Road Improvement and Poverty Reduction in Laos

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abstract

Laos is a mountainous country with poor roads and a high rate of poverty incidence, especially in rural areas. It is obvious that better roads could reduce poverty, but by how much? And what forms of road improvement reduce poverty the most? The economic effects of road improvement are complex and multi-channeled. This paper uses a multi-household general equilibrium modeling approach to study these issues. The results indicate that road improvement does reduce poverty but that the quantitative impact depends heavily on the types of road that are provided and the areas in which the road is located.

Key words: General equilibrium modelling; infrastructure; poverty; Southeast Asia.

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1. Introduction

It is obvious that low quality roads impose costs on people living far from market centers. This is nowhere more apparent than in a country like Lao PDR (subsequently Laos, for brevity). The terrain 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, this means that these people are the most disadvantaged by the high transport costs resulting from bad roads. Over the past two decades Laos 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 very 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 Laos. The investors include the Lao government itself and a vast array of bilateral and multilateral aid donors. 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 Laos, 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 attempts to draw out the major conclusions that follow from the study.

2. Road Quality, Transport Costs and Poverty Incidence[2]

Motorized vehicles are the dominant mode of transport in Laos, carrying 91 per cent of total freight ton-kilometers and 95 per cent of total passenger-kilometers. The road system in Laos, which totals just above 31,000 kilometers, is mostly in poor condition. 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, or about 23 percent of the road network. About half of this national road network is now paved, with the remainder having gravel or earth surfaces. In consequence, only about half of the best segment of

[2] This section has benefited from information kindly supplied by Jay Menon and others of the Asian Development Bank, Manila.

the overall road network – the national roads – can be relied upon to provide all weather connectivity.

Road quality and poverty incidence

Table 1 summarises information about the importance road access by comparing the results from the two most recent rounds of the Lao Expenditure and Consumption Survey (LECS) – for 1997-98 (LECS 2) and 2002-03 (LECS 3). In 2002-03 rural areas represented 77 per cent of the population of Laos but a much higher proportion of its poor people because poverty incidence is much higher in rural than in urban areas. Within rural areas, 42 per cent of the population (33 per cent of the national population) lacked all season road access. Among these rural villages, poverty incidence was higher than the rural average and very much higher than the national average.

Three types of road access within rural areas can be distinguished within these data. 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. This does not necessarily mean that the village is completely isolated from commodity trade. It may still be able to accommodate some forms of transport. These include human-powered vehicles such as shoulder poles, backpack frames, handcarts and bicycles, animal-powered devices such as carts and sledges and possibly two-wheeled motorized vehicles such as 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 throughout the year. During the wet season, such roads will at times be impassable. At other times, vehicles will be required to use alternative routes that may facilitate passage but would result in higher transport costs due to a change in travel distance, road roughness, and speed. This category includes 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 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. One point that comes across clearly from Table 1 is that over the five year interval between these two surveys there was a 12 per cent decline in the proportion of rural households living in villages with "dry season access only" road access, a corresponding increase in the proportion with "all season access", but no change in the proportion having "no access any season". In 2002-03 almost one third of all rural households still lived in villages without roads that support motorized vehicle access.

The socio-economic status of rural households living in these three types of villages is quite different. Table 2 takes this comparison further, using data from the LECS 3 survey for 2002-03. Villages without road access 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. The implications seem clear. Higher transport costs mean higher rates of poverty incidence, lower rates of school attendance and lower health status. Anything which increases transport costs is bad news for the poor and threatens Laos' chances of achieving its Millennium Development Goals.

Road quality and transport costs

Starkey (2001) analyzes how vehicle operating costs (VOCs) for different modes of transport change with distance and tonnage. His estimates are summarized in Table 3. 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 3, measured in US dollars as the cost per ton of output per kilometer traveled.

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. It seems unlikely that the VOC for two-wheeled vehicles such as bicycles or motorcycles will be significantly affected by the quality of roads. 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 described below, relating to the impacts 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 Lao Economy

This section describes *LaoGEM* (Lao General Equilibrium Model), a 20 sector, 400 household general equilibrium model of the Lao economy. Unless otherwise stated, the database of the model refers to the year 2002. The model's main features are as follows.

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.[3] 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. However, an exception is the "Immediate impact" simulations, in which levels of labour and capital employment are held constant. The nominal exchange rate between the Lao *kip* and the US dollar is endogenous and the nominal prices of services are fixed exogenously. Monetary and exchange rate policies are assumed to adjust so that nominal prices of services do not change.

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.

[3] The structure also draws on elements of a revised version of the *ORANI* model of the Australian

The core of the production side of the model is a 20 sector input-output table for Laos, estimated especially for this study. No official input-output table is currently available for Laos 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 Laos, relating to the year 2003, recently reported in Asian Development Bank (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 Laos, 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 Laos.

The resulting table has a structure which reflects the industry structure of Laos, as indicated by its National Accounts, but within each industry the input-output technology reflects that of Savannaket Province. The method thus assumes that the input-output technology for each industry in Laos is similar to that of Savannaket, even though the relative importance of these various industries in Laos 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 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

economy called *ORANI-G* (Horridge 2004).

these imported and domestically produced versions of the good and (b) the (Armington) elasticity of substitution between them.

Technology

Each sector is assumed to have a constant returns to scale, constant elasticity of substitution (CES) production technology. There is a sector specific fixed factor (immobile capital or land) in each sector, ensuring diminishing marginal returns to variable factors alone. 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 to scale 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 period of adjustment

The mobility of factors of production is a critical feature of any general equilibrium system. 'Mobility' here means the capacity of factors among industries, in response to changes in rates of return, rather than the capacity to move geographically. The greater the factor mobility built into the model, the greater is the simulated flexibility of the economy, as reflected in its capacity to respond to changes in the economic environment. It is essential that assumptions about the mobility of factors of production be consistent with the length of run that the model is intended to capture. The longer the period of adjustment, the greater the degree of factor mobility that is consistent with it. The *LaoGEM* model offers considerable flexibility in the specification of factor mobility.

First, to capture the immediate impacts of the shocks to be discussed, labour and capital are both assumed to be completely immobile. This describes *Simulation Set A*. Second, an intermediate period of adjustment is represented by *Simulation Sets B and C*. In these simulations, labour is assumed to be fully mobile across all sectors, implying that wages must be equal in all sectors and move together. There are then 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.

The above assumptions mean that the analysis of *Simulation Set A* refers to a short run period of adjustment – less than one year. *Simulation Sets B and C* refer to an intermediate-run period of adjustment – not short-run, or else labour would not be fully mobile and capital might not be mobile at all – and not long run, or else capital would be more fully mobile. The period of adjustment consistent with these assumptions is around 5 years.

Households

The model contains the four major household categories mentioned above – one urban (subsequently HU) and the three rural categories differentiated by the quality of road access shared by the members of the village concerned summarized in Table 4 – HR1, HR2 and HR3. The incomes of each of these four 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.[4] The Social Accounting Matrix underlying the model is based on data from this survey, the input-output 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.[5] 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 are set at 20. The elasticities of supply of imports to Laos are 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 are set at 2 for all commodities.

Treatment of transport costs

[4] 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.
[5] 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.

The information on transport costs in the three categories of roads 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 the distance to the nearest market multiplied by vehicle operating cost per kilometer on this type of road, based on Table 3, above, drawn from Starkey (2001). Transport costs are incurred primarily between the local market and the village concerned and 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.

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. As described in Section 2.3, VOCs are estimated for HR2 to HR3 from an ADB study of Champassak province (ratio = 2.01) and the ratio for HR1 to HR2 is derived using work done by 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 5. 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.

In summary, the estimates of the relative magnitudes of total transport costs shown in row E of Table 5 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

The shocks

The *shocks* are summarized in Table 6. The shocks are interpreted as changes in VOC 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 5.

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 Laos, 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.

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' in 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 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.

Simulation results

The estimated effects are summarized in Tables 7 and 8. In each case, real GDP increases and both rural poverty incidence and total poverty incidence decline. But it is notable in Simulation S2 that 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.

The results summarized above differ somewhat from those obtained from earlier econometric analysis of cross-sectional household survey data, such as those described in ADB (2005). In particular, the econometric results suggested that the gross returns (in terms of poverty reduction) from upgrading dry season access roads to all weather roads, relative to the returns from upgrading no access roads, were somewhat more substantial than those indicated by the results from the general equilibrium approach summarized here. There are two possible reasons for this difference, both of which relate to problems with cross-sectional econometric analysis – an omitted variable problem and an endogeneity problem.

First, in cross-sectional econometrics, different regions differ for reasons other than the variable of central policy interest – in this case, the type of road that is present. In econometric analysis, multiple regression is a statistical means for overcoming this problem, but it can work properly only if the data available include *all* relevant differences between regions other than the policy variable of interest. If the data collected are incomplete in this respect, and the omitted variables are correlated with the policy variable of interest, the econometric results will be biased.

Second, cross-sectional econometrics suffers from an endogeneity problem. The data used in the analysis are not generated by a randomized controlled experiment. The areas which receive improved roads were chosen by the road building agencies road improvement using some allocation criterion. For example, suppose richer areas were chosen for road improvement, or that a criterion was used which is positively correlated with income. The variable describing road improvement is then not exogenous, but is endogenous to income. This will mean that, *ex ante*, areas with higher incomes will be more likely to receive improved roads. When the *ex post* econometric analysis finds that areas which received roads had higher incomes, this will not mean that the improved roads caused the higher incomes. In part, at least, it will mean the reverse. That is, causation is very difficult to sort out in this kind of econometric research and it is usually unclear how much effect this has had on the results.

The advantage of general equilibrium modeling in these respects is that the analysis is directly comparable to a fully controlled experiment. Only one variable – the exogenous variable - is changed at a time. The direction of causation is then unambiguous and the results are free of both the omitted variable problem and the endogeneity problem, both of which are a problem for econometric analysis.

5. Conclusions: How improving roads reduces 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 and both contribute to overall poverty reduction. Moreover, the costs of road building in the two cases need to be taken into account in determining the most appropriate road building strategy. It is likely that the cost per kilometer of providing road access where there is currently none is bound to be significantly higher than upgrading existing roads. This paper has not looked into these costs but this is an important area that future research could address. However, our results confirm that there is considerable scope for reducing poverty incidence in Laos by reducing rural transport costs through improving the quality of rural roads.

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Table 1 Laos: 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.

Table 2 Laos: 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 database.

Table 3 Vehicle operating cost estimates by type of road

	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).

Table 4 Naming of household categories

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

Table 5 Laos: 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).

Table 6 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%

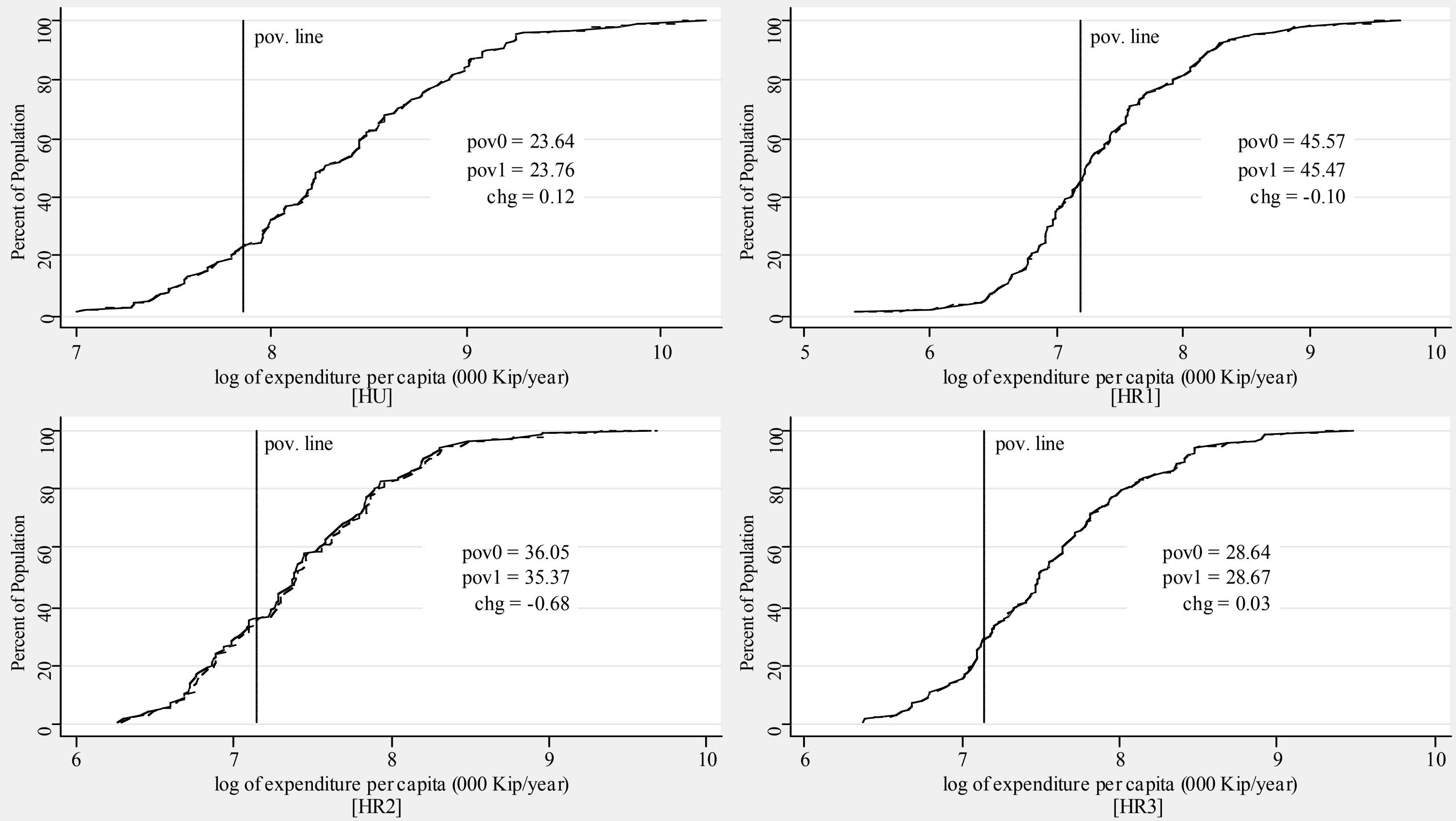
Table 7 Simulated Macroeconomic Effects of Road Improvements
(Units: per cent change)

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 8 Simulated Distributional Effects of Road Improvements
(Units: as indicated in parentheses)

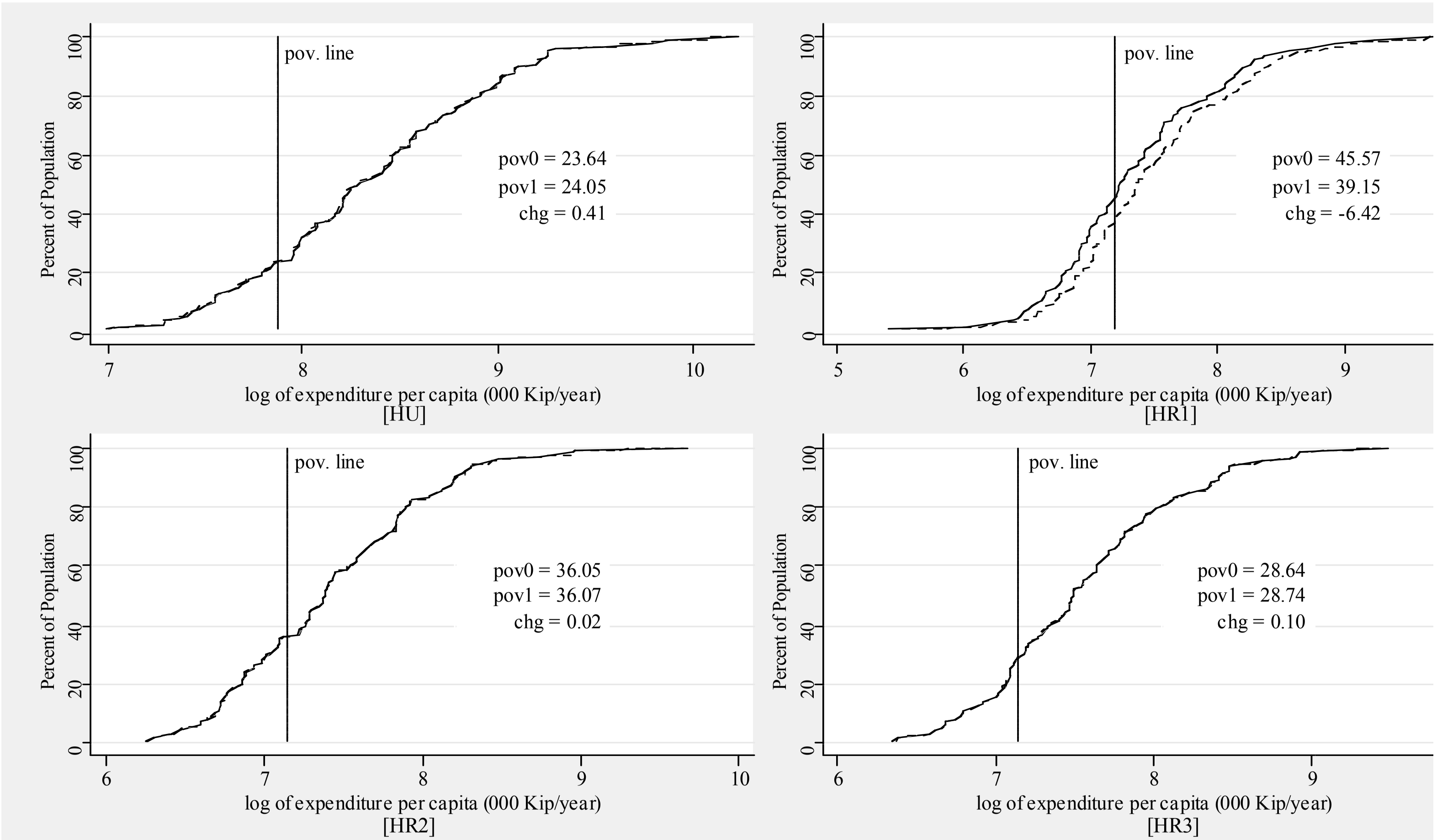
Simulation			S1	S2	S3	S4
Real consumption expenditures per person, deflated by household-specific CPI (% change, except ex-ante levels)						
		Ex-ante level	**Per cent change**			
		(thousand kip)	**S1**	**S2**	**S3**	**S4**
Rural households	HR1	1,712.6	0.27	15.40	7.48	3.68
	HR2	1,917.0	2.83	0.13	0.03	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 1 Changes in the cumulative distribution of real expenditures in Simulation S1



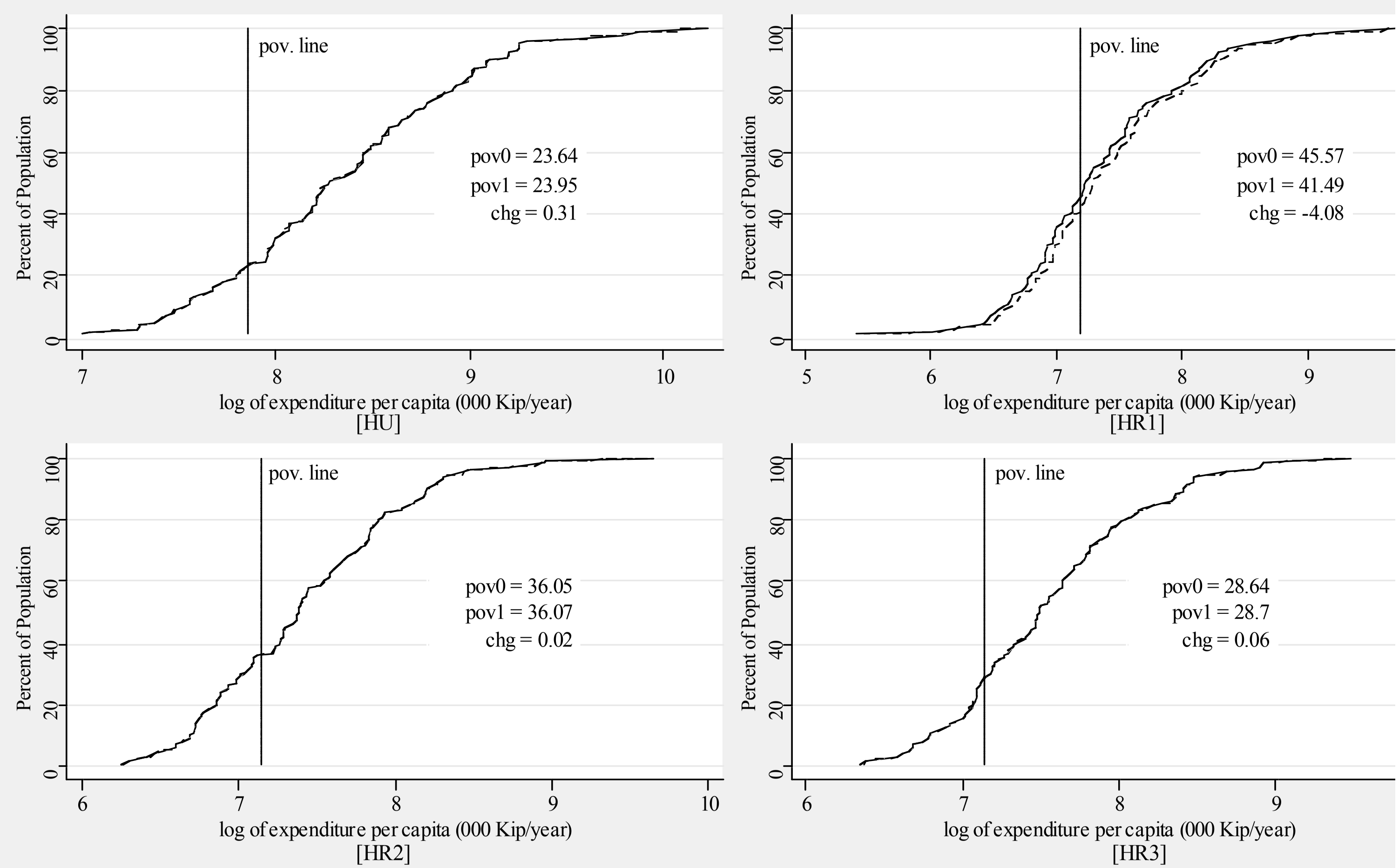
Note: [HU] urban [HR1] rural no-road [HR2] rural dry season [HR3] rural all season

Figure 2 Changes in the cumulative distribution of real expenditures in Simulation S2



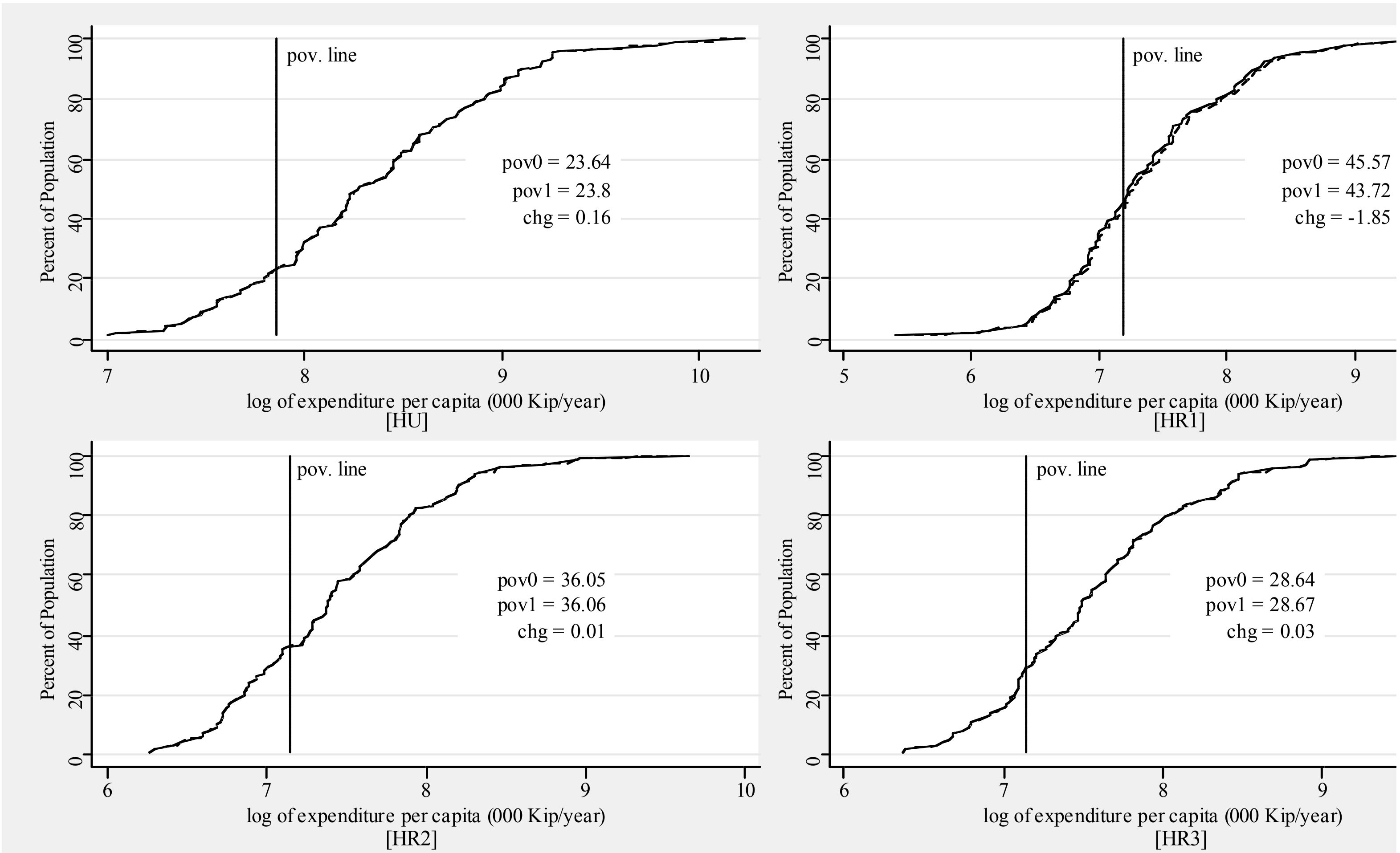
Note: [HU] urban [HR1] rural no-road [HR2] rural dry season [HR3] rural all season

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



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

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	2	3	4	5	6	7	8	9	
	Intermediate	Investment	Households	Export	Government	Stocks	Margins	Total	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