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Poverty and Access to Infrastructure in Papua New Guinea

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Poverty and Access to Infrastructure in Papua New Guinea

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Abstract

In this paper, our overall goal is to understand how effective access to infrastructure is in reducing poverty in PNG. To meet this goal, we examine poverty in PNG, and seek to show the relationship between poverty and access to infrastructure and then identify the determinants of poverty. In our analysis, we test whether or not access to infrastructure is a significant factor in a household's poverty status. Finally, we want to understand what policies will be effective in overcoming poverty in PNG. Our results show that poverty in PNG is primarily rural and is associated with those in communities with poor access to services, markets, and transportation. Our simulations illustrate that improving access to school leads to large declines in poverty. Increasing access to poverty for those that are currently most isolated would have a significant effect in decreasing the severity of poverty.

JEL: I32, O15
Keywords:; Poverty, Papua New Guinea

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Poverty and Access to Infrastructure in Papua New Guinea

When considering the role that infrastructure can play in poverty alleviation and the size of investments by developing countries into infrastructure, it is somewhat surprising that so little work has been done on such an important topic.[1] Developing countries invest over $200 billion US dollars per year into basic infrastructure, about 4 percent of their Gross Domestic Product (World Bank, 1994). While there are many reasons for these investments, different arguments can be made as to why basic infrastructure investments in a developing country would be effective in reducing poverty (Lipton and Ravallion, 1995). One is that poor areas have the least access to infrastructure and so will benefit the most from new investments. If infrastructure provides benefits to a nation's people and previous investments have mostly been in nonpoor areas, then new projects should provide most of the benefits for the poor. Another argument is that the poor are concentrated in sectors of the economy in which rates of return to infrastructure are high (van de Walle, 1985).

The Papua New Guinea (PNG) economy provides a unique opportunity to study the effect of access to infrastructure on poverty. Because of PNG's unique status as such a late developing country (one in which vast parts of the country remained isolated from the rest of world until after 1950) and because of its mountainous and rugged terrain, the country suffers from a fragmented system of transportation (World Bank, 1999).[2] In cities and some better-off rural areas, residents

[1] Although there is less understanding of the relationship between the level of investment in basic infrastructure and poverty than other aspects of poverty allevation (e.g., migration or agriculture), economists have begun paying attention to the infrastructure linkages that bind rich and poor areas together and the impact of these on growth (for example, Binswanger, Khandker, and Rosenzweig, 1993; World Bank, 1994; van de Walle and Nead, 1995; Fan, Hazell, and Thorat, 1999; Jacoby, 2000).

[2] Indeed, PNG is a country that has one of the most fragmented highway networks and most difficult terrain in the world. In a study on the benefits of rural roads in Nepal, Jacoby (2000) claims he has chosen an interesting place to work because of the extreme need for roads. The mean travel time in Nepal between the average household and the nearest marketing center is 2.8 hours. Arguably, however, PNG's rural communities are even more isolated. The average travel time to the nearest government station (which is the closest thing in PNG to a Nepali market town) is more than 3 hours. The average travel time to the nearest road is 2.5 hours. Moreover, this geographic isolation is exacerbated by extreme social-ethnic heterogeneity. Within the confines of a nation with only 4 million people, the population is home to 850 separate languages, one-seventh of the world's total (Grimes, 1992).

have access to multiple modes of transportation--paved roads, airports, and water travel. In poorer areas, however, a high proportion of PNG's rural residents live many hours from the nearest basic social services. And, while recent investment in rural infrastructure has made PNG compare favorably with other developing countries in terms of meters of roads per person and per square kilometer, access to many social services is still poor mainly because the road system is poorly maintained and frequently inaccessible during and after rains. In fact, in some areas the deterioration of roads has reached such a serious level that it has pushed local rural residents to demonstrate and even riot when national ministers visit.

In this paper, our overall goal is to understand how effective access to infrastructure is in reducing poverty in PNG. To meet this goal, we pursue three objectives. First, we examine poverty in PNG, and seek to show the relationship between poverty and access to infrastructure. Next, we identify the determinants of poverty, most importantly testing whether or not access to infrastructure, ceteris paribus, is a significant factor in a household's poverty status. Finally, we want to understand what infrastructure-related policies will be effective in overcoming poverty in PNG.

To meet these goals and objectives, the rest of the paper is organized as follows. In section II, we first describe our study's data set and explain how we created our measures of poverty. In the next section, we examine the contours of poverty and its relationship to the access that PNG residents have to infrastructure. Section IV creates a model of the determinants of poverty and presents result about the effect that access to infrastructure has on the poor. We simulate the impact of various investment strategies on poverty. The final section concludes.

To narrow the scope of our analysis, we focus on rural poverty for two reasons. First, as we will show, most of the poor in PNG live and work in rural areas, a characteristic common to most

Asian countries. Second, the main infrastructure problems in PNG are in the rural areas. Access to services, markets and transportation, measured in travel time, are much better in cities.

II. Data and Measures of Poverty

Data used in this paper come from the Papua New Guinea Household Survey (PNGHS), which is the first nation-wide survey of consumption and living standards in PNG. The survey design and enumeration, which was overseen by the authors in 1995 and 1996, covered a random sample of 1200 households, residing in 120 rural and urban Primary Sampling Units (PSUs). Enumerators conducted interviews between January and December 1996. The survey team selected PSUs from the enumeration areas of the 1990 Census, stratifying the sample by sector (the National Capital District was separated from the rest of the country), by environmental conditions (elevation and rainfall), and by the level of agricultural development.[3] A set of household weights were derived from the variation between the 1990 Census estimates of the size of each cluster and the actual size found during the survey, and from the deviation of the actual number of households surveyed in each cluster from the target number. The results reported below are estimated from the 1144 households that had complete information on their consumption, and take account of the clustered, stratified and weighted nature of the sample.

The survey interviewed each household twice, with the start of the two-week consumption recall period signaled by the first interview. This first interview also collected information on education and literacy, occupations and employment (but not income levels), dwelling characteristics and a limited range of questions on agricultural assets and inputs. The interview team collected expenditure data on all food (36 categories) and other frequent expenses

[3] This was established from an agricultural mapping project (Allen, Bourke and Hide, 1995).

(20 categories) during the recall period. The expenditure estimates include the imputed value of own-production, net gifts received, and stock changes, so they should be a good measure of consumption during the recall period.[4] An annual recall covered 31 categories of infrequent expenses. The survey also included an inventory of durable assets that we use to estimate the value of the flow of services (from these assets), including rental services from owner-occupied dwellings. In addition to the household interviews, a community questionnaire, conducted in both urban and rural areas, collected information on prevailing prices, community facilities and estimates of the time needed to reach the nearest public services. In asking about travel times, the survey specifically asked documented the usual mode of travel, which in rural areas, was almost exclusively by foot.[5]

Poverty lines were set for five regions of Papua New Guinea – the National Capital District (NCD), the South Coast, the Highlands, the North Coast, and the Islands – using methods outlined by Ravallion (1994).[6] These poverty lines were based on baskets of locally consumed foods that provide 2200 calories per day, using average prices obtained from the community questionnaires. An allowance for non-food items was based on the typical value of non-food spending by households whose total expenditure equals the cost of the food poverty line, where this displacement of required food spending suggests that the included non-food are essentials. The resulting poverty lines were

[4] The monetary values for self-produced foods were the values used by respondents. Estimates of average expenditure are unchanged if these respondent-reported unit values are replaced by either cluster medians of the unit values or cluster averages of market prices (Gibson and Rozelle, 1998).

[5] Travel time to the nearest road or alternative mode of transportation (e.g., plane or boat) in PNG is not subject to the same problem of endogeneity raised by Jacoby (2000) in his study of access to markets by road travel. His concern about the endogeneity of access to services arose from the idea that households with high plot values (his dependent variable) might be able to afford to invest in better means of transportation, thus shortening travel time. In the case of PNG, almost all travel time in rural areas is measured in terms of walking time on small dirt paths. No other mode of transportation is available.

[6] An "upper" poverty line and a "food" poverty line were also calculated and reported in World Bank (1999). Details on the calculations of the poverty lines and the differences found when alternative poverty lines were used are discussed there.

K779 per adult equivalent per year in the NCD, K496 in the Papuan/South Coast region, K390 in the Highlands, K280 in the Momase/North Coast region and K424 in the New Guinea Islands region, with a national average value of K400.[7] Separate urban and rural poverty lines were not calculated within regions because most regions had only one urban PSU included in the sample, and there were no rural PSUs in the NCD region.

III. Poverty in PNG and the Nation's Infrastructure

Although PNG is classified as a lower-middle income country with an average annual per capita income of US$890, the living standards of the vast majority of the population are akin to that of low-income countries (World Bank, 1999). PNG scores poorly on most social indicators compared to its income level. Infant mortality per 1000 live births is 61. Life expectancy at birth is only 58 years. Only 22 percent of the population have access to adequate sanitation. More than 40 percent of children aged 0 to 5 years, and more than 50 percent of those in the poorest quartile, are stunted (or have height for age scores less than -2.0). Although the nation is rich in natural resources, its high Gini ratio is one of the highest in the world (48.4 for per capita expenditures). The size of the gap between the rich and the poor suggests that many of its residents do not share equally in the nation's wealth (World Bank, 2001).

Poverty measures clearly illustrate the breadth and depth of poverty in PNG, especially in the rural regions of the country (Table 1). Based on our estimated poverty line, 33.5 percent of PNG's rural population and 11.4 percent of the urban population live in households in which the real value of consumption per adult equivalent is below the poverty line (rows 7 and 8). Overall (

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[7] The adult-equivalence scale counts children aged 0-6 years as 0.5 adults and all others as 1.0, and is based on estimates of child costs, made using the Engel and Rothbarth methods outlined by Deaton and Muellbauer (1986), and

since the rural population accounts for 85 percent of the nation's population—column 7), the national headcount index of poverty is 30.2 percent (row 6). Using a more austere poverty line (the food poverty line), slightly over one-sixth of the population have a total consumption valued at less than the cost of the poverty line food basket, meaning that they could not even meet the basic caloric requirement implied by the typical food consumption basket of the poor even if they spent *all* their money on food. From these results it is clear that poverty in PNG is a rural problem. The rural poor account for 94.3 percent of PNG's poor.

While the headcount index indicates the proportion of the population with a standard of living below the poverty line, the measure does not indicate how poor the poor are and does not change if people below the poverty line become more or less poor. One indicator of the depth of poverty, the poverty gap index, is constructed by measuring the income shortfall between the standard of living of poor people and the poverty line. PNG's gap index shows that the poor's income shortfall is equivalent to 9.1 percent of the value of the poverty line averaged over the whole population (Table 1, columns 3 and 4).[8] The poverty gap figures, like the head count statistics, demonstrate rural nature of poverty. The poverty gap measure is nearly 5 times higher for rural (10.3) than urban (2.2), and the rural poor account for an even larger share of the total poverty gap (96.3 percent) than they do for the headcount index.

The poverty severity index is a distributionally sensitive poverty measure that takes into account the distribution of consumption of those falling below the poverty line.[9] This index (3.9

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on a comparison of the dietary requirements of adults and children of various age groups. Details are provided by Gibson and Rozelle (1998).

[8] The aggregate shortfall from the poverty line can also be calculated in monetary terms by multiplying the PG index by the value of the poverty line and by the population size (4.3 million adult equivalents). This calculation shows that it would require perfectly targeted (and costless) tranfers.

[9] The headcount index, the poverty gap index, and the poverty severity index can all be estimated using the same general equation, through choice of values for a parameter (Foster, Greer and Thorbecke, 1984 – hereafter FGT). The equation is:

nation-wide) also shows that poverty is even deeper in rural areas of PNG (4.5) than in urban areas (0.7--Table 1, columns 5 and 6). In other words, the extent by which the average consumption of poor households in rural areas falls below the poverty line is significantly higher than that of poor households in urban areas. Even more than the headcount or poverty gap index, the rural poor contribute 97 percent of the poverty severity index.

Regional Patterns of Poverty

Finding out where poor people live is one of the most basic pieces of information for an antipoverty program. Ideally, a household survey should be able to help in placing targeted interventions. However, the diversity of environments in Papua New Guinea makes this an impossible task for a survey of any feasible size. Even the more limited goal of estimating poverty rates by province would require a very much larger household survey than the one conducted in 1996. Instead, the poverty comparisons presented here are for the four major geographical regions of the country -- the Papuan/South Coast; the Highlands; Momase/North Coast; and the New Guinea Islands. The map in appendix A illustrates the location of these areas.

The incidence and extent of poverty vary significantly across PNG's major regions (Table 1, rows 1 to 5). Poverty is lowest in the NCD and highest in the Momase/North Coast region (column 1 and 2). Only about 16.2 percent of the population of the NCD falls below the poverty line. Nearly 39 percent of the population in the Momase/North Coast region falls below the poverty line and its share of national poverty is 37.5 percent. The other three regions (Papuan/South Coast, Highlands, and New Guinea Islands) have poverty rates that are clustered slightly below the

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$P_\alpha = \frac{1}{n}\sum_{j=1}^{q}\left(\frac{g_j}{z}\right)^\alpha$ where the poverty line is z, the value of expenditure per capita for the jth person's household is x_j and the poverty gap for individual j is $g_j = z - x_j$. Total population size is n and q is the number of poor people (those where $x_j < z$). When parameter α is set to zero, P_0 is simply the headcount index. When α is set equal to one, P_1 is the poverty gap index, and when α is set equal to two, P_2 is the poverty severity index

national average, ranging from 26.0 percent to 30.3 percent. While the headcount of poverty is higher in the Momase/North Coast region, the large population share in the Highlands (40.1 percent) means that the Highland's contribution to poverty is also high (34.6 percent—column 7). The poverty gap and the poverty severity measures also are highest in the Momase/North Coast and the Highland Regions.

The poverty in PNG regions is closely correlated with the several important measures of each region's human capital, one of the most important indicators of PNG's long term development prospects. Educational attainment is lowest and the proportion of people who never attended school is highest in the Highlands and the Momase/North Coast region (Table 2, columns 1 and 2). Illiteracy rates are also highest in the two regions (column 3). Moreover, access to health services is poorest in these regions (column 4). Although not as bad as the Highland and Momase/North Coast, the record of education and health is not good in the Papuan/South Coast region and the New Guinea Islands and relatively poorer than in the urban NCD.

Given the remoteness and rugged terrain of PNG, poor access to roads may be one of the proximate causes of poor record of the government in the provision of education, health and other public goods. If roads are poor and travel time is high, the cost of attending school or seeking health care may be prohibitively high. In fact, measures of the access to roads in PNG's four main regions shows that road access in the two most poverty stricken regions (the Momase/North Coast region and the Highlands) is the poorest (Table 3, column 1). In the Highlands, for example, rural residents have to walk more than 4 hours to reach the nearest road. Travel times in the Papuan/South Coast and the Momase/North Coast regions both exceed 90 minutes. While access to any transportation mode (including boat docks and dirt airstrips) is better in the Highlands (than

the Momase or Papuan regions), individuals still have to walk about an hour, on average (column 2).

With road access so poor, access to health and educational services are poor. Access to aid posts (PNG's most basic health service centers) also is the poorest for the Highlands and the Momase/North Coast region (although it is equally as poor for the Papua/South Coast region—Table 3, column 3). Even to get access to the most basic health services, households in these regions much walk from 66 to 76 minutes. Access to community schools is equally poor; travel times in the poorest regions are all around one hour (column 4). Travel times to high schools average more than 3 hours (column 5)

To illustrate an even closer linkage between poverty and rural infrastructure, Table 4 demonstrates the strong correlation between poverty, school attainment and access to roads. According to the headcount measure of poverty (column 1), when households live more than 60 minutes from the nearest road (rows 4 and 5), the incidence of poverty more than doubles when compared to those living less than 60 minutes from a road (rows 3 and 4). The same is true for access to schooling (rows 6 to 9). Poverty headcount measures increase markedly when the nearest school is more than 60 minutes away. The correlation between poverty measures and rural infrastructure increases when the depth and severity of poverty indices are used (columns 3 and 5).

Consumption and Price Effects of Access to Roads

The effect of access to roads on poverty can most clearly be illustrated by the marked differences in access to transportation infrastructure among income groups. The lowest consumption quartile must travel over twice as long to gain access to the closest mode of transport than the richest quartile. The poor travel 75 percent longer than the non-poor to the closest mode of transportation and over three times longer to reach the closest road.

A simple regression of per capita consumption against travelling time to the nearest transport facility demonstrates that consumption is negatively correlated with access to transportation (Figure 1). A one-hour increase in travelling time to the nearest transport facility reduces real consumption by 10 percent. This suggests that measures that improve the access of rural communities to transport infrastructure could be an important aspect of poverty alleviation in PNG.

While there may be a number of effects of access to infrastructure that affect consumption (for example, see Jacoby, 2000), our sample data clearly illustrate two. Access to a road affects the price farmers receive for their crops and the prices that households must pay for their purchased food (Figure 2). The relationship between the average price of sweet potato, calculated at a Census Unit level, and the travelling time from the Census Unit to the nearest road or other transport facility suggests that sweet potato prices are lower in communities that are further from roads and other transport points.[10] Specifically, the rate of price decline is around seven percent for each extra hour to the nearest transport facility. This rate of price decline can also be interpreted as the rate at which the net returns to marketing food and other crops produced by rural households decline as infrastructure becomes less accessible.

To provide additional evidence of the impact of transport facilities on food prices, the data from the 1996 survey were used to calculate the average price (at the Census Unit level) on a one kilogram packet of Trukai rice, one of the most widely available foods in trade stores across PNG in 1996. Figure 3 demonstrates the relationship between the average price and the distance that each Census Unit is from the nearest transport facility, such as a road, airstrip or boat docking

[10] The sweet potato prices are shown using a logarithmic scale, so that the slope of the relationship can be directly interpreted as the percentage change in price when moving to a community that is an extra hour away from the nearest transport point.

point. The slope of the regression suggests that each additional hour further away from transport infrastructure raises the trade store price of rice by 3.4 percent (with a standard error of one percent, making the regression coefficient highly statistically significant).[11]

Finally, roads and other transport infrastructure also give households better access to markets that may help them engage in a wider range of income earning activities. This diversification does not only increase income, it can help to stabilise the cash incomes of households, and in this manner improve food security by increasing the reliability with which food can be purchased to supplement own production. Some partial evidence for this point is presented in Table 5, which contains the results of regression analyses of the number of income earning activities engaged in by respondent households from the 1996 household survey.[12] In this analysis, each one-hour increase in travelling time to the nearest road appears to reduce the number of income-earning activities by an average of 0.15, which is a 2.6 percent reduction in the number of activities per extra hour to the road (column 1). This result is robust to the inclusion of provincial and monthly dummies (column 2).

[11] Of course, it is clear from the wide scatter of points on the graph that many things other than distance from roads explains the price of rice. Adding in control variables for each province (as a proxy for their distance from the rice mills and rice terminals) and for each month (as a proxy for the general price inflation occurring over the course of 1996) raise the R^2 to 0.48, so just under one half of the variation in rice prices is explained by these three factors. Most importantly, adding in these additional variables does not alter the basic relationship between transport access and price, with each one hour increase in travelling time to the nearest transport facility estimated to cause a 2.8 percent increase in the village-level price of rice (which is still statistically significant).

[12] This is the household total of a question that is asked of each individual adult, in contrast to the 1990 Census which asked about similar economic activities engaged in, but only at the household level. See Gibson, 2001 for a more complete and detailed argument.

IV. The Determinants of Poverty in PNG

While the profiles of poverty in PNG are a useful way of summarizing information on the levels and location of poverty and on the characteristics of the poor, they are essentially cross-tabulations and no matter how imaginative their uses (see, e.g., Grootaert, 1994), they are restricted in the number of dimensions that can be varied at one time (e.g., poverty rates broken down by region of residence and economic activity of the household head). To answer questions about the effect of a particular variable, conditional on the many other potential determinants of poverty, requires multivariate analysis. In particular, multivariate analysis may help show whether geographical pockets of poverty exist just because people with poor endowments cluster together (Ravallion, 1998).

A common approach to the multivariate analysis of poverty is to define a 0-1 variable; $h_i = 1$ if the *i*th household's per capita consumption expenditure, c_i is less than the poverty line, z and proceed with probit estimation:[13]

$$\Pr\langle h_i = 1 | \mathbf{x}_i \rangle = \Phi(\mathbf{x}_i \mathbf{b})$$

where Φ is the standard cumulative normal, and $\mathbf{X}$ is the matrix of explanatory variables. Usually interest is not centred on the coefficient vector $\mathbf{b}$ but on the 'probability derivatives' which can be obtained from $\mathbf{b}$ and show the change in the risk of poverty as the explanatory variables change. Although this approach ignores the *depth* and *severity* of poverty, it might be justified by the widespread concern of policy makers with the *incidence* of poverty. But unlike the usual case where binary response models are used, the underlying variable that generates h_i is fully observed, as can be seen from the general equation for several common poverty measures for the *i*th household (Foster, Greer and Thorbecke, 1984):

$$P_i^{\alpha} = [\max((1 - c_i / z), 0)]^{\alpha} \quad \alpha \geq 0 \ ,$$

where α=0 gives the binary headcount measure of poverty, α=1 gives the poverty gap index, and α=2 gives the squared poverty gap or poverty severity measure, which is sensitive to inequality amongst the poor. Moreover, the parameters of interest – including the probability of the *i*th household being poor – can be estimated more directly by regressing c_i on $\mathbf{x}_i$ – whilst making weaker assumptions about the errors than are needed by probit models (Ravallion, 1998).

Rather than using poverty probits, the approach of this paper is to model the determinants of consumption, using standard regression analysis, and then derive from the regression model estimates of the various poverty measures following simulated changes in certain variables. More specifically, the model is of (log) nominal consumption expenditure per adult equivalent, deflated by region-specific poverty lines – a ratio known as the "welfare ratio" (Blackorby and Donaldson, 1987):

$$\ln(c_i / z) = \mathbf{x}_i \mathbf{b} + u_i \, .$$

Because the poverty measures are homogeneous of degree zero, the results of the poverty simulations should be the same if the ratio of the regional poverty lines was used as a spatial price deflator and the regression was carried out using variables in real terms. Normalizing consumption by the poverty line implies that $\ln(c_i / z) < 0$ for poor households and the probability of the *i*th household's (log) welfare ratio being less than zero can be derived from the estimated parameter vector $\hat{\mathbf{b}}$ and the standard error of the regression, $\hat{\sigma}$:

$$\text{prob}(\ln(\hat{c}_i / z)) < 0 = \Phi((-\mathbf{x}_i \hat{\mathbf{b}}) / \hat{\sigma}).$$[14]

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[13] Examples include Bardhan (1984), Gaiha (1988) and Grootaert (1997). Gibson (1998) also uses this approach, for PNG urban poverty in the mid-1980s.

[14] One complication with this procedure is that to get an estimate of the standard error of the regression when the data come do not come from a simple random survey, it may be necessary to use a pseudo-maximum likelihood estimator (see Skinner, Holt and Smith, 1989, pp. 80-83). The reason is that the usual regression estimator for clustered, stratified

A weighted average of the household probabilities of being poor gives the predicted incidence of poverty, where the weights are the household sampling weights in terms of person-numbers. This same approach can be extended to the simulated poverty gap and poverty severity measures, when the integrals are solved in terms of the estimated log consumption model (Datt, 1998).

Model Specification

A wide range of variables measuring the potential determinants of rural poverty are available from the survey and these are described under the following seven headings: demographics, education, employment and occupations, assets, community characteristics, geo-climatic characteristics, and regional fixed effects. Variables that directly contribute to the construction of the dependent variable were ruled out as regressors because of the spurious relationships that may be obtained. In particular, estimates of the value or possession of household durable goods and dwelling characteristics are not included among the set of explanatory variables because the imputed value of the use of durable goods and dwellings is already included as a component of consumption.

Demographics: A linear and quadratic term in household size, the number of children (below age 15) and number of elderly (above age 50) household members, plus linear and quadratic terms in the age of the household head and a binary variable for female-headed households are included. The welfare interpretations of some of the demographic variables is unclear because, for example, the effect of household size may just be due to the excluded effects of scale economies in

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and weighted survey data makes no assumptions about normality of the disturbances, and strictly speaking there is no σ in such a model. The pseudo-maximum likelihood estimator relies on the stronger assumption of normality of disturbances in the population. This estimator can be implemented using the *svyintreg* command in Stata, and we are grateful to William Scribney for advice on this issue.

consumption within households (Lanjouw and Ravallion, 1995), although attention has been paid to the differing costs of children and adults.

Education: the household average of completed school years for those household members over the age of 15 and a binary variable for whether the household head is literate are used. Although correlated, something is gained by specifying these two variables separately. Literacy is a basic functioning, which may help raise living standards even of those with little connection to the market economy (e.g., semi-subsistence farmers reading food crop extension bulletins) while years of schooling may matter both for human capital and screening reasons. Moreover, informal teaching may allow literacy to improve even without raising average years of schooling, so it is interesting to separate the two variables for policy simulations.

Employment and occupation: the household head's main source of income was grouped into four occupational classifications – formal sector, tree crop farmer, food crop farmer, and minor occupations (hunting, fishing, firewood selling and making of artifacts). In addition, the proportion of adults in each household who had no sources of cash income over the past 12 months was included. This variable could be considered a measure of unemployment because the absence of a labour market in most areas of PNG makes the usual definition of actively seeking work somewhat inapplicable.

Assets: the survey did not collect information on land holdings, due to (i) the difficulty of measuring this in a system of customary tenure with widely scattered plots, and (ii) the sensitivity of the issue following a recent failed land registration drive. But data on the number of pigs, which are the major type of livestock, are available and used. Also used is a dummy variable for whether the household owned major agricultural capital goods (trucks, tractors, sprayers, coffee pulpers, cocoa fermentaries and copra driers), where these goods – with the possible exception of trucks –

were not included in the list of household durables and so should not be spuriously related to consumption expenditure.

Community characteristics: an index of market development, based on the combined number of tradestores, public transport businesses and fresh produce markets located in the PSU, the travelling time to the nearest road, and the combined travelling time to the nearest of each of three key social services: high schools, health centres, and government stations. Although data on the travelling time to lower level health (aid post) and education (community school) facilities are available, the quality of these appears more variable than for the higher level services (but was not measured by the survey); users sometimes appear to travel past the lower level services to reach the higher level services of more consistent quality – making travelling time a more reliable measure of access to public services for the higher level services. The index of market development is designed to capture the notion that missing markets prevent households from gaining from specialisation, thereby reducing living standards (e.g., minimising involvement in cash cropping because of concerns about food market failures).

Geo-climatic characteristics: consumption and several of the household and community characteristics are likely to be affected by various agroecological factors that impact the productivity of land. Failure to control for this omission of relevant variables will give biased results. For example, consumption and ownership of agricultural capital goods are both likely lower in areas of poor agricultural potential, leading to a spurious positive effect if there is no measure of agricultural potential in the model. The variables used are rainfall (a binary variable for wet regions where annual rainfall exceeds 2500mm) and elevation (binary variables for three zones, <600m, 600-1200m, and >1200m) which affects climate and limits the range of crops that can be grown.

Regional fixed effects: Even with the geo-climatic variables, there are likely to be spatial effects whose omission biases the coefficients on the included variables. Therefore, a set of fixed effects are included. Although it is possible that the relevant fixed effects are at the PSU level, capturing any unobserved community-level determinants of living standards, the inclusion of a PSU set of intercept dummies would make it impossible to identify any of the community level variables. As a compromise, the fixed effects are defined at regional (n=4) level.

Since our interest is on rural poverty, we report only estimate models for the rural sector. We also estimate separate rural models since we believe that it is likely that there is genuine heterogeneity in the effect of the independent variables on the welfare ratio across sectors, a hypothesis that we test. Table 6 contains descriptive statistics on the variables in the model for rural sector.

Determinant of Poverty Results

Since our interest is on rural poverty, we report only the results for the model estimated on rural households. However, a similar model has been estimated on urban households and tests with a pooled sample suggest that the coefficients were not the same across urban and rural sectors (World Bank, 1999). The results of the model for the rural sector are in Table 7.

In general, the model performed well. The goodness of fit measure, R^2, was 0.32, sufficiently high for models using cross sectional household data. In addition, many coefficients of our control variables were of the expected sign and statistically significant. For example, the results show that there are significant gains from both extra years of schooling and literacy of the household head in rural areas. While participation by the household head in the formal sector does affect consumption levels, the proportion of adults in the household without access to cash incomes in the previous year does not emerge as a significant determinant of consumption. Finally, high

rainfall, but not elevation, emerges as a negative influence on consumption in rural areas while regional fixed effects are also relevant.

Even after controlling for the demographic, educational, employment and environmental factors, community characteristics appear to be relevant. Consumption in the rural sector rises with market development. Moreover, as access to the nearest road falls (or travel time increases), the rural welfare ratio falls. In other words, remoteness may matter to poverty not just because remote areas tend to have people with poor endowments of human capital but because rural infrastructure matters directly. Of course, part of the returns to education and occupation may be due to the ease in which rural residents have access to these basic services and economic opportunities.

Concerned about differences among different types of households, Datt and Jolliffe (1999) suggest that the marginal effects of household and community characteristics on consumption are not constant across households and add interaction effects into their model to control for them. Although every variable can potentially be interacted with every other variable, multicollinearity is likely to result, with fragile coefficient estimates leading to potentially unreliable poverty simulations. Therefore, Datt and Jolliffe restrict attention to just a few interactions, mainly between schooling and other variables. After trying a large number of combinations, the presence of interaction effects was not supported for the rural sector of PNG ($p<0.43$) and we must conclude that in general, including the interaction terms did not change the coefficients on the community characteristics. The only significant interaction effect that we could find was for lower returns to education for female-headed households.[15]

Poverty Alleviation and Investments in Infrastructure

Table 8 reports the results of various poverty simulations done with the model in Table 7. The beneficial effect of increasing literacy, schooling and access to social services and roads is readily apparent from these simulations. The incidence of poverty would fall by 17 percent if all household heads could be made literate (row 3). Although the incidence of poverty would fall by only 3.74 percent, following a one year rise in average school years per adult, if the average schooling in PNG was raised from the current level, 3 years, to a minimum of an elementary (middle) school education, poverty could fall by more than 10 (20) percent (row 4). The depth and severity of poverty measures would fall by a greater percentage since those in greatest poverty currently have the least access to education (rows 3 and 4, columns 2 and 3). To the extent that improved access to schooling in terms of travel times will assist in expanding education, PNG's poverty rates will be benefited by investments both in the education system itself and in the rural infrastructure.

Increasing access to services will also have an independent effect on decreasing poverty. The headcount index would fall by 3.56 percent if the travelling time to key social services could be cut by 50 percent, with the greatest proportionate gain in the urban sector (row 5). If access to the three key services were reduced by 50 percent for those who live more than 6 hours away from them now, poverty could be reduced by 4.48 percent (row 6). Likewise, reducing the travelling time to the nearest road would also be an effective anti-poverty strategy in the rural sector, with the greatest gains arising from an approach targeted at the most remote households rather than on making across-the-board cuts in travelling time to roads (rows 7 and 8). As in the case of education, providing such services also targets the poorest of the poor, since in all cases, the depth and severity indices fall faster than the headcount measures (rows 5 to 8, columns 2 and 3).

[15] These results are not reported here for brevity but are in World Bank (1999).

V. Conclusions

Our results appear to support the argument that poor areas have the least access to infrastructure and so people in those areas may benefit the most from new investments. Thus, infrastructure spending, whether on new assets or maintenance of existing facilities, can provide a form of targeted interventions that favors the poor. This is an especially relevant finding for PNG, in part because the existing infrastructure is so poorly developed, and the returns to such projects high. But more importantly, infrastructure spending may be one of the few feasible means for policy interventions to reach the poor in PNG.

In many cases the results of poverty measurement and profiling exercises might be useful as inputs into some system of directly targeting the poor, for example, by schemes based on cash grants, food stamps or other selective subsidies. But in PNG there is little capacity to do this because the vast majority of the poor are located in remote, rural areas and most have only limited involvement in formal activities. While there is a value-added tax, it excludes transactions carried out in informal markets. Since the poorest of the poor participate so little in the cash economy, this means that there is little scope for targeting the poor by setting lower tax rates on basic consumption items that are formally marketed, such as rice. Other approaches to targeting, such as supporting cash crop prices, are also unlikely to be feasible because there is a history of these price support schemes collapsing in PNG.

Papua New Guinea also is marked by an unusually low capacity of the government to provide services to the poor, so other agencies such as churches fill the gap. For example, the household survey shows that amongst the poorest quartile of the population, 42 percent of the births taking place outside the home are in church-run health facilities (as compared to 13 percent

in the richest quartile). But it is a rather more difficult task for churches and NGOs to build major infrastructure such as a road system, which remains an obvious role for the state.

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Table 1. Poverty Measures in PNG in 1996 by Region

	Headcount Index		Poverty Gap Index		Poverty Severity		
	Index	Contribution to total (%)	Index	Contribution to total (%)	Index	Contribution to total (%)	Share of total population
National Capital Dist.	16.2	3.0	3.8	2.3	1.4	1.9	5.5
Papuan/South Coast	30.3	14.8	9.8	16.1	4.3	16.4	14.9
Highlands	26.0	34.6	8.0	35.1	3.4	34.7	40.1
Momase/North Coast	38.8	37.5	11.2	35.9	5.0	36.9	29.2
New Guinea Islands	29.8	10.2	9.3	10.5	3.8	10.1	10.3
PNG	30.2	100.0	9.1	100.0	3.9	100.0	100.0
Urban	11.4	5.7	2.2	3.7	0.7	2.6	15.1
Rural	33.5	94.3	10.3	96.3	4.5	97.4	84.9

Source: Authors' Household Survey

Table 2. School Attainment, Illiteracy, and Access to Health Care in PNG's Major Rural Regions in 1996.

	School Attainment of Adults (%)	Percent of Rural Population that Never Attended School	Illiteracy Rates (%)	Percent of Rural Population with Access to Health Care
Papuan/South Coast	52	31	41	50
Highlands	44	57	65	63
Momase/North Coast	51	37	44	65
New Guinea Islands	68	18	22	46

Source: Authors' Household Survey

Table 3. Travel Times (in minutes) to Roads, Schools, and Health Services in PNG's Major Rural Regions in 1996.

	Nearest road	Nearest transportation, including nearest road, airport or boat dock	Nearest aid post (nursing station/clinic)	Nearest community school (or elementary school)	Nearest high school
Papuan/South Coast	93	57	67	75	213
Highlands	256*	53	66	58	134
Momase/North Coast	95	76	76	70	297
New Guinea Islands	67	21	28	19	98

* Two Highland census units are outliers. One community is 30 hours from the nearest road, but only 6 hours from the nearest airstrip. The other is 24 hours from the nearest road, but only 15 minutes from the nearest airstrip.

Source: Authors' Household Survey

Table 4. Distribution of Poverty by Access to Services in Rural PNG in 1996.

Distance in time to nearest road or school	Headcount		Poverty gap		Poverty severity		Share of total pop (%)
	Index (%)	Contribution to total (%)	Index (%)	Contribution to total (%)	Index (%)	Contribution to total (%)	
Rural PNG	**33.5**	**100.0**	**10.3**	**100.0**	**4.5**	**100.0**	**100.0**
Road < 30 minutes	29.8	58.6	8.6	55.1	3.6	53.0	65.9
30 ≤ road < 60 minutes	17.8	5.4	4.6	4.5	1.9	4.4	10.1
60 ≤ road < 120 minutes	56.7	11.4	19.2	12.5	8.7	13.0	6.7
120 minutes ≤ road	47.6	24.6	16.6	27.8	7.7	29.6	17.3
School < 30 minutes	31.1	48.7	10.2	52.2	4.8	55.3	52.4
30 ≤ school<60 minutes	22.8	14.8	6.7	14.1	3.0	14.4	21.7
60≤school<120 minutes	49.0	20.1	12.1	16.1	4.1	12.4	13.7
120 minutes ≤ school	45.0	16.4	14.9	17.6	6.6	17.8	12.2

Note: "School" refers to community (or elementary) schools.

Table 5. Regression Estimates of the Determinants of the Number of Income Earning Activities of Surveyed Households in 1996.

	(1)	(2)
Hours to nearest road	-0.147 (3.80)**	-0.138 (2.42)*
Number of adults in household	1.424 (4.57)**	1.481 (4.83)**
Number of adults, squared	-0.042 (1.35)	-0.043 (1.39)
Elevation exceeds 1200m	-0.957 (1.74)+	0.373 (0.31)
Dry: rainfall <2500mm	-0.025 (0.04)	1.239 (1.47)
Urban Census Unit	-2.558 (2.30)*	-0.599 (0.67)
Controls for each province	No	Yes
Controls for each month	No	Yes
Constant	2.732 (4.17)**	-1.956 (1.87)+
F-statistic	24.13**	19.92**
R^2	0.22	0.38

Note: Absolute value of *t*-statistics in parentheses, corrected for clustering, stratification and weights. + significant at 10%; * significant at 5%; ** significant at 1%. Sample has *N*=1144 observations.

Table 6. Descriptive Statistics for the Model of Rural Poverty (*N*=830).

	Mean	Std Dev.	Minimum	Maximum
ln (real expenditure per adult equivalent)[a]	0.429	0.763	-1.608	3.170
Demographics				
Household size	5.709	2.917	1	18
Number below age 15	2.458	1.853	0	11
Number above age 50	0.408	0.708	0	5
Age of household head (years)	40.410	12.783	18	85
Dummy: Female-headed household	0.079	0.269	0	1
Education				
Dummy: Household head is literate	0.485	0.500	0	1
Average years of schooling of adults	3.107	2.750	0	12
Employment and occupation				
Dummy: Head's income from minor sources[b]	0.036	0.187	0	1
Dummy: Head is tree crop farmer	0.433	0.496	0	1
Dummy: Head is in formal sector	0.185	0.388	0	1
% of adults with no cash income sources	0.261	0.322	0	1
Assets				
Dummy: Owns agricultural capital goods[c]	0.189	0.392	0	1
Number of pigs owned	2.213	3.387	0	26
Community characteristics				
Index of market development[d]	7.050	6.802	0	36
Travelling time to nearest road (hours)	3.215	7.275	0.25	30
Travelling time to key social services[e]	10.043	14.792	0.75	106
Geo-climatic variables				
Dummy: Wet zone (>2500mm rain/year)	0.564	0.496	0	1
Dummy: Low elevation (<600m)	0.441	0.497	0	1
Dummy: High elevation (>1200m)	0.472	0.500	0	1
Regional fixed effects				
Dummy: Papuan/South Coast region	0.154	0.361	0	1
Dummy: Highlands region	0.440	0.497	0	1
Dummy: Momase/North Coast region	0.288	0.453	0	1

Note: Means and standard deviations based on household sampling weights. The excluded dummies are male household head, illiterate head, household head's main occupation is food crop production, household owns no major agricultural capital goods, household lives in a PSU in the dry zone, at mid-elevation (600-1200m) and in the New Guinea Islands region.

[a] The adult equivalence scale counts children age 0-6 as 0.5 adults and all others as 1.0. Nominal annual consumption expenditure is normalized by region-specific poverty lines (at national average prices).

[b] Includes hunting, fishing, firewood selling and making of artifacts.

[c] Includes trucks, tractors, sprayers, coffee pulpers, cocoa fermentaries and copra driers.

[d] Combined number of tradestores, public transport (PMV) businesses and fresh produce markets in the PSU.

[e] Combined travelling time to the nearest health centre, high school and government station (by usual means of travel for the people in the PSU).

Table 7. OLS Estimates of the Basic Model of Log Welfare Ratio for Rural Households (*N*=830).

	Coefficient	Std Error	|*t*|	*p*-value
Demographics				
Household size	-0.106	0.030	3.51	0.001
Household size, squared	0.005	0.001	3.62	0.001
Number below age 15	-0.070	0.020	3.45	0.001
Number above age 50	-0.015	0.044	0.34	0.738
Age of household head (years)	-0.014	0.012	1.21	0.231
Squared age of household head	0.000	0.000	1.21	0.233
Dummy: Female-headed household	-0.043	0.097	0.44	0.662
Education, employment and occupation				
Dummy: Household head is literate	0.213	0.056	3.81	0.000
Average years of schooling of adults	0.026	0.012	2.09	0.041
Dummy: Head's income from minor sources	-0.348	0.120	2.89	0.005
Dummy: Head is tree crop farmer	-0.145	0.088	1.65	0.104
Dummy: Head is in formal sector	0.252	0.102	2.47	0.016
% of adults with no cash income sources	-0.142	0.097	1.46	0.148
Assets				
Dummy: Owns agricultural capital goods	0.200	0.072	2.78	0.007
Number of pigs owned	0.020	0.009	2.33	0.023
Community characteristics				
Index of market development	0.013	0.007	1.82	0.073
Travelling time to nearest road (hours)	-0.011	0.006	1.80	0.077
Travelling time to key social services	-0.005	0.003	1.33	0.189
Geo-climatic variables				
Dummy: Wet zone (>2500mm rain/year)	-0.224	0.089	2.50	0.015
Dummy: Low elevation (<600m)	0.104	0.162	0.64	0.526
Dummy: High elevation (>1200m)	-0.059	0.148	0.40	0.693
Regional fixed effects				
Dummy: Papuan/South Coast region	0.237	0.146	1.62	0.110
Dummy: Highlands region	0.432	0.198	2.18	0.033
Dummy: Momase/North Coast region	0.095	0.169	0.56	0.575
Intercept	0.955	0.359	2.66	0.010
Standard error of disturbances (σ)[a]	0.628	0.021	30.29	0.000
R^2	0.322			
Zero-slopes *F*-test[b]	$F_{(24,37)}$=10.51			0.000

Note: Results corrected for the effect of clustering, sampling weights and stratification. For notes on definition of variables, and excluded dummies see Table 1.

[a] With a pseudo-maximum likelihood model on complex sample survey data, σ can be viewed as a variance in terms of the population distribution, which is assumed normally distributed.

[b] This is an adjusted Wald (*W*) test: $\left(d-k+1/kd\right)W \sim F(k, d-k+1)$, where *d* is the number of clusters minus the number of strata (60), and *k* is the number of slope variables (StataCorp, 1999).

Table 8. Simulated Effect of Certain Changes on Rural Poverty in Papua New Guinea in 1996.

	Headcount	Poverty gap	Poverty severity
	(Percent change from baseline predicted values)		
Baseline: Actual values	33.51	10.31	4.51
Baseline: Predicted values	32.60	11.27	5.38
Increase literacy rate of household heads to 100 percent	27.06 (-16.97)	8.76 (-22.27)	3.99 (-25.85)
Increase household average school years per adult by one year	31.38 (-3.74)	10.73 (-4.80)	5.08 (-5.53)
Decrease combined travelling time to 3 key social services by 50 percent[a]	31.43 (-3.56)	10.64 (-5.57)	4.99 (-7.11)
Decrease combined travelling time to 3 key services to 6 hours if currently > 6 hours	31.13 (-4.48)	10.44 (-7.32)	4.87 (-9.51)
Decrease travelling time to road to 3 hours for communities where currently > 3 hours	31.25 (-4.12)	10.55 (-6.41)	4.94 (-8.12)
Decrease travelling time to road to 2 hours for communities where currently > 2 hours	31.15 (-4.43)	10.49 (-6.85)	4.91 (-8.66)

Note: Each simulated change is considered in isolation of the other changes. The model used to predict poverty is reported in Table 3. The percent change from base is calculated from the *predicted* baseline values.

[a] Health centre, high school and government station.

Figure 1. Consumption and Access to Transportation in PNG in 1996

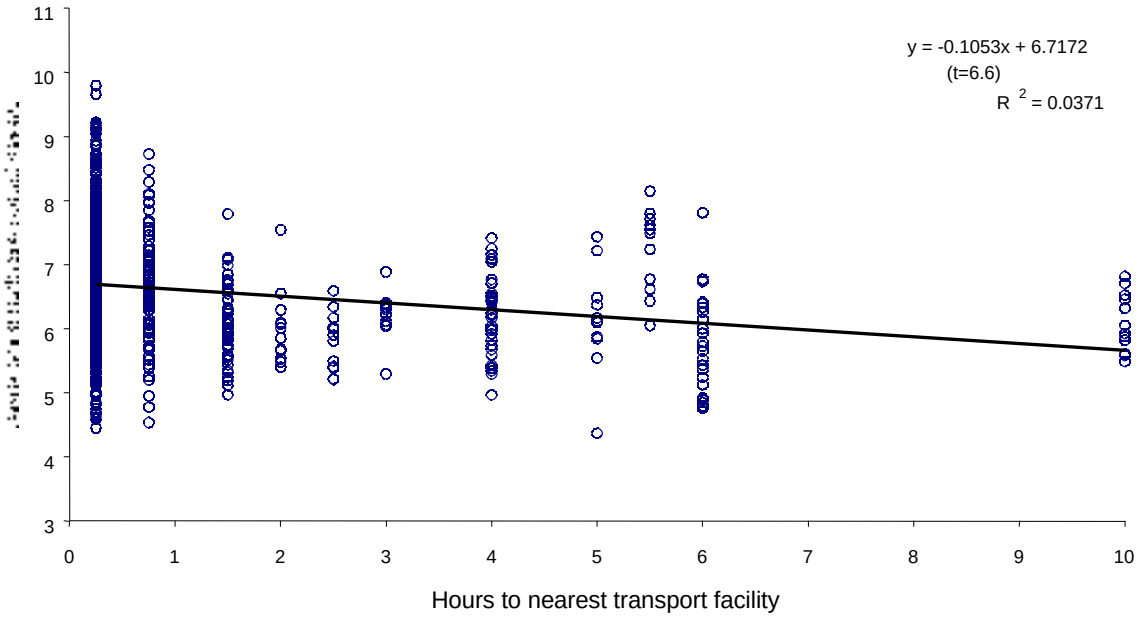
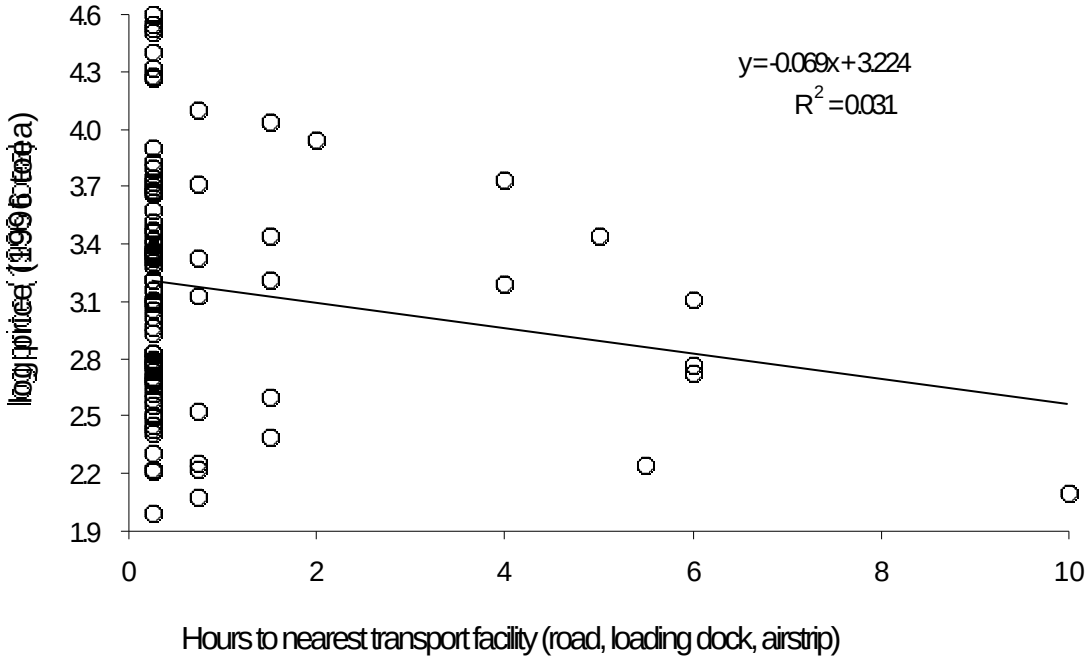
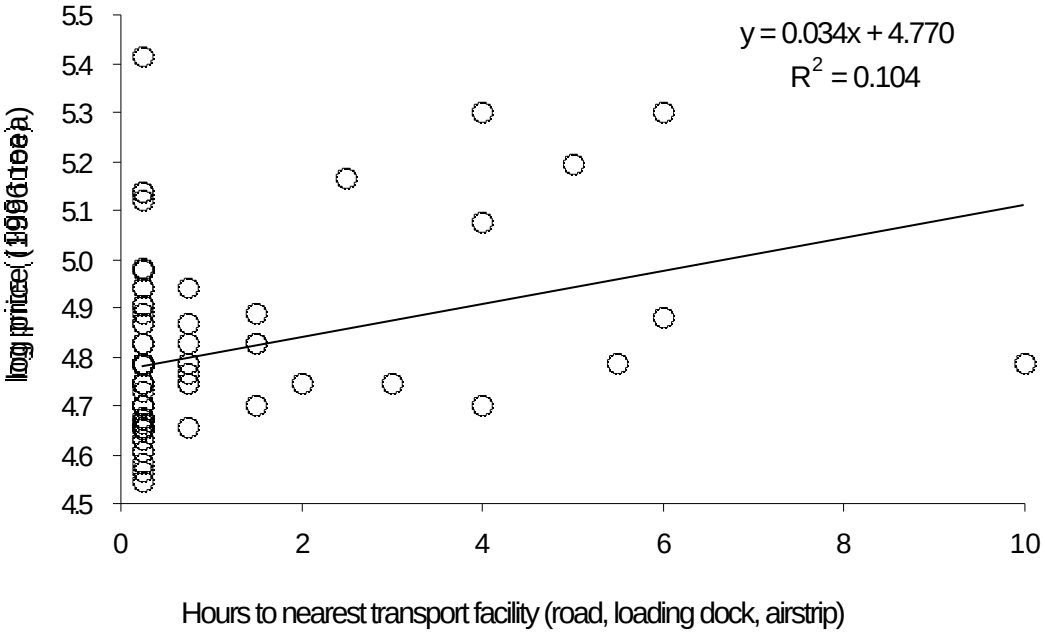


Figure 2. Effect of Access to Transport Facilities on Price of Sweet Potato



Source: Author's calculations from 1996 Household Survey data.

Figure 3. Effect of Access to Transport Facilities on Consumer Price of Rice



Source: Author's calculations from 1996 Household Survey data.