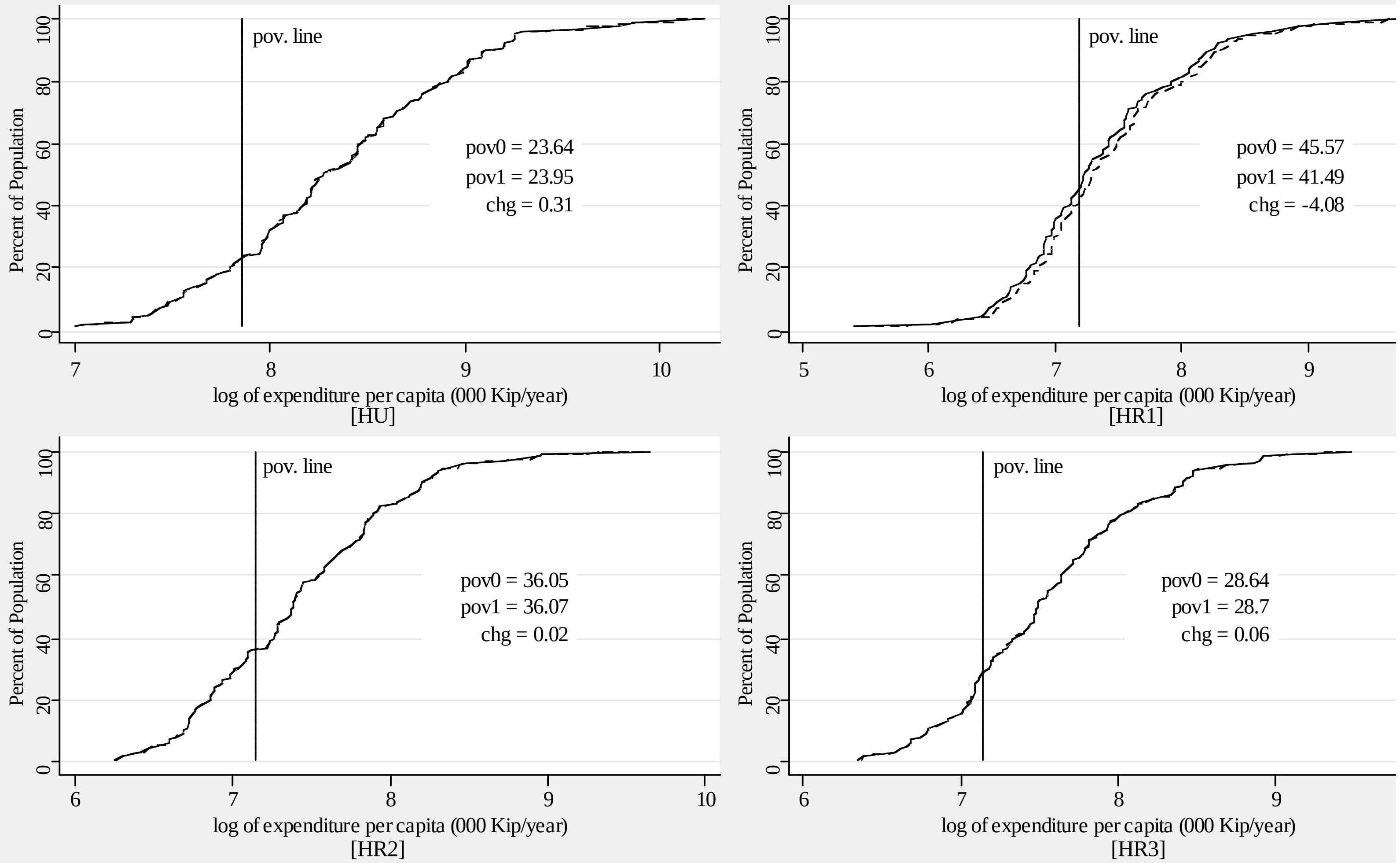
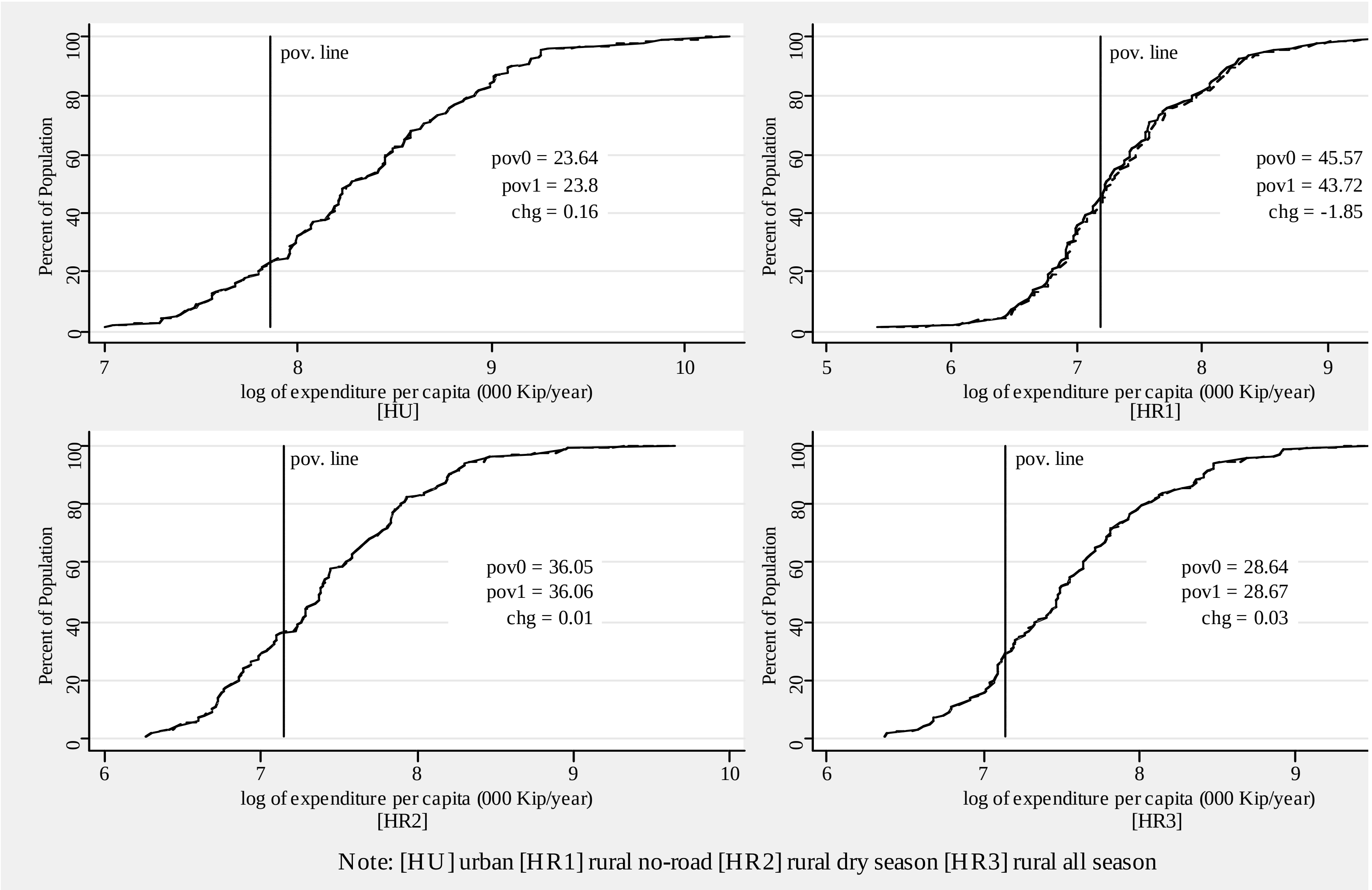


Figure 4.3 Changes in the cumulative distribution of real expenditures in Simulation S3



Note: [HU] urban [HR1] rural no-road [HR2] rural dry season [HR3] rural all season

Figure 4.4 Changes in the cumulative distribution of real expenditures in Simulation S4



Appendix Table 1 The *LaoGEM* Model: List of Industries

Crops	1 CROPS
Livestock and poultry	2 LVSTK
Forestry and logging	3 FOREST
Mining and quarrying	4 MINING
Food, beverage and tobacco	5 FOOD
Textiles, garments & leather products	6 TEXTILE
Wood & paper products; printing/publishing	7 WOOD
Petroleum and chemical products	8 PETROLEUM
Non-metallic mineral products	9 MINERAL
Metal prods, machinery, equipment, spare parts	10 METAL
Other manufactured goods	11 OTHMAN
Electricity and water supply	12 ELECWAT
Construction	13 CONSTR
Transportation	14 TRANSP
Post and telecommunication	15 POSTEL
Wholesale and retail trade	16 TRADE
Banking, insurance, business services	17 BANK
Real estate & ownership of dwellings	18 ESTATE
Public administration	19 GOVT
Personal, social & community services	20 OTHSERV

Appendix Table 2 The *LaoGEM* Model: Cost Structure of Domestic Industries (Million Kip)

Industry	1 Intermediate Domestic	2 Intermediate Imported	3 Margin	4 Indirect Tax	5 Labor	6 Capital	7 Land	8 Production Tax	Total
1 CROPS	242,954	100,077	22,661	3,719	2,745,382	1,766,305	883,152	1	5,764,251
2 LVSTK	1,386,197	150,889	120,191	15,107	844,254	1,519,619	759,808	1	4,796,067
3 FOREST	20,760	13,988	4,861	1,359	241,079	199,710	99,855	1	581,613
4 MINING	416,239	1,430,354	219,600	24,821	31,996	35,120	17,560	1	2,175,692
5 FOOD	6,426,728	264,542	457,400	86,018	885,301	1,806,187	-	1	9,926,175
6 TEXTILE	116,471	56,690	21,104	1,870	64,003	134,604	-	1	394,744
7 WOOD	418,414	140,440	88,632	29,851	30,608	72,898	-	1	780,844
8 PETROLEUM	2,879	16,105	2,392	205	261	796	-	1	22,641
9 MINERAL	49,160	53,510	16,252	1,956	37,046	70,513	-	1	228,438
10 METAL	23,424	124,715	19,445	1,476	17,235	33,163	-	1	219,459
11 OTHMAN	11,879	114,847	18,745	907	43,859	118,104	-	1	308,343
12 ELECWAT	209,009	67,005	26,488	12,016	133,952	348,218	-	1	796,690
13 CONSTR	352,785	511,014	163,392	9,271	159,856	229,981	-	1	1,426,301
14 TRANSP	72,942	116,749	21,399	2,458	465,901	463,261	-	1	1,142,711
15 POSTEL	19,644	39,002	6,172	658	54,258	84,834	-	1	204,569
16 TRADE	171,540	242,173	56,453	7,797	563,077	1,073,985	-	1	2,115,025
17 BANK	31,194	2,839	7,887	986	12,295	133,455	-	1	188,656
18 ESTATE	43,086	609	1,220	1,278	87,633	391,718	-	1	525,546
19 GOVT	252,489	123,958	32,813	6,389	510,126	1	-	1	925,777
20 OTHSERV	330,197	826,517	177,493	12,534	192,129	316,125	-	1	1,854,996
Total	10,597,991	4,396,025	1,484,601	220,675	7,120,254	8,798,596	1,760,376	20	34,378,536

Appendix Table 3 The *LaoGEM* Model: Sales Structure of Domestic Industries and Commodities (Million Kip)

	1 Intermediate	2 Investment	3 Households	4 Export	5 Government	6 Stocks	7 Margins	8 Total	9 Imports	Total
1 CROPS	2,754,562	488,542	2,190,597	330,549	0	1	0	5,764,251	224,806	11,753,308
2 LVSTK	4,087,407	647,224	28,763	32,670	0	1	0	4,796,067	0	9,592,132
3 FOREST	456,644	66,678	29,999	28,291	0	1	0	581,613	0	1,163,227
4 MINING	130	695	0	2,174,866	0	1	0	2,175,693	0	4,351,385
5 FOOD	984,019	717,400	8,217,420	7,334	2	1	0	9,926,176	372,004	20,224,356
6 TEXTILE	106,344	25,497	226,109	36,793	0	1	0	394,744	238,884	1,028,371
7 WOOD	35,259	1,423	5,496	738,665	0	1	0	780,844	117,941	1,679,629
8 PETROL'M	12,919	1	1,132	8,589	0	-1	0	22,641	2,292,650	2,337,932
9 MINERAL	221,442	1	5,310	1,685	0	-1	0	228,438	0	456,875
10 METAL	142,370	40,577	24,751	11,759	0	1	0	219,459	2,324,624	2,763,543
11 OTHMAN	180,407	16,862	78,087	32,986	0	1	0	308,343	28,193	644,880
12 ELECWAT	625,640	1	171,050	0	0	-1	0	796,690	0	1,593,380
13 CONSTR	67,154	1,346,019	13,127	0	0	1	0	1,426,301	0	2,852,601
14 TRANSP	0	1	0	0	0	-1	1,142,711	1,142,711	132,988	2,418,410
15 POSTEL	122,301	1	82,267	0	0	-1	0	204,569	0	409,137
16 TRADE	124,399	13,657	73,446	0	1	1	1,903,522	2,115,025	0	4,230,051
17 BANK	180,052	1	8,604	0	0	-1	0	188,656	0	377,313
18 ESTATE	65,233	1	460,313	0	0	-1	0	525,546	0	1,051,092
19 GOVT	0	1	121,949	0	803,828	-1	0	925,777	0	1,851,555
20 OTHSERV	431,707	1	1,423,289	0	1	-1	0	1,854,996	0	3,709,992
Total	10,597,991	3,364,582	13,161,709	3,404,187	803,832	2	3,046,233	34,378,540	5,732,091	74,489,168